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Operational Improvement of a Chiller to Reduce Water Usage in the Cooling of Turkey Cuts

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***Abstract* — *Cleaner production is the application of an environmental strategy that seeks to integrate the production processes with products and services so as to reduce the risks to humans and the environment. This work gathers data from a study conducted in a slaughterhouse for birds in the production of turkey leg quarters. An improvement opportunity was identified in the water consumption of the sanguine fluid removal process of the turkey leg quarters with a particular technological chiller. The area of intervention was chosen because of its history of higher-than-expected water consumption in relation to the acceptable limit negotiated with the local Federal Inspection Service. The evaluated criteria were water flow per kilo of leg quarter and the structure of the adsorption equipment used in the industry. The results of these analyses were directly linked to water savings and changes in equipment, increasing knowledge about the implementation of cleaner production in the slaughterhouse industry, aligned to the continuous improvement of the process. The control of the water flow and the direct changes made in the chiller resulted in water savings of 83,435 L/week and 1,001,220 liters/year, based on the production of the slaughterhouse under study, in addition to savings of R$ 289.52 per week or R$72,959.04 per year.*

Keywords*— *Cleaner production, water savings, chiller, turkey leg quarter.

I. INTRODUCTION

Cleaner production (CP) using the principle of pollution prevention seeks to optimize the use of resources and reduce the generation of waste in the production processes. It covers a series of measures ranging from the use of clean technologies to the use of less polluting and more durable materials (Andrade et al., 2007).

Adjustments may be made in the productive processes that enable the reduction of emissions/waste generation. These adjustments can range from small repairs on the existing model to the acquisition of new simple and complex technologies (United Nations Environmental Program/United Nations Industrial Development Organization - UNEP/UNIDO).

The meat industry is one of the most productive industries in Brazil, and the production of turkey stands out in this industry. According to the 2016 annual report of the Brazilian Association of Animal Protein (*Associação Brasileira de Proteína Animal*, ABPA), Brazil produced 327,179 tons of turkey meat in 2015. 41% of this production is destined for export, 0.05% of which involving the whole turkey, 37.18% involving processed meat and 62.77% involving cuts. Given the importance of the production of turkey cuts in Brazil and in the state of Santa Catarina, in particular, the processing of these cuts consumes a considerable amount of water (ABPA, 2016).

According to Medeiros, Gheyi and Soares (2010), the increase in water demand to meet the human, industrial and agricultural consumption requirements puts pressure on indispensable water resources for the supply. Despite the fact that Brazil possesses 13% of the fresh water available on the planet, its distribution is unequal, with 81% concentrated in the Amazon region, where the country's population is smallest (Ana, 2015).

The world is undergoing intense cyclical and ever faster changes and these transformations are affecting everyone, without exception. Based on these phenomena, there is growing concern among companies regarding the environment and the health and safety of their employees, in addition to the social responsibility and ethics with respect to the community in which they operate (Lemos and Nascimento, 1999).

A chiller is a widely employed piece of equipment in bird slaughterhouses, and it is used in food industries in general to cool products. It is a stainless steel tank fitted with a worm thread and containing a mixture of water and ice. Its purpose is to cool bird carcasses or cuts and, consequently, to slow down microbial multiplication (Simas et al., 2013).

The cooling system evaluated in this study has a different function than the previously mentioned chillers. Its function is to reduce the sanguine fluids of the turkey leg quarters with the circulation of cooled water alone, making

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no use of ice. In this kind of chiller, an effective control of the water temperature must be maintained in the pre-cooling-by-immersion system. This temperature may not exceed 4ºC in accordance with Ordinance No. 210 of the Ministry of Agriculture, Livestock and Food Supply (1998).

In order for the chiller to be efficient, some factors need to be controlled, such as the microbial load of the product before and after passage through the equipment, the constant renewal of water, the ratio between the quantity of water per kilogram of product, in addition to the ideal temperature (Northcutt et al., 2008).

