General Model Simulation of the Mexican Poultry Value Chain

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Abstract: The use of simulation contributes to better analysis and understanding of the interactions between the major variables of the Mexican poultry value chain. This general model of the value chain poultry considers biological processes such as growth and reproduction, as well as economic factors and food costs operating at different stages of industrial poultry farming. The program was designed for poultry producers in general and for the Mexican poultry industry as an aid in the evaluation of different economic scenarios for the production of chicken meat. Although this model is based on the Mexican poultry industry, this can be used where operating conditions are presented here assumed. The integrated simulation model can perform poultry simulations to establish correlations between various parameters of production and their output under standard operating conditions at farms and stands. It can provide answers to parameters such as growth and viability, the number and weight of birds at feedlots, the number of births and the total production cost per kilogram. The model provides a holistic description of the production system and its outputs, reflecting the random variation in the stalls and booths between birds, which is important to represent the production risk. Thus, simulations of poultry value chain through this model can provide answers to what would result if changes were made to specific production parameters.

1 INTRODUCTION

In Mexico, poultry can be classified as the livestock industry with more historical background, before the arrival of the Spaniards to the Americas, raising poultry was practiced mainly in turkeys. With the arrival of settlers, breeds and varieties of birds were introduced to the conquered territories that were adapted to the operating conditions of Mexico. Production began on a small scale. It should be noted that at the time of the colony, it was allowed to employees of poultry farms to maintain self-sufficiency, which is considered the origin of the current system of backyard poultry or rural, practiced in large parts of the country. The predominant pattern of production and trade until the early 50's consisted of medium and small farms supplying urban areas, a system that was interrupted by the outbreak of the Newcastle disease in México. Following this event, the authorities in coordination with producers developed an intensive poultry development program, which marked the foundation for the current poultry endeavor. It may be noted that from the second part of the early 80's, technical production has replaced both semi-technical production and backyard that was practiced in areas close to expanding urban areas. Currently, the poultry sector is a branch of farming that has reached a technological level of efficiency and productivity, which is comparable to that of developed countries, adjusting quickly to the levels demanded by the population. In the past 10 years, the poultry industry has experienced a phenomenon of expansion that has led this segment to be the second place in the consumption of meat produced in México, and the lowest price meat alternative in the country.

2 METHODS AND MODEL DESIGN

It can be assumed for the purpose of the simulation model, (Calderón Ph.D. Dissertation), that the system of interest consists of a set of lots of birds that pass through the stages of breeding and egg production, to later produce batches of eggs entering the stage of incubation. Once this is completed, a new batch of birds is sent to the broiler process. A lot of (13700 males and 4725 females) birds is considered to be the transaction flowing through the model for the purposes of this model, which must complete their breeding cycles, egg production, incubation and growth on the farm stands. Likewise,

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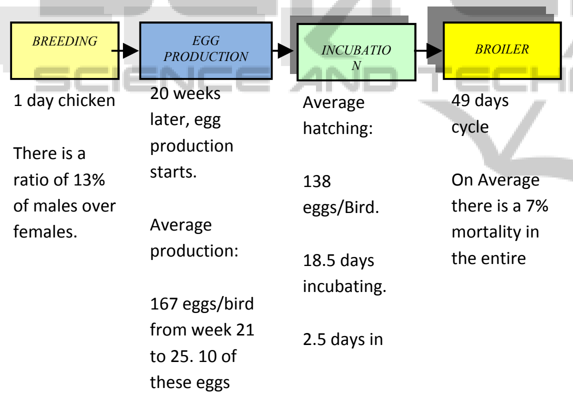
lots of fertile eggs should complete its cycle in incubation machines. Each process facilities, stalls and setters have a finite capacity to determine the number of transactions (lots) that are able to accommodate for each of these elements within the system, and in turn, each lot is composed of a number of specific units at the corresponding stage (birds or eggs). Each stage requires a specific time to complete the cycle before moving on to the next process. These cycles must be coordinated and balanced, so that there is an adequate flow of transactions in the system. The explanation of the process just presented, forms the basis of the conceptual model of the system under study. It is noteworthy that the conceptual model can be used for any poultry value chain under the assumptions and conditions presented here. Figure 1 shows the conceptual model approach to simulate the poultry value chain.



