The mate, which is the main form of consumption of yerba mate, is increasingly available to consumers around the world. However, errors in estimating production and operating costs are commonly found, especially in emerging companies. Moreover, for various reasons, many industries do not have necessary investments in technology to achieve maximum efficiency in productivity, or even have no more insightful analysis into their manufacturing processes. According to Harrel (2002), the simulation is a process of experimentation with a detailed model of a real system to determine how the system may respond to changes in its structure, environment or boundary conditions. The simulation software used in process modeling and performance evaluation systems is able to provide the visualization of flow processes, giving all the necessary understanding. They also allow capture and record the reality, simulation of business process changes to try and promote the optimization of the compositions, and facilitate the documentation and analysis of metrics for evaluating performance of the processes involved, so that all remain on the path lead to the goals of your business (DALL’AGNOLL, 2005). The objective of this paper is the development and application of computer simulation techniques in a system of industrial drying of yerba mate to mate, evaluating the performance of its production line by creating simulation scenarios and thus contributing to integration of information technology (IT) in industry of yerba mate, which currently requires more satisfactory and conclusive data.
1. Introduction

The mate, which is the main form of consumption of yerba mate, is increasingly available to consumers around the world, not only in cold regions as southern Brazil, Argentina, Paraguay and Uruguay, where it is drunk more routinely, but also in places where they cultivate the habit of drinking mate cold, called “terere”, shifting the idea of having it related only to the culture of the state of Rio Grande do Sul. However, errors in estimating production and operating costs are commonly found, especially in emerging companies. Moreover, for various reasons, many industries do not have necessary investments in technology to achieve maximum efficiency in productivity, or even have no more insightful analysis into their manufacturing processes.

As stated by Rocha (2001), despite the efforts of some agents of agribusiness mate, there is a great lack of investment in technology that can compromise the entire system. Based on this lack of technology to obtain more conclusive data on industrial production of yerba mate to mate, a tool that can be used to help with this survey data is the modeling process, a key element within the context of theory and simulation project discussed in this paper.

According Harrel (2002), the simulation is a process of experimentation with a detailed model of a real system to determine how the system may respond to changes in its structure, environment or boundary conditions. The simulation software used in process modeling and performance evaluation systems is able to provide the visualization of flow processes, giving all the necessary understanding. They also allow capture and record the reality, simulation of business process changes to try and promote the optimization of the compositions, and facilitate the documentation and analysis of metrics for evaluating performance of the processes involved, so that all remain on the path lead to the goals of your business (DALL’AGNOLL, 2005). Still, according to Harrell (2002), simulation can be very effective in revealing solutions to minimize the impact of variances, or even eliminate them altogether. It supports research into the consequences of change and promotes access to instances of random changes in a system in relation to a goal.

The simulation, according Spinola & Pessoa, (1998) can be defined as the appropriate use of computing tools, communication and automation, including the techniques and concepts of organization and management, aligned with business strategy, allowing increased company's competitiveness through the analysis of scenarios and evaluating the various performance indicators.

The objective of this paper is the development and application of computer simulation techniques in a system of industrial drying of yerba mate to mate, evaluating the performance of its production line by creating simulation scenarios and thus contributing to integration of information technology (IT) in industry of yerba mate, which currently requires more satisfactory and conclusive data.

2. Context of Production of Yerba Mate

2.1. Description and Aspects of Yerba Mate

According Maccari (2005), the plant of the yerba mate has similar characteristics to oranges, with gray stems, usually with 20 to 25 cm in diameter and may reach 50 cm. The height is variable, being influenced by site conditions, by management and by the age of the plant.
Bragagnolo et al. (1980) claim that the height can reach 15 meters in areas of dense forest. Its leaves are dark green on top and lighter at the bottom, with average length of 5 to 8 cm and width of 4 to 5 cm (REITZ et al., 1978).

The exploitation of yerba mate is based on the harvesting of the branches of the plant, to obtain the leaves, harvested and processed to give rise to major products, including the mate.

2.2. Brazilian Production

The product yerba mate to mate is homogeneous, but has the characteristic of having a green tint, which is obtained using good sources of raw materials and an improvement process that can maintain the sensory characteristics desired for each market where the product is marketed.