In addition to prolonging shelf life, the main objective of the 4ºC cooling is to prevent the proliferation of microorganisms. Some pathogens can develop at low temperatures, but most cannot grow or produce toxins at temperatures below 4°C (James and James, 2014).

This equipment has been developed by the slaughterhouse under study itself. Its modifications were made based on the need to wash the product with the constant renewal of water. Before the adjustments, this renewal of water resulted in a large volume of consumption. As such, this stage was singled out as an opportunity for improvement. This is in alignment with the cleaner production concepts, i.e., modify the equipment to reduce the consumption of water, generate savings and reduce the generation of effluents.

The environmental impacts produced by companies have resulted in an intensifying pursuit of cleaner production programs in its procedures. This depends on the establishment of eco-teams within companies in order to carry out the work. People who operate within the productive process of organizations with continuous and correct training are capable of controlling the system, generating major changes.

In this sense, the objective of this study is to improve the operating conditions of a technological chiller in the production line of turkey leg quarters, focusing on water savings, the reduction of effluents and the deployment of cleaner production.

II. MATERIALS AND METHODS

The first action undertaken was a meeting with the managers of the company to discuss the most urgent improvement opportunities within the company. As such, it was agreed that the change in the technological chiller of the turkey leg quarter production line had the most immediate importance because of the high water consumption in the production line. Subsequently, it was necessary to establish parameters and timeframes for the projects implementation guidelines. Tables 1 and 2 show the defined the actions.

Table.1: Actions to be undertaken in the short term.

Opportunity	Name of the Action	Description of the Action	Indicators	U/M
1	Establish the Eco team.	Form a multidisciplinary team in order to identify the gaps in the process and establish the site for the application of the CP.	Training of the team.	-
2	Raise awareness of the team.	Conduct awareness meetings with the sample monitors and chiller operators in order to explain the objectives of the work and achieve the engagement of all.	Training of the team.	Number of trained employees
3	Refresher training	Educate operators on the importance of the project, targets, actions implemented and responsibility of each operator.	Training of the team.	Number of trained employees

U/M = Unit of Measurement.
Source: Developed by the authors.

Table 2: Actions to be undertaken in the medium term.

Opportunity	Name of the Action	Description of the Action	Indicators	U/M
1	Data collection	Accompany the data collection on water flow in the leg quarter chiller.	Water Flow Rate	L/Kg

U/M = Unit of Measurement.
Source: Developed by the authors.

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The Eco-team was formed as a multidisciplinary team composed by the Production Manager, Maintenance Manager, Production Supervisor, Maintenance Supervisor, Machine Operators, Operators, Maintenance Technicians and the manager responsible for the efficiency in the unit. Figure 1 shows the flowchart of the process and highlights the intervention site of the study.

After this process, the next step was to define the axes that would guide the present study, described in the course of the study.