Source: Own elaboration

Figure 1: Conceptual model.

For this study, the operation manuals and performance objectives by Ross Bird (2001), form the basis for the progeny of breeding birds as well as for broiler. Such data also establishes the empirical distributions of times of chick placement of birds, the mortality of females and males at different stages, the average weight of birds at the beginning of the cycle, and its uniformity in breeding flocks, posture and broilers. To estimate the probability density functions, we associated empirical data relevant to the above input, using the results of operations for one year of a Mexican Poultry Company operating under the conditions assumed in this research work.

2.1 Conceptual Model Validation

Conceptual model validation is defined as determining the theories and assumptions underlying the conceptual model correctly, and that representation of the problem in the model is "reasonable" for the purpose required. The verification of the model ensures the correct implementation of the conceptual model and of the computer program. Operational validation of the simulation model is achieved if the model output behavior closely resembles the real system having sufficient accuracy for the intended purpose. The validity of the data is to ensure that the data needed for building, evaluating, testing and conducting experiments using the model in solving the problem are adequate and correct (Sargent, 2004). By using earlier approaches to model the stages of breeding, egg production, and broiler hatching we may conduct trials in order to compare with available historical results of poultry operations at each stage. This is done in order to validate the theories and underlying assumptions in the conceptual model, as well as to validate the representation of the model structure, its logic and to verify that the mathematical causal relationships are "reasonable" responding to the objective of the model. In order to verify the simulation program in SIMNET II, we performed several simulation runs having the model already validated and under different conditions and scenarios. The resulting values are compared against the historical data available to determine whether the computer program implementation is correct. The behavior of the system model can be explored by examining the output of various sets of experimental conditions of interest. To support the verification and complementing the above, the simulation language SIMNETII provides a powerful TRACE command to verify the logical flow of transactions through the stages of the simulation model, observing the consistency of input and output relations, verifying also the internal consistency of the model. Behavioral output is plotted for different experimental conditions. The number of experiments is determined according to the accuracy required for the purpose for the model. Expert opinion complements the determination of the accuracy by providing feedback to contemplate adjustments in the structure of the program code. The purpose of this is to improve the representation of the overall integrated model and the operation of the submodels to reflect a better approximation to the real system under study. In order to obtain reliable results, the first step is a proper analysis of the steady state of the system. This is achieved by considering the stability of the response variables with respect to the next process. We consider being at steady state if the current variability does not affect the next process performance. Once this is achieved, the selection of the number of runs is determined based on the accuracy required for the specific problem at hand. The length of each cycle time in this case is several weeks, which leads to evaluate horizons of operation cycles for at least one year or more. The analysis of results considers the overall operation of the integrated model but focusing on the growing stage since it generates the final value to the consumer.

3 EXPERIMENTATION

An experiment was carried out to determine if one or more independent variables affects one or more dependent variables and the reasons behind. From experience and evidence of key causal relationship, it was decided to manipulate the independent variables but keeping track of the variation of the dependent variable. This manipulation is synonymous to the assignment of different values to the independent variables (Hernández et al., 2003).

In this paper we have defined the critical research variables (dependent variables) based on the key strategic indicators of operation of the poultry value chain under study, which include:

• The production of fertile eggs in the laying stage
• The density of birds in breeding stages, posture and Broilers
• The final mortality in the breeding stage, posture and
broilers
• The conversion of feed into meat in broilers
• The rate of productivity in the growing stage
• Production of kilograms of meat in broilers
• The cost of production in the breeding stage, posture, hatching and broiler production.

Independent variables investigated are:

• Initial number of breeding birds, egg production and broilers
• Mortality in the 1st week of the broiler cycle
• Fertility rate, egg hatching at the incubation stage
• Food costs in the production broiler
• Direct and indirect costs of breeding, posture, hatching and broiler stages.