Companies that benefit from yerba mate has adopted different strategies depending on the size of industries, so that large and medium companies have linked their strategies on setting marks, improvement in production processes and distribution logistics. Small and micro enterprises have adopted the strategy of cost reduction. Due to the market structure of industries from yerba mate to be highly sprayed, there is no market leader (ANTONI, 1999). From this precept, the company that has good access to raw materials, the field of beneficiation process of yerba mate, knowledge of consumer preferences, good logistic distribution has a high likelihood of consolidation in the market.

<table>
<thead>
<tr>
<th>State</th>
<th>Native</th>
<th>Planted</th>
<th>Total</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paraná</td>
<td>115,069</td>
<td>37,070</td>
<td>152,139</td>
<td>42%</td>
</tr>
<tr>
<td>Santa Catarina</td>
<td>69,569</td>
<td>35,064</td>
<td>104,633</td>
<td>29%</td>
</tr>
<tr>
<td>Rio Grande do Sul</td>
<td>20,692</td>
<td>80,910</td>
<td>101,602</td>
<td>28%</td>
</tr>
<tr>
<td>Brazil</td>
<td>206,916</td>
<td>154,284</td>
<td>361,200</td>
<td>~100%</td>
</tr>
</tbody>
</table>

Source: Adapted from Deser (2001)

Table 1 - Production of Brazilian yerba mate in Tons

2.3. The Process of Industrial Drying of Yerba Mate

According to Costa (2007), is the industrial drying operation, which comes from the moisture contained in various materials and manufacturing operations is one of the most used in practice, both for the finish or the moisture balance itself between the various materials processed with the ambient air. Concerning the industrial drying of yerba mate, the mechanical dryers are today the most modern equipment in the industry, because the dry parts of the leaves evenly, faster, minimizing losses due to better utilization of the heat source. However, Rocha (2001), says that over the years, the process of industrialization and processing of yerba mate was very little changed, both in terms of process, as the technological, with most of the mills improvement works so rudimentary, low-technology investment in the issue, there are some companies that use mechanical dryers and sporadic cases of companies that have automated the process using electronic equipment to control the processing of raw materials.

So that the yerba mate is harvested, the branches are removed with twigs of diameter of about 20 mm in mature leaves, these in turn are roughly the plant and deposited in a blanket around
the trees called “poncho”. Thereafter, baling the yerba, heading to the fastest possible for the next step, the singeing, which is held inside the drying plant, consisting of a metal cylinder rotating and tilted, with internal pads that lead leaves of yerba mate.

At one end of the cylinder, there is a flame where the leaves are rapidly coming into direct contact with fire.

The blades inside the cylinder take the lightly toasted leaves to the other end, where the yerba goes on the drying period (Figure 1), which dehydrate the leaves until they acquire a crisp and brittle consistency.

Finishing the drying phase of yerba mate, then it is crushed and fragmented, with more modern version made by unending screw, which grinds the yerba mate according to their rotation, taking the yerba directly to the warehouse, from where it will be routed to another production plant for further refinement and packaging. However, the information given by Schiff (1997) and cited by Rocha (2001) corroborate with those of Valduga (1995), which reports that there are wide variations in the manufacturing process of yerba mate from region to region, depending on the steps process, layout of the plant, the region where the yerba is harvested and industrialized as well as sources of energy required to process, so that each company has an array of equipment and logistics that maximize use of resources of the firm.

3. Process Approach by Simulation

3.1. Process Simulation

Simulation is the process of designing a computer model of a real system and conducting experiments with this model in order to understand their behavior and/or evaluate strategies for their operation (PEGDEN, 1990). A model can be defined as a representation of the relationships of the components of a system, being considered as an abstraction, in that it tends to approach the true behavior of the system (CHWIF & MEDINA, 2006). Figure 2 presents the methodology for building a simulation model.

According to the manufacturer, the software Arena is an integrated graphical environment, which contains all the resources to process modeling, design and animation, statistical analysis and outcome analysis.
Prado (1999), says that simulation is a technique for solving a problem by examining a model that describes the behavior of the system using a digital computer and, which, like most software simulation, Arena displays the system to be modeled as consisting of a set of workstations that provide services to clients (also called entities or transactions) that move through the system.