2.1 Location where the study was carried out

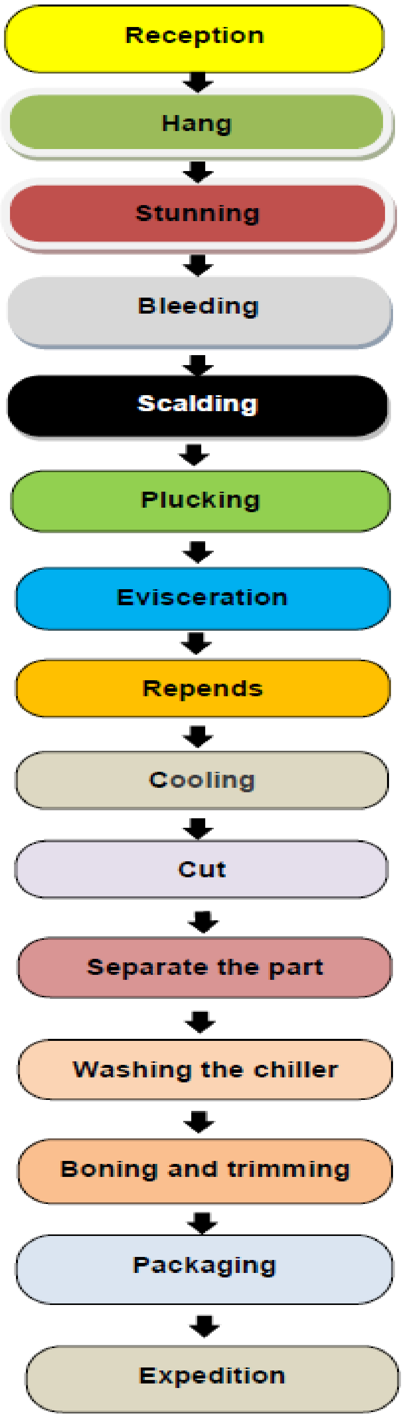

Fig. 1: Flowchart of the turkey leg quarter processing

The location chosen by the Eco-team to implement the cleaner production was the turkey leg quarter chiller, of proprietary manufacture. It functions as a technological chiller that assists in the washing of the product to remove the sanguine fluid in the slaughter and evisceration phase.

Until the date of the conclusion of this study, there was no legislation for technological chillers for turkeys. As such, the company needed to perform its own standardization of the process based on the legislation for poultry meat, and defend these standards before the local Federal Inspection Service. Once defended, the company could continue using the turkey leg quarter chiller in the processes based on ordinance n° 210 of the Ministry of Agriculture, Livestock and Food Supply (1998).

The turkey leg quarter chiller under study has a capacity of 2,800 liters of water in constant renewal, with a water flow rate of 0.4 L/Kg of turkey leg quarter, being fed in the counter flow. It has a spiral that carries the leg quarter to a remover to extract the product from inside the chiller.

After the passage of the leg quarters through the chiller with water, they are sent through conveyor belts to the boning and manual fileting section to remove the bone, excessive fat, arteries, tendons and defects, such as hematomas, gore and others. In this step, the cuts are standardized according to the intended final product. Figure 2 shows the chiller used in the work.

Fig. 2: Turkey leg quarter water chiller studied in this work

2.2 Determination of the water flow

To establish the water consumption in liters, a spreadsheet for data collection had to be created to register the sex of

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the turkey (male or female) in the caption field, the initial and final reading of the hydrometer (Itrón brand), the number of slaughtered birds in the period of collection and the water consumption.

Figure 3 shows the data collection spreadsheet for the chiller used to control the process.

DAY/MONTH/YEAR:									
Conversion Parameters	Caption	Initial reading		Final reading		Water consumption	No. of birds slaughtered	Flow rate	Monitor signature:
		Hour	Reading	Hour	Reading				
Average leg quarter weight: • Female: • Male:									Supervisor signature:
									QA signature:

Fig. 3: Chiller flow rate tracking spreadsheet.

Legend: No.: number; QA: Quality Assurance

Source: Developed by the authors.

The initial and final reading of the hydrometer was collected through the information recorded in the spreadsheet. 60 hydrometer readings per month were taken for the data collection, 30 of which for male turkeys and 30 for female turkeys. The preliminary data collection occurred from April 2016 to June 2016, and the study continued until the month of November 2016 in order to observe whether the improvements implemented were relevant.

With the data of the initial and final readings of the hydrometer, the consumption of water in the analyzed period could be obtained according to Equation 1.

According to Ordinance No. 210 of the Ministry of Agriculture, Livestock and Food Supply (1998), the water used to fill the tanks or stages of immersion coolers for the first time should not be included in the calculation of these quantities.

Water consumption (L) = Final reading of the hydrometer (L) - Initial reading of the hydrometer (L) (1)

The water flow calculation used in the leg quarter chiller is shown in Equation 2. Samples were taken every 2 hours and the conversion factor considered was the average weight of the leg quarter for the male and female turkeys.