The Model construction is based on established performance standards for the Ross 308 breed type, both for breeding and broiler birds. Ross 308 broiler chickens have genetic characteristics for rapid growth, efficient feed conversion and viability. These broilers have strong legs and powerful cardiovascular system. They are designed for high meat production. Performance of birds can be influenced significantly by many factors including flock management, quality of feed, health and climate conditions (Ross, 2001).

Six experiments were performed using the model. The first one evaluates the amount of birds that begin breeding at this stage to establish the appropriate range of birds that provide the best balance between increased productivity and lower costs in the value chain. The second experiment assesses the square meters required in the bird flocks to provide a better first approximation of the range of outcomes as a result of greater comfort and space for the birds without increasing operating costs. The third experiment focuses on mortality in the first week of the cycle of broilers, which is critical in poultry production. The fourth experiment evaluates the range of values of key input variables that are directly related to the birth of poultry production that feed the growing stage. The fifth experiment evaluates the operating range of values of the costs of the feeding cycle with the least possible impact on cost. Finally, the sixth experiment analyzes the range of values for direct and indirect costs of operation for all stages of the poultry value chain. The followings variables are estimated by the simulation model, which vary according to the case in study: fertilized eggs production, density of birds in flocks, dead birds at the end of each cycle, feed conversion into meat, productivity rate, kilograms of meat production, and complete cycle costs. Since then the experiments mentioned above are illustrative. There is a wide range of applications that can be tested with the simulation model. For example, we can perform simulations where changes could be considered simultaneously, like an increase in the number of birds at the beginning, with an increase or decrease in the available area in the breeding flocks; or separate experiments to find out the model response to shifts of certain factors.

3.1 First Experiment: Number of Birds at the Beginning of the Breeding Stage

It is important to know the behavior of the breeding and production stages. The number of birds at the start is critical, in order to take the necessary actions to prevent or reduce negative consequences such as high mortality, excessive costs and low production. It is assumed that increasing the number of birds at the beginning of breeding in flocks, also increases the number of fertile eggs in the laying stage, the density of the flocks, and as a side effect to some extent rising mortality. The magnitude of these increases can be estimated quantitatively by the simulation model. In the following tests, it is assumed that the capacity of the flocks is fixed, with a standard value of 1800 m2 for both breeding and egg production flocks. The simulation considers 9 flocks in the process of breeding and 16 flocks in the egg production stage. It may consider any other capacity of the bird houses, since is only necessary to reflect these values in the simulation model set for initial conditions. It is also assumed that the major constraint of the breeding farms and egg production is the available space for bird growth. This also includes the associated costs of having more space. To reflect the increase in the birds at the beginning of breeding and egg production, the number of flocks (male and female quantities) can be modified in the attribute value of the corresponding transactions, in order to evaluate what the system can process at a real operating poultry company. The results are the mean and confidence intervals for fifteen observations using the simulation model and under the prevailing conditions at a Mexican Poultry Company that is taken as the basis of this research. The summary of results for these tests is shown in Table 1.

Table: 1: First Experiment.

Experiment	Density (Birds/m2)	Fertile egg production	Final Mortality	Costs
No. of starting Birds	6	19225	4234/1623	60/76.2
	6	20629	4544/1748	60/76.2
	7	22032	4855/1868	59.8/76