![Simulation Methodology](image_url)

Source: Adapted from Chwif & Medina (2006)

**Figure 2 - Simulation Methodology**

On the practical functionality of the simulation system for industrial drying of yerba mate set the following parameters: a) input variables: kg of yerba mate, b) system parameters: velocities and lengths of tracks, number of servers operation, power of electric motors, wood consumption used for operation and c) output variables: volume of production of leaves and sticks, electric power costs, costs of manpower and liters of water evaporated during the drying processes.
3.2. Industrial Drying Plant

A unit of industrial drying of yerba mate to mate first with regard to the following steps:

a) Belt feeder: aims to standardize the flow of food and improving the product distribution, with axis equipped with knives to shred the raw material;

b) Chopper: In some cases, fragmentation of the raw material must be intense so that there is the possibility of further injections in the operating system, this becomes possible by making use of resources such as chippers and grinders to shred the yerba mate still green;

c) Roaster: is defined by a cylinder with a dimension of 9.8 meters in length and diameter of 2.8 meters, moved by electric motors. According Maccari (2005), the rotation of the cylinder usually ranges from 10 to 15 rpm;

d) Dryer: is a device for quick drying, with a cylindrical shape, measuring 13.50 meters long and 2.30 meters in diameter;

e) Cyclone: the device looks like a metal funnel large proportions, which the yerba mate already dry, but with vapor condensation caused by the drying process is routed through carrier until his entry, causing a separation method by gravity of the material;

f) Sieve: It consists in making the cleaning of yerba mate by means of sieves, fans and filters dust collectors, which allows the separation of inert materials and minor impurities;

g) Dryer Sticks: the residence time of material in rapid drying results insufficient to dry the thick stems of the yerba mate, requiring more time to dry sticks separately for both, it is exclusive use of dryers to the sticks;
h) Cyclone Sticks: The sticks of the remaining screening process, but with vapor condensation caused by the drying process of sticks are routed via conveyor to the entrance of the cyclone sticks, causing a method of separation by gravity of the material.

4. Project Simulation

4.1. Procedures for Data Collection

Data for analysis were collected through interviews with employees and owners of the drying unit, as well as measurements, specific timings of operations and process analysis. The processing capacity of each system was provided through contact with the engineer responsible for it and also through analysis of equipment. For the assessment of the costs involved in the drying process by computer simulation the electric energy was analyzed in engines used in the handling of roaster, dryer, mats and cranes for transportation of yerba mate and chipper/shredders from raw material by consulting the digital electric energy meter from the company, enabling the achievement of accumulated power and capacitive induction. All that in addition to the amount of kWh established by the electric company from the region being R$ 0.16, the wood used to feed the furnaces at a cost of R$ 35.00/m³ and the cost of labor employed in the local equivalent R$ 0,05/kg of dry yerba mate.

4.2. Designation of Entities for Simulation

The calculation for the arrival time of entities and scaling cell size of the mats for the program was made by weighing 1kg of raw materials through analog scale and by measuring the area that holds 1kg of material in the conveyor belt system. Continuing with the determination, the result was that, 1kg occupies approximately 1 linear meter inside the dimension of 73 cm width of the conveyor belt, and that the arrival time for the entities would be 1 second, simulating the injection of matter by mat feeder.

4.3. Construction of Simulation Model

The first industrial drying stage to be examined was the receiving the material, which covers some fundamental parts of control in the process, namely: a) Arrival of trucks, b) Entry of Raw Material, c) Weighing Trucks, d) Transport to discharge, e) Unloading Trucks.

The following procedure was the metrology of operations and records the number of trucks and kg of raw material per day which comes to the company, and even the time of weighing, transport and unloading of trucks. In order to find out what frequency distribution best applied to these processes, and simultaneously collect data relevant to simulation was done using a program that generates random numbers, in which it was informed the range of minimum and maximum values of measurements, waiting for thus obtain the generation of 100 numbers for effective removal within that range.

Following, it was carried out using the tool Input Analyzer from the software Arena, since the use of histograms is crucial for the identification or delineation of the theoretical distribution of probabilities, and thus can obtain the average value of the process and its standard deviation. Subsequently, the measurement phase of steps for drying of yerba mate to mate went into the production plant, obtaining relevant information from each machine and each process required to collect data for building the simulation model. After the removal of previous drying steps, which refer to receipt of the material that comes to industry and the
timing of processes directly related to industrial drying of yerba mate has established a flowchart of operations relating to 1 kg of yerba, as shown in Figure 4.

![Flowchart of Industrial Drying Yerba Mate for mate](image)

With time analysis of processes, machinery operation, transportation and servers that govern the system already done and the statistical distributions of the frequency obtained is then passed to implementing the simulation itself, starting with the control logic, thus making the programming its modules.