Water Flow (L/kg) = Water consumption / number of birds processed x Conversion factor x 2 (2)

2.3 Determination of the critical acceptable flow limit

The first thing you need when there is no specific legislation for a given parameter that you want to monitor in industry, is a theoretical foundation of the fact under study. The chiller under study is technological and there is no legislation governing the water utilization threshold for the equipment. In this case, two primary factors were taken into account: the renewal of water and the visual analysis of the cleaning of the water contained inside the chiller. Subsequently, a defense was presented to the local Federal Inspection Service (SIF) in order to validate the control and use of the equipment to be deployed. During the study, these factors have already been validated and were being practiced by the company.

The critical limit for the water flow of the turkey leg quarter chiller established by the company and validated by the local SIF was therefore 0.4 L/Kg of leg quarter, regardless of the sex (male or female).

2.4 Observation of the site

The Eco-team conducted a visual analysis of the chiller of turkey leg quarters in order to check the structural conditions of the chiller, such as: a) the structure of the remover, taking into account whether the opening of the perforated plate was enough for a better water flow; b) cleaning of the renewal water through a visual inspection of the water quality, i.e., whether it contains many suspended particles that may interfere in the color and in the amount of suspended particles.

2.5 Data analysis and interpretation techniques

Inferential statistics were used for the interpretation of the results, with the flow rate data being compared through the Tukey test, using the *Statistica* software at a significance level of 5%. The existence of significant differences between the flow rates obtained each month were compared, in addition to the differences between sexes (male and female leg quarters).

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III. RESULTS AND DISCUSSION

During the execution of the proposed actions, the flow adjustment system was identified as a barrier to the deployment of the actions. This was not a system where access was restricted, making it difficult to monitor the opening of the valve, because the operator responsible for data collection performs this collection every two hours, and in the meantime other operators may cause interference.

This risk was mitigated by seeking the constant training of the operators who operated the chiller as well as the entire team handling the turkey leg quarters. This way, no other operator would interfere when the operator in charge wasn't doing the monitoring, thus ensuring that the process occurred as planned. The data collection was recorded through the previously mentioned spreadsheets, and the water flow for both the male and female leg quarters was calculated, with the chiller only being fed with one sex per batch. The structure of the chiller was also observed in order to find opportunities to improve the structural part of the equipment.

Through the completion of the calculations, it was found that the average water consumption spent was 1.05 L/Kg for female leg quarters and 0.58L/Kg for male leg quarters. Taking into account that the critical limit established was 0.4 L/Kg, an action plan was established for the identified improvement opportunities in order to deploy the CP in the case under study. The objective of the action plan was to reduce the water consumption up to the acceptable limit, and to standardize the consumption for both sexes (male and female). The action plan (5W1H) is represented in Figure 4. The differences in the leg quarter remover with the deployment of the proposed actions can be seen in Figure 5.

Before the actions, the paddles of the remover had very closed plates, which caused a great loss of water from the chiller, i.e., instead of removing only the leg quarters, the remover also took out water along with the product. This process caused two visible problems: a great waste of water on the floor and also a risk of accidents for the workers due to the water on the floor, which in turn made the floor slippery. Figure 5 allows for a comparison of the remover structure before and after the changes.

For the female leg quarters, this water removal was more evident because the paddles were not only more closed and straight, but the surface and mass of the product were smaller when compared to the male leg quarters, requiring a larger quantity of mass on the paddles to be removed from the chiller. More water was removed than product.

The other action carried out was to change the angle of attack of the paddles, facilitating the removal of the product inside the chiller. The male leg quarters have a larger surface and mass compared with the females, and stay on the paddle for a longer time, which makes the removal easier. Figure 6 provides a better visualization of these modifications of the product remover, seen from above, after the actions were carried out on the leg quarter chiller.

What to do	Why	Who will do it	How will it be done	Where	When
Ensure that all employees involved in the process are aware of their responsibilities	To educate and engage the team	Supervisor of operation	Educating operators on the importance of the project, targets, actions implemented and responsibility of each operator	Supervisor training room	20.06.2016
Change the paddle structure of the leg quarter remover of the chiller	Enable the water present on the paddles to drain back into the chiller during the removal of the product from the chiller.	Maintenance Supervisor	Modifying the structure of the leg quarter remover, making the structure more open	Turkey leg quarter remover of the chiller	01.07.2016
Change the paddle angle of the leg quarter remover of the chiller	To improve the product removal efficiency	Maintenance Supervisor	Changing the paddle angle of the leg quarter remover	Turkey leg quarter remover of the chiller	01.07.2016
Ensure constant renewal of water	To improve the efficiency of the water renewal flow	Maintenance Supervisor	Expanding the water output channel of the	Water output channel of the chiller.	01.07.2016

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			chiller.		
Ensure that there is no water on the floor on either side of the chiller.	To avoid water from spilling on the floor	Maintenance Supervisor	Expanding and altering the position of the water output channel of the chiller.	Water output chute of the chiller.	01.07.2016

Fig. 4: Action plan (5W1H) to reduce water waste in the chiller.

(a) (b)

Fig. 5 - Changes in the leg quarter remover (a) before with the more closed surface and (b) after the undertaken actions with a more open surface.

Fig. 6: Changes in the leg quarter remover from above

Figure 7 shows the improvement that was performed in the outlet piping to renew the water of the leg quarter chiller. This water removal occurred through the exit of the technological chiller, i.e., together with the output of the product, causing a problem for the company since the correct thing would be for the water renewal to occur at the entrance of the chiller, along with the entry of the product (against the chiller flow). This way, the renewal of water was taking place incorrectly and the existing spillway did not reach the level of the water for renewal.

Fig. 7: Improvement in the water renewal piping of the chiller

Figure 7 shows the improvement in the spillway, where the water renewal of the leg quarter chiller occurs. In the dashed area there was an extension of the water renewal piping from top to bottom, thus increasing the area where the water renewal occurs and making the output flow of water from the chiller (more dirty and hot water) more effective.

After the implementation of all the actions proposed by the

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ECO-team, along with the results collected through the spreadsheets, the statistical analyses and the results obtained through the implementation of cleaner production could be performed and presented.

Table 3 shows the means of the water flow results of the chiller using male and female turkeys as a function of the months of the study.

Table 3: water flow per kilogram of male and female turkey leg quarter ± standard deviation Equal letters do not differ significantly among themselves by the Tukey test at a significance level of 5%.

Month	Water Flow Rate (L/kg)	
	Female	Male
April	1.12 ± 0.16 a	0.57 ± 0.18 a
May	1.18 ± 0.25 a	0.58 ± 0.12 a
June	0.87 ± 0.25 b	0.59 ± 0.15 a
July	0.47 ± 0.02 c	0.45 ± 0.03 b
August	0.47 ± 0.01 c	0.46 ± 0.02 b
September	0.48 ±0.03 c	0.43 ± 0.03 b
October	0.47 ± 0.01 c	0.45 ± 0.02 b
November	0.48 ± 0.01 c	0.46 ± 0.02 b

The Tukey test reveals that there was no difference between the months of April and May for the female turkeys. This occurred because the action plan for the reduction of water consumption was not yet in operation. June was the month where the implementation of the action plan started. This month already shows a significant difference in relation to the other months, this occurs because the process is still in transition.

The remaining months showed no significant difference, i.e., from July the action plan was already deployed and running and a significant reduction in water flow can be observed when compared to the first months of the study. Based on the comparisons, the action plan can be said to have been effective for female turkeys, with a reduction of more than half of the water consumption and coming close to the critical acceptable threshold of 0.4L/kg, as previously described.

As for male turkeys, one can see the months of April, May and June showed no difference. This occurs because April and May are the months that precede the implementation of the actions and because June is the month when the changes were initiated. Another point that contributes to this similarity is that the male leg quarters are heavier than the female ones. In this case, less liters of water are added to the chiller, corroborating with the statistical analysis. And as mentioned earlier, in the male leg quarters, the paddles of the remover could remove the product without taking a large amount of water with it.

For the months of July to November no difference was observed, just as was the case for the female turkeys. In these more recent months, the action plan was already deployed and in full operation, i.e., the flow of water in the chiller was already controlled and inside the established limits, revealing the continuity of the implemented actions as well as their effectiveness.

Figure 8 shows the comparison chart of the water flow for male and female turkeys in relation to the critical limit established between the company and SIF. One can see that before and during the implementation phase of the action plan (April to June), the water flow in the chiller is higher than the target imposed by the legislation.

After July there is a visible reduction in the use of water in the company, which starts complying with the water-per-kilo-of-meat targets, in addition to reducing the amount of water in this process. The flow value cannot be less than this critical threshold value, because otherwise there would be insufficient water renewal to maintain the constant temperature of a maximum of 4°C, which also controls the microbial load.

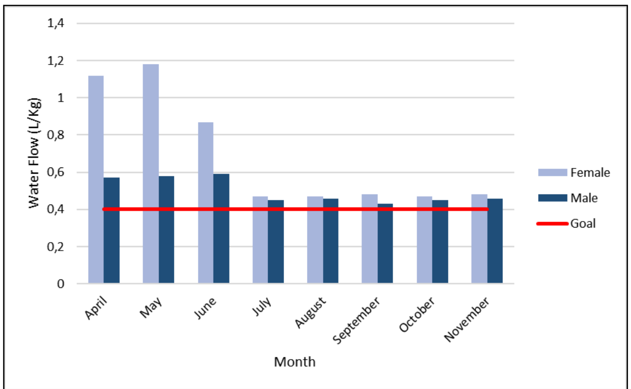

Fig. 8: Comparison chart of the water flow for male and female turkeys with the established critical limit.

To determine the savings generated with the implementation of these actions, some important data needs to be taken into consideration, such as the cost of the water that comes from the treatment plant, which is estimated at R$ 0.40, the cost to generate iced water (approximately R$1.37), and, finally, the cost to dispose of water after use in the effluent treatment station (R$ 1.70).

Adding up these values, we get R$ 3.47 spent per liter of water used in the process. The difference in water flow used before and after the implementation of the action plan was approximately 0.7 L/kg for female and 0.16 L/kg for male turkeys. As such, R$ 283 per days in savings were generated and taking into account that the average number of days worked in the month is 21 days, the savings added up to R$ 6,079.92 per month and R$ 72,959,04 per year. In addition, the most important gain was the contribution to the environment with the reduction of 83.435L/week and 1,001.220L/year.

Through these results, it can be said that the company was able to apply the principles of cleaner production, which is supported in the fact that the most effective way for the reduction of pollution is to analyze the process at the origin of the production and eliminate the problem at its source (MEDEIROS et al., 2007).

After the implementation of the actions, we pursued the maintenance of the improvements implemented in the process. This was possible through monitoring the water consumption used in the leg quarter chiller. The follow up was done with the previously mentioned data collection spreadsheets (Figure 2), as well as through the frequent employee trainings and the monitoring by the Eco-team.

IV. CONCLUDING REMARKS

The obtained results allow for the conclusion that the study has achieved its desired objectives. 83,435 L/week of water was saved and these savings directly impacted the company's bottom line. The statistical analyses reveal that a primary change of equipment can generate large energy savings in an entire process.

In particular, the study shows that it is possible to produce the same amount of products while respecting the allowed water consumption limits and collaborating in environmental preservation. Consequently, less effluents will be generated in the process. Thinking about environmental preservation and the reduction of expenses means always thinking about the future.

The implemented actions are therefore in alignment with the precepts of cