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The System Dynamics Use for Measurement of the Results of Technological Applications for Genetic Improvement in Milk Supply Chain

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The Brazilian economy is based on natural resources, classified as an exporter of commodities, with an emphasis on milk production in the last decade, represented by the ranking of having the second largest dairy herd in the world. In this scenario, this paper aims to use the system dynamics to simulate scenarios and to measure financial results related to production that milk supply chain gets by using genetic improvement technology. Methodology initially discusses qualitative aspects, identifying members, links, and attributes of supply chain management researched, which allowed to describe the systemic structure and to identify the variables used to design scenarios with and without the use of genetic technologies. The model was tested in a real situation, in a country state that has adopted these technologies. The final result of the study showed that, in the scenario of use of genetic improvement technologies, the variables production (liters), revenues and net income increased by 45 % and 53 %, comparing with non-use scenario. The model showed to be effective to simulate the deployment of genetics in dairy herd.

1. Introduction

Brazil, an exporter of commodities (Bianconi et al., 2013), has its economy based on natural resources. With the second largest dairy herd in the world, it produces more than 29 Mm^3 of milk, with global representation in the growth of dairy exports (Picinin, 2013). The author also states that this number may be even more representative in 2020, reaching 38.2 Mm^3. According to Instituto Brasileiro de Geografia e Estatística. (IBGE, 2009), the annual growth rate is higher than the growth rate of the Brazilian population, which also indicates an increase in consumption of dairy products. According to Petrus et al. (2009), in Brazil often the quality of the raw material is low, but with genetic improvement raw material could be better.

The increase in national milk production implies additional income and employment, improving the well-being of rural families (Delatoura et al., 2014). Subsistence farming increases the economic development in rural communities. The state of Rio Grande do Sul has the second largest Brazilian milk production, behind only the Southeast region (IBGE, 2009). The climate, similar to the European, influences on productivity (Picinin, 2013). Taking advantage of this increased production, dairy companies are diversifying their products, increasing their market share. To increase production the partnerships between milk producers and the beneficiary industries promote the sector of economic growth (EMBRAPA, 2013).

In this scenario and taking advantage of future research suggestions by Pettersson and Segerstedt (2013), who suggested a genetic gain analysis in the production chain, and Su and Lei (2008), who considered that economic returns evaluations should be done in productive chain, this research aims to study one of the milk production chain links, the first link, known as “production.” In this way, we used system dynamics to develop a tool that enables small farmers who use livestock for milk production to simulate scenarios on the use of genetic improvement through in vitro production.

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2. Milk Production Chain

Supply chain emerged in the late 1980s (Ramanathan, 2013). It is defined as a network of organizations, flows and processes in which companies cooperate along the chain from the initial raw materials to the final product (Ivanov et al., 2012). The management of the supply chain is applied by companies to successfully meet customer´s needs, improving the overall performance of the productive chain (Ivanov et al., 2012). Agreements between partners have proven that the supply chain management can be successful and world-class, such as led by Wal-Mart, Sara Lee, and Nabisco (Ramanathan, 2013). The chain management is an integral part of the new business management in the conception of services from suppliers to customers (Jalali et al., 2011). Regarding the management of the milk production chain, it is observed that this is composed by several links that pass by the producer, industry, and retail (Canziani, 2003). However, these links can be viewed in a broader sense, since the link production, which includes the production chain of the producer, through the transport stage, processing in industry, transport to the distributor until the final link in consumer (Shepherd and Flanders, 2008).

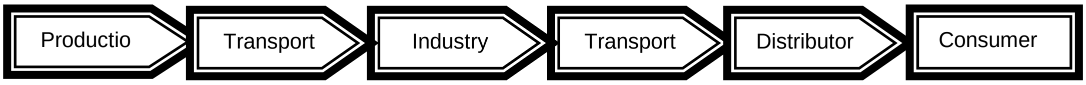

Figure 1: Milk Production Chain- Adapted from (Shepherd and Flanders, 2008)

In this point, the initial link of production has its own characteristics that configures almost a new chain inside of this link, since it involves the producers of inputs for production, machinery and equipment, inputs for pasture, technical assistance, veterinary, and animal genetics.

2.1 Genetic Improvement and System Studied

Brazil has been increasing in the global agribusiness as a user and a provider of bovine genetics. In animal improvement Market, the main products are: semen, embryos, and live animals (bulls, matrices, and recipient cows). The bovine genetics division also includes the clone market, which are embryos that carry the same genetic content of their donor. In the scope of livestock focused on milk production, there are variables such as cost of production, productivity per animal, and genetics of animals. Herd genetic improvement through certified bulls' semen has great importance for livestock, because it provides more productive and adapted animals, continuing the evolution of a breed.

Looking for efficiency and sustainability of production systems, choosing animals better adapted, fertile, and efficient to produce milk from their diets, it is necessary to increase production, which makes important the coherence between research, creators, and biotechnology centers to promote genetic improvement programs and to make them accessible to all ranchers.

Biotech production *in vivo* embryos (embryo transfer - ET) and in vitro (in vitro production - IVP) are important tools to accelerate genetic improvement of high value livestock and shorten the interval between generations, facilitating comparative observations between products of different mating and promoting rapid selection of the most productive animals. To make it possible, technology is a necessary element contributing to this development. The technology enables studies related to genetic improvement through studies of "genes" between the classified animals. The production of IVP embryos has advantages in relation to ET, since it does not require removal from the donor and it enables the realization of numerous collections in the donor without the need to wait periods of recuperation, since it is not done hormonal induction in the donor.

In this context, the adoption of genetic technologies in livestock production often depends on the investment capacity and professionalization of the producer. To obtain positive financial result from this practice, it is important to know variables such as initial investment, cost of purchasing animals, gestational age, number of births, time for the animal to be able to milking, cost of inputs, such as food, management and veterinary care, physical capacity of property, constructions, and milk selling price.

Based on this context, this research aims to study the link production of milk production chain, in particular the activity of livestock, which, when developed with tools and genetic improvement techniques, provides better financial results to producers. To perform this study, we used dynamic systems model and iThink software, which helped us to build scenarios that allowed compare results and demonstrate the gains that genetic technology provides.

Therefore, by modeling it was possible to simulate scenarios with and without genetic improvement in markets where the selling price may vary, as well as the producer can simulate average productivity and investment that could be done, and at the end the tool demonstrates the financial advantages and disadvantages of the use or not of genetic improvement.

3. Systemic Structure

We developed systemic structure based on the purpose of this study in order to determine the main variables of the model. Implementation of genetic improvement by insemination *in vitro* makes livestock activity focused on milk production acquire a high degree of professionalization. This implies investment to acquire more animals, which enable more inseminations and consequently more births, increasing the number of herd members able to be milked after a certain period, raising the productivity of the property and increasing revenues. Moreover, more animals born according to a higher number of inseminations, which improves the quality of milk and causes higher prices. Investments in genetic improvement in livestock generate fixed and variable cost increases, which reduce the financial gain of the property. However, this process also provides financial gains through revenue increase, which increases the level of professionalism of the property and provides the dilution of fixed costs for each production cycle.