The create block was programmed to generate only 100 entities, presenting 1 entity per arrive, which will be termed kg of raw material, so each entity will be designated as 1 kg of raw material.

As the Create block generated 100 entities, the simulation was representing an intake of 100 kg of matter in the system.

**5. Results and Discussion**

In order to understand the whole structure of the system and its processes the (Figure 5) represents the full layout of the programming modules in Arena environment and provides an overview of the computational model designed.
When the execution control of the simulation program was shot, the dynamics of the entities through the processes can be observed, feeding performance indicators relevant to the production line drying of yerba mate, in sync with the animation layer, parallel to the designed production plant.

The main factors analyzed during the simulation were: the time regarding obtaining the first kg of dried leaves in the drying unit and the income made by the resources and their performance figures and costs.
With the succession of the simulation, the results showed that the first kg of leaves from the industrial drying process comes to bagging 14 minutes and 56 seconds after the start of the process, thereby obtaining the initial values of income from production.

Soon after the start of the first income dried leaves are then bagged and placed in rows on the plant floor, which forms buffers waiting to be transferred to deposit.

With the completion of the simulation, the Figure 6 shows the time called Instant T34, which means that the whole drying process simulation of 100 kg of raw material injected into the system is over 34 minutes and 54 seconds after the start of the process and as well as the demonstration of placing the bags in stock intermediate (buffer), and also the process of loading and transfer.

With the aim of establishing confidence in the data generated by simulation of production, 100 replications were designed for the scenario to be simulated, where it could produce the
reports generated by the Arena, which showed a series of good results to the research and clarification of the simulation.

The total cost of production and value added to entities through the system was approximately R$ 10.00, which is the cost of funds applied along the path of the simulation. The resource sieve was the highest rate of waiting time in queue. From this, it was possible to correlate that, because it is an outfit that needs a longer time to perform the physical process of separation of the plant material resource that takes longer than the others. The dryer resource and the dryer cyclone resource were the most used. This utilization rate reinforced the principle that the most time consuming step of drying process in terms of time and energy is in this range.

The roaster station showed the highest proportion of operating costs for manufacturing resources, costing about R$ 3.16, even higher than the dryer station, second only to the cost of manpower officials, which was assigned to bagging station, the total cost of manpower/Kg of all employees.

It was realized the accumulation of material in only one of the conveyors. This is located on the conveyor belt called a helical screw conveyor, which carries out transportation of sticks formed by the process of drying out of the sieve season until the beginning of the season dryer sticks. Another possible point of accumulation of entities may be due to the slow speed of helical screw, less than 1m/s or still due to its length, from 6 to 7 meters.

The belts that transport the dried material show results with low values, and can be better designed. Still, concerning the use of mats, the Arena software shows that after the study done with 20 replications of the simulation mat that presents the greatest use is the first, receiving dosages mat feeder. The flow of entities is intense, because it is the entry process, and usually do not show delays of any nature. The flow of entities becomes smaller in the 2nd than the 3rd mat, that because the 3rd is located at the exit of the process singeing, where the entities are for a longer time than in the case before the 2nd, the process chopper.

With reference to the total costs of the proceedings, the average processing 1 kg of raw material held in the 100 replications was R$ 0.1016.

Analyzing the processes, it is noticed that the ones who have time to wait per entity in the queue are the processes of bagging leaves and the process buffer. Under these conditions, either one or the other might be considered normal because, following the programming of the simulation, to obtain control of the intermediate stock, and this, in number of bags of 50 entities was normal for there to be some waiting time in queue.

The process remains stuck for longer within the resources of drying and showing the dryer sticks process as a means of further delay. It is important to note that, for automated operations, the process of chopping the material is what gives the smallest total processing time, suggesting that there may be possibility of slack in the functioning of the resource.

The report of simulation also confirms that the system to overload in drying processes, where the processing time is longer, being effected by the cyclone and dryer processes, both vital systems of industrial drying.
After rounds of the 100 replications of the simulation, the average number of entities that have passed through the system were 69.42 for the efficiency of the drying of leaves and 30.58 for the efficiency of the drying process of sticks. (Figures 7 and 8).

The results showed queues in the procedures for transfer of material and not at the critical processes such as drying and therefore those involving higher production value. By contrast, waiting times in queue are assigned to processes that require the use of human resources, such as bagging and transporters.