We performed 15 simulation runs in order to obtain representative observations of the behavior of the poultry value chain. Three levels for the number of birds at the start were considered. The first level (six) is based on the standard operation of a poultry company in Mexico and increases at other levels are taken into account according to any increases that may exceed the current demand for the facilities which were used as based values. By increasing the number of birds at the start, increases the number of fertile egg production, but as a logical consequence, note that with an increase of the density of birds in the flocks, produces a negative effect on the comfort of birds, therefore reducing the space available for breeding, which increases the number of dead birds at the end of the cycle. On the other hand, production costs decrease in terms of kilograms of meat at this stage. It is noteworthy, that the main purpose of this stage is raising healthy males and females to produce as many fertile eggs as possible. Therefore, what we seek is the balance between total costs and the optimal production of fertile eggs. Although this experiment only considered variables or indicators of interest at the strategic breeding stage, is of great importance because the output stage are breeding birds (female and male healthy enough for reproduction at sexual maturity). It is the entrance to the position stage, and if the birds do not arrive in optimal conditions, appropriate results may not be obtained in these first two links of the value chain. This will result in the underutilization of poultry at the company. Accordingly, as a first approximation to the final conclusions, we could say that a controlled increase in birds at the start of the stage of breeding under the conditions and assumptions of this study, may lead to increase the production of fertile eggs at a lower cost in the production stage.

3.2 Second Experiment: Available Area

The infrastructure of poultry varies from region to region depending on the space and capital available for each farmer. A common goal is to streamline any poultry infrastructure to maximize its production capacity. The dimensions of the stalls for breeding and position are generally the same; this paper builds on an area of 1800 m2. For broiler houses an area of 2016 m2 was considered. Simulations assess changes that could arise if there is more or less space. Table 2 assesses the density for breeding flocks, egg production and broilers in a smaller area, and higher than the standard. Similarly, evaluating the impact on mortality at the end of the cycle, and for the case of the broiler stage, effects are observed in the final kilograms production of chicken meat. That is the main objective in the value chain for poultry. The importance of space for the birds is a direct function of comfort in the flocks where they grow. Having the appropriate space and climatic conditions, the desired production standards can be achieved.

Table 2: Second Experiment.

Experiment	Density (Birds/m2)	Final Mortality	Kg. Production (Kg/1000)
Available Area (m2)	Female 7/12/5	4234/4242/4227	26556/26557/26556
	Male 3/4/2	1623/1630/1615	12737
	Broiler 12/14/10	607/608/507	79500/79589/79669

The bird comfort directly affects the rates of poultry mortality at any stage and represents a critical point of attention in monitoring operations in poultry production. It can be inferred form Table 2, that a larger production area with a low ratio of birds per square meter, decreases the amount of mortality in birds and consequently increases the production of kilograms of meat in the final stage of broiler. As mentioned earlier, these experiments as well as the other ones are the results of basic operating characteristics of a Mexican poultry company. The generic simulation model developed has no limits for these variables for future exploratory research experiments.

3.3 Third Experiment: Broilers Mortality at First Week

In the broiler growing stage, the first week is critical for best bird's performance. This situation arises depending on the good or bad operating conditions and health of birds in the first week which affect considerably the end of the cycle and production goals. The purpose is to get the best yields of poultry operations along the entire value chain. A high mortality rate in broiler farms or houses during the first week will affect the operation of the booth throughout the cycle and the conversion of the birds and their productivity. The simulation model is used to evaluate the effects of an increase in the mortality rates during the first week of broiler chicken. It is assumed that the standard mortality rate in the first week of broiler´s cycle is between 0.2% and 0.3% (based on observations taken from a poultry company in Mexico). On the other hand, we explored two different mortality rate ranges, from 1.0% to 1.1%, and also from 1.4 to 1.5%. These interval values are specified in the initial parameters conditions of the simulation model. The summary results are shown in Table 3.

Table 3: Third Experiment.

Experiment	End Mortality	Conversion	Productivity Rate	Kg. Production	Costs
First	608	1.65	377	79600	4.73
Week	769	1.66	371	78765	4.75
Mortality	830	1.67	369	78445	4.75

The simulation model shows that there are large negative impacts as we increase the mortality rate in the strategic indicators of the value chain. Increased mortality results in poor conversion of birds, which negatively affects the resulting productivity index of the flock, and therefore the production of chicken meat in kilograms, affecting costs. In the previous simulation, the adverse effects are contemplated for the first week only, assuming no problems the rest of the cycle. For research purposes, it is possible to explore both cases.

3.4 Fourth Experiment: Appropriate Percentage of Births

A wide variety of experiments can be performed with the simulation model with variables of interest in the poultry chain, such as fertility rate, percent of egg hatching, percent of defects, and the incubation capacity represented by the number of hatching machines. This will assess the main effects that are directly related to the number of resulting births, which will become healthy birds to enter the growing stage. For this research, simulation experiments were performed using fixed percentage amounts, however the simulation model can handle ranges of values in frequency distributions. It is assumed that the standard values for fertility percent of eggs produced in the laying stage is 92%. The percent of eggs hatching handled in the incubation stage is 92%. The percent of defects present in the egg entering the incubator is 8% and there are 20 machines available for incubation. The Capacity of these machines is 30240 eggs, which is the number of eggs hatch by each machine. For the case of the number of hatching machines, the simulation experiments considered de minimum installed capacity that is needed to process the number of eggs produced in the previous stage position, under current operating conditions. The critical variables of interest or strategic indicators that were evaluated due to the expected impact were fertile egg production expressed in volume, the productivity rate, production of meat in kilograms and the cost in the early stages of laying, hatching and broiler chicken.

Table 4: Fourth Experiment.

Experiment	Fertile egg production	Productivity rate	Kilograms Production	Costs
Births	19226 18616 19819	377 378 377	79600 79585 79596	1.80 2.75 4.74

An increase in the fertility egg production not necessarily increases the number of kilograms production, and the cost per kilogram of meat increases in the growing stage. It is noteworthy that the numerical combination of selected variables has a wide area of opportunity for experimentation. The main purpose of this experiment is to evaluate the main cause and effect relationships. Although this experiment only shows part of the wide variety of possible strategic indicators at the stage of incubation, is of great importance since the outcome of the incubation stage will be the input of the broiler´s cycle, stage at which the birds should arrive in optimal conditions. A first conclusion from this experiment is that a high percentage of fertility is necessary to achieve a solid production of meat in kilograms, along with a smaller percentage of defects in the next stage.

3.5 Fifth Experiment: Operating Range of Feeding Costs

The common objective when discussing these costs is to find the point where the marginal gain is the greatest. Any poultry infrastructure to be competitive needs to maximize their production while reducing operating costs. In the present study, the effects of feed costs are evaluated in the broiler chicken, since they represent 70% of the total cost of chicken production. The base value is a production cost of 2.8 pesos per kg. feed given to birds in the first week, 3.1 pesos per kg. feed during the second and third week, 2.5 pesos per kg. feed supplied in the fourth and fifth week of the cycle, and finally 2.8 pesos per kg. feed for the remaining weeks. Table 5 presents the results, evaluating higher and lower values than the standard, showing the impact on the final cost of chicken production. The effects observed in the final production of meat kilograms are directly proportional to the total cost of the feeding cycle. The importance of cost control is vital because it makes the difference between competitive poultry companies.

Table 5: Fifth Experiment.

Experiment	Costs ($ x Meat Kilogram)		
	Scenario 1: Standard	Scenario 2: Quality grains	Scenario 3: Reprocessing
Broiler's Feed Costs	4.73	5.16	4.31

This experiment evaluates the scope or range of competitive fluctuating costs, looking at pessimistic and optimistic scenarios in the production and cost of feed for birds. Table 5 shows that an increase in feed costs increases the total production cost of meat kilograms in the final broiler´s cycle stage. This experiment as well as the other five are for exploratory purposes, but are the guidelines for future research experiments.

3.6 Sixth Experiment: Direct and Indirect Costs

As the poultry full-cycle ends, the full picture of the costs incurred in each of the stages of the poultry value chain is obtained. In order to take action to avoid or reduce costs, both direct and indirect, the simulation model can be used to analyze the scenarios, to obtain a first approximation of what areas or activities should be monitored to prevent an increase in operating costs. The scenarios considered in this experiment are based on amounts present in a poultry company in Mexico. In the following tests, we included direct and indirect costs of breeding stages, egg production, and broiler hatching. Direct costs include: feed, gas, electricity, vaccines, straw, cleaning, disinfection and direct labor. Indirect costs include indirect labor, depreciation, maintenance, and laboratory analysis. As mentioned above, the simulation considers 9 flocks in the breeding stage, 16 flocks in the laying stage, 20 and 60 incubation broiler houses. Of course, you may consider any amount of poultry facilities. The ultimate goal of this experiment is to take the first steps toward an administrative structure that results in higher profits for any poultry enterprise. In this experiment, as in the previous ones, the results come from the average of fifteen observations of the simulation model. The summary of cumulative results for each scenario is shown in Table 6. We considered three levels of costs; the first level is based on the standard operation of a poultry company in Mexico, the other levels being an increment and a decrement from the standard that might occur in a normal operation of a poultry enterprise at a Mexican poultry company in the state of Veracruz.

Table 6: Sixth Experiment.

Experiment	Costs ($ x Meat Kilogram)		
	Scenario 1: Standard	Scenario 2: Higher quality	Scenario 3: Cost efficient
Direct and Indirect Costs	Breeding 76.27	78.26	76.22
	59.99	61.16	59.08
	Egg prod. 1.82	2.05	1.36
	Incubation 2.77	3.45	2.16
	Broiler 4.73	5.43	4.53

Observe in this experiment, the relationship of fluctuations in costs. Subsequent tests with the model can complement experiments to simulate the behavior of the total operating costs, as a function of critical variables of poultry operations. Production costs of meat kilograms are critical and a fundamental part of the poultry sector, determining the gains or losses for companies at this point in time. A successful industrial poultry operation contemplates the right balance between costs and optimal production. There is a wide variety of analysis on costs across the entire value poultry chain that can be addressed using the simulation model. It can be used as the basis for evaluating the use of poultry resources available at Mexican companies, with the aim of increasing their competitiveness.

4 SUMMARY

The simulation experiments presented above showed that there are many areas of opportunity at each of the poultry stages. Strategic indicators were taken from the poultry value chain to assess their impact and to establish initial cause-effect relationships that could improve the overall results of operations in the flocks and poultry farms for the production of chicken meat. The final objective is to meet the needs of consumers, and to increase the competitiveness of the poultry sector to conquer new markets.

For the first strategic indicator, the production of fertile eggs, it is observed based on the input variables, that the number of birds that begin at the stage of breeding, the fertility rates, egg hatching and the percentage of defects are major factors that influence a high yield. The evaluation of the density of birds in the stands, allowed us to evaluate the bird comfort in their living space which has a direct relationship with the number of birds at the start of the simulation, and the square meters available for birds in production. The main objective is to find the right balance between these two variables for the optimization of the poultry chain. The third strategic indicator is mortality, which is set according to the assumptions of the system under study. The input variables directly affecting this indicator are: the number of birds at the start, the available area for breeding flocks, egg production, and broiler chicken. For broiler chicken an important factor of great weight is the evolution of birds in the first week of the cycle, which directly affects the performance of broiler houses at the end of the production of chicken meat. The conversion is a strategic indicator directly related to the growing stage, which is affected by the mortality that occurs early in the cycle. This indicator is also closely related to the welfare of birds in the flocks, which requires control and care of various factors, such as the climate and the health of birds. For the purposes of this research, the number of variables and indicators are the most representative of a poultry operation. However, there is a wide spectrum of research to be addressed in subsequent projects. Finally, for the cost of production of chicken meat kilograms, the mortality behavior in the first week of the broiler's cycle is the main factor that directly affects the direct and indirect feed costs of poultry operations.

5 CONCLUSIONS

Simulation is a good tool to get started and provide a basis for holistic solutions. The simulation model developed focuses on the core part of the supply chain to evaluate strategic poultry production opportunities areas for taking decisions to improve the system-wide integrated poultry from producers to consumers. The poultry industry faces challenges with the opening of global markets. The simulation model provides an effective mathematical support to improve the growth of Mexican poultry companies and their production operations at all levels.

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