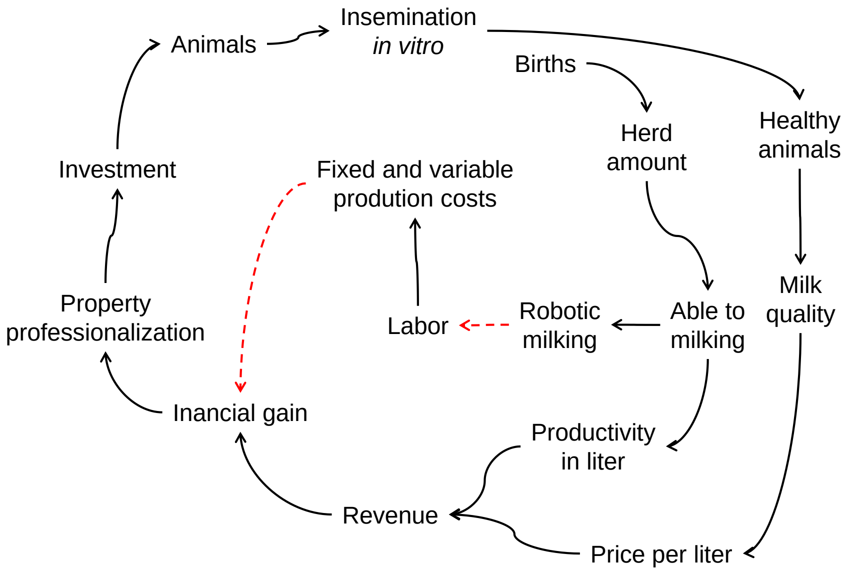

Figure 2: Systemic Structure - Research Data

4. Dynamic model

After the definition of the main variables in the system structure, the dynamic model was developed using iThink software, which allows through a temporal analysis to simulate different scenarios in predetermined contexts. To accomplish the purpose of simulating different scenarios, the model was built based on the variable “Initial Investment,” which includes the monetary value invested. The investment is a basic element to develop the “stock” of animals of the property, i.e., the amount invested is, actually, divided by the amount of R$ 2,500.00, which is the average price paid for animals without genetic certification and in reproduction phase. In this model, it is simulated a small property with ten cows able to be inseminated by *in vitro* insemination.

The combination of both variables contains the “Initial Squad,” which represents confirmed pregnant animals. The next step in the model is the variable “T pregnancy,” variable that represents the time that each animal takes to generate their offspring. This analysis step is necessary to identify a possible total amount of animals with a herd of ten animals using in vitro production technique in a period of 60 months. The variable “Final Stock” contemplates that, at the end of 60 months, 70 animals will be produced on the property.

The variable “Unit Cost” explains how much it costs per month each animal on the property, this variable is flexible and allows it to be modified and adapted according to the reality found in each property (variation between R$ 30.00 and R$ 150.00). Multiplying the variable “Unit Cost” x “Final Stock,” we found the variable “Cost of rearing,” which represents the total amount spent by the property with reproduction, rearing, labor, opportunity cost, and feeding.

The model shows four generations, all of them have a similar logical of construction, the main change is the time required of each generation to enter a milk production phase, i.e., the animal inseminated in the first generation will take nine months to generate the first offspring. The new animal will be able to be inseminated only 24 months later, so, the production phase of this animal will be when it is 33 months old.

We can apply the same logic to generation 2, generation 3, and generation 4, which will have the average time of 33 months to enter the phase of milk production and compose the stock of variable “milking.” The variable “Milking” is the total number of cows in dairy production. Note that, due to the time required for the animals coming into production phase, at the end of 60 months, only 40 of the 70 animals of the property animals will be in production phase.

The variable “Genetics” simulates the scenario of the property. According to the existing genetics, this variable can be changed, since there is the need to conduct a careful analysis in relation to the genes of each animal, in order to know how much each can contribute to the genetic improvement. After this analysis, there is an average that can be adjusted as needed.

“Average Productivity” is how each animal produces on average; this will vary with each property. Therefore, this variable is also adjustable in the model to provide a custom analysis of each property. Multiplying the stock of “milking” by the variable “Genetics” and the “average productivity” counts to provide the total volume in liters of milk produced on the property. Note that the model allows for a detailed analysis of the months contemplated in the scenario. The variable “Price of Milk” details the average value that is being practiced by the market at the time of the simulation. This variable is multiplied by the quantity produced, which will generate the volume of “Net income” of the property.

At the end, the model shows the variable “Result,” which means a comparison between the variables “Net income” minus “Cost of Rearing.” The variable “Results,” as well as other variables, makes it possible to know by month the result that the property is generating.

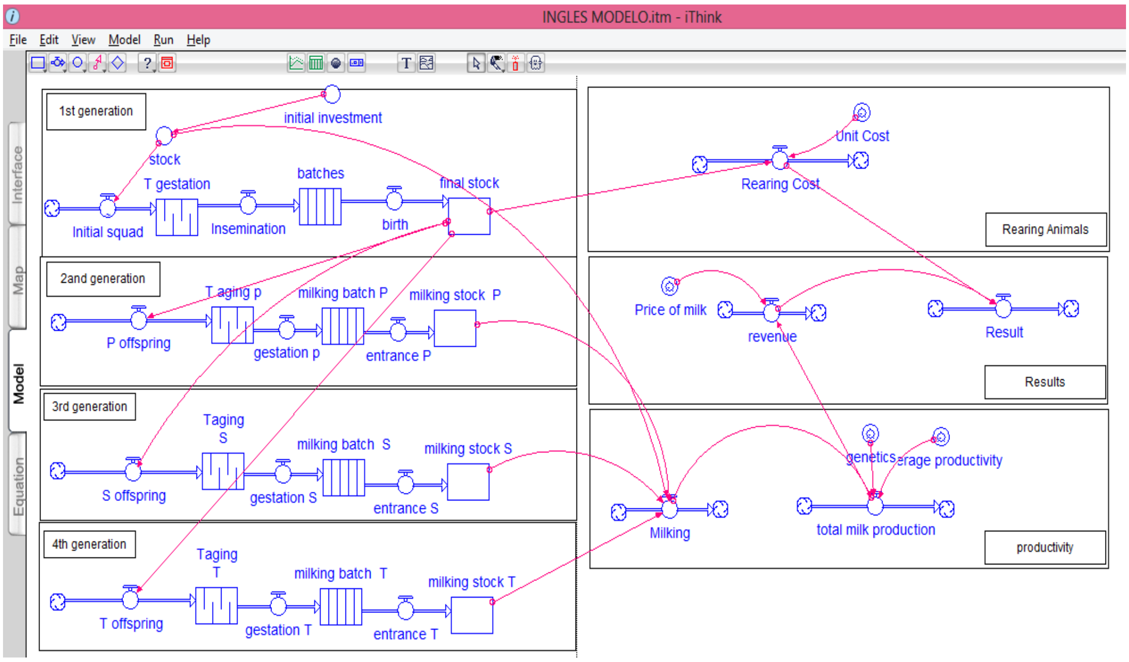

Figure 3: Systemic Structure - Research Data

5. Scenarios Projection in Model

The model allows farmers to use it to identify the financial results that the implementation of genetic improvement can provide to their properties. The user can simulate scenarios that can vary the average monthly productivity, the selling price of a liter of milk, the unit monthly cost per animal, as well as estimate the desired percentage gain that genetic technology can provide.

The system displays a button with the variable “Average Productivity,” which means how many liters of milk per day each animal can produce. The yield varies according to each property, as well as to the season, e.g., on summer the production can be less than on winter.

The variable “Price of Milk” is determined by the market and varies according to the quality of the milk and its supply. Therefore, we used to the initial simulations a regional average of the central region of Rio Grande do Sul, which ranges from R$ 0.69 to R$ 1.25; however, for other scenarios, these values can be adjusted. The “Unit Cost” is a variable that changes according to the existing structure on each property, i.e., considering the cost structure of the property, including the variables investment cost, structure, facilities, management, outsourcing, food, veterinary care, labor, and other fixed and variable costs. Based on these variables, it is possible to determine, based on the accounting system adopted by the property, the monthly unit cost of each animal. The variable “Genetics” simulates how much producers wish to gain with genetic improvement over traditional methods. The simulation starts in level 1, i.e., absence of genetic improvement in squad, to level 1.45, that increases by 45 % the production potential of the animal, however, these percentages can be adjusted for each situation.

5.1 Simulations

After the construction, the model was used based on two scenarios built on a farm in the central region of Rio Grande do Sul. Initially, we created scenario 1, without any genetic improvement, using an average productivity of 36 L/animal/d, milk sales price of R$ 1.00, unit cost of rearing animal of 100.00 R$/animal/d, and genetic potential on level 1, i.e., not using genetics.

The result was the variable ending inventory equal to 70 animals, which corresponds to the number of animals in the property at the end of 60 months; the variable milking is the number of milking animals being milked and the number of animals is 40 at the end of the 60 months; the milk production is the variable that is from an average (which can be changed according to the reality of the property) of 36 L/cow/d and, at the end of 60 months, milk production volume would be 43,200 L/month milk; the cost of rearing includes the whole squad and, at the end of 60 months, corresponds to a monthly value of R$ 7,000.00; the variable revenue is based on the sale price of a liter of milk R$ 1,00 (which can be changed according to the market trend) and, at the end of the 60 months, it consists in R$ 43,200.00 monthly revenue, which is considered only the sale of milk. Finally, the variable result includes the revenues minus cost, which is, at the end of 60 months, a net income of R$ 36,200.00.

On the other hand, scenario 2 consists in using genetic improvement with the same average productivity per animal, the same selling price of milk and unit cost equal to scenario 1, the only change was in relation to the genetic potential, from 1 to 1.45.

With changes in genetic potential of animals, we note that the variables ending inventory, milking and cost of rearing remain the same as in Scenario 1. However, the variables total milk production, revenues, and result were increased, because the average production per animal increased too. It is important to remember that this scenario simulates a future of 60 months from an average of the amount that is produced on the farm, i.e., we calculate how profitable would be investments in higher genetic potential of animals.

5.2 Comparison of Simulation Results

Comparing the two scenarios analyzed, it was observed that the financial result of the property increases, mainly for the reason that investment in genetic improvement provides gains such as increased animal productivity, healthier animals, and consequently better milk quality; these are factors that increase revenue, as we can observe in Table 1.

Table 1: Scenario Simulation with Genetic

Monthly variables	Scenario 1 Without Genetics	Scenario 2 With Genetics
Ending Inventory (Qtd)	70	70
Milking (Qtd)	40	40
Total Production (Lts)	43,200	63,640
Cost of Rearing (Lts)	7,000.00	7,000.00
Revenue (R$)	43,200.00	62,640.00
Net Income (R$)	36,200.00	55,640.00

We also observed that, in the scenario with genetic, the net income increases, because the cost structure remains the same, so that fixed costs are diluted with increasing revenues.

6. Conclusions

The use of dynamic systems in uncertain scenarios enables decision makers an important source of reference to make decisions. Even if the model is not fully complete and it does not address all possible variables, it is still better to decide without any information. This work provided the creation of a modeling tool aimed at small farmers who use livestock for milk production purposes and, sometimes, are reluctant to accept the new genetic technologies, because they cannot see the time and the value that any investment returns.

Using iThink software, it was possible to develop a dynamic and simplified model that can be adapted to different contexts and markets, enabling the user to look at the advantages of the use of genetic improvement, in our case in vitro production. With the simulation of scenarios “with” and “without” genetics, we observed that, in a period of 60 months, the herd increased, as well as milk production in liters also increased, facts that made the sales also increase. Thus, production costs were diluted, providing to the farmer a superior financial gain compared to not using genetic improvement.

The study has some limitations, since we did not consider mortality rate, because in the property analyzed this rate was irrelevant. We did not consider also the rate of cost of money for the necessary investments to adopt genetic improvement; however, it can be reconsidered for future research.

For future research, we suggest to be detailed, by a costing system, all costs related to production *in vitro*, which can be inserted in the model. Also, the model may be used for genetic improvement utilizing properties of other types of animals, such as sheep, goats, and poultry.

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