The evolution of the simulation also showed that the yield of leaves was 47.8 kg/minute. After rounds of the 100 replications of the simulation of drying, was obtained the values of the minimum processing time from 34.01 minutes and maximum processing time from 36.01 to complete the scenario.

It is possible to admit that, considering that the simulation showed a yield of 68 kg for the process leaves, feed moisture on the yield of the process leaves would be 55.6% as Maccari (2005).

Thus, 68 kg with 55.6% moisture in green yerba mate, that they get 4.4% moisture at the end of the drying process which also says Maccari (2005) are needed that 51.2% moisture evaporate, thereby generating a discount of 51.2% in the 68 kg of leaves indicated by the simulation, with a total yield of 34.8 kg in the process leaves, or approximately 35% yield. With the correction factor of evaporation, yields are considered to be 24.47 kg/minute. After the process dryer, the stick still has a moisture percentage of 27.7%. Therefore, to reach the moisture of 16.4% according Maccari (2005) must pass through another drying process. The yield indicated by the simulation for the sticks was 32 kg, after the correction factor of evaporation, after drying of sticks, the process by which lost 23.3% more moisture has a total of 6 kg of sticks.
The cost of the manpower embedded in the bagging process was R$ 3.4630. However, this reference value was calculated at 68 kg of productivity. To be able to adjust the cost is necessary to use as reference the production value of 34.8 kg of leaves and multiplying this value by the cost of manpower employed. The result found equalized is R$ 1.74 for processing 34.8 kg of dry matter. Recalculating the cost of evaporating water leaves, the total cost of the procedure for processing 100 kg of raw material with discounted process of drying of sticks was around R$ 6.66 or R$ 0.066/kg, leading nearly the entire cost of operations per kg of product in terms of manpower within the industry.

Exemplifying the equalizer parameters described above with reference to a total arrival of 57,000 kg of matter in a single workday relationships with all the evaporation of water and labor costs per kg yield of leaves, resulting in so the actual values of yield of leaves and sticks that leave the system as well as financial costs spent on electricity and thermal energy for the completion of the process, the operating value obtained for the processing of 57,000 kg of raw material was R$ 3427.53. The total value found in the simulation of the distributed electric power, thermal energy and manpower was R$ 275.67, R$ 2064.96 and R$ 1086.90 respectively.

6. Conclusion

The analysis showed by the simulation in this work concluded that the system of industrial drying of yerba mate studied is well sized and operating below its maximum capacity. The results, however, show some queues in some cases, causing a possible increase in production may be compromised. Among these processes are: the sieves, the conveyor system and workers.

Another conclusion that the simulation study showed was that the dry stations, drier and cyclone are the highest number of accumulated material, which makes the process delicate and more responsibility within the industrial drying of yerba mate. The reports of the simulation showed accumulation in the mechanism of the helical screw conveyor and also indicated that the first mat, leading to a raw material for the grinding process is the most crowded among all installed in the plant production, suggesting a bottleneck injection of matter in the system. It was noted a moderate range of values between replications of the simulation.

The study of simulation and analysis of the input data showed that the operations before and after entering the drying system are well distributed, with a predominance of Beta frequencies type, representing uniformity in the system. The approximate total costs of production raised by reports of the simulation are R$ 0.07/kg of raw material, indicating the energy expenditure as the main factor, and the thermal energy has the highest cost electricity. The manpower demonstrated appear second in the item costs for the industrial drying of yerba mate, and in some cases, the need for higher production, to balance the values of energy. The yield of production of industrial drying occurred during the simulation is around 35%. The addition on staff proved to be necessary if there is the possibility of an increase in production, with increasing speed of mats and a fit in the sizing of equipment processors.

The effectiveness and use of computer-aided simulation for analysis, verification and performance of the production line of the industrial drying of yerba mate to mate proved to be an efficient tool for data collection and simultaneously contributes to the integration of technology in the sector. However, the techniques of production can be improved and future building programs and specific models or dedicated to industrial drying simulation may
contribute greatly to the development of the sector. This, therefore, may have cost impacts on the dried product. However, if there is better control over the process, it will be possible to establish a final product of better quality, with a forecast of anticipated costs, with an optimized production and above all, with a better control the unwanted surprises in the financial market.

References


VALDUGA, E. Chemical and anatomical leaf of Ilex paraguariensis Saint Hilaire and some species used in adulterating the mate. (Chemical Technology Dissertation). UFPR, Curitiba, 1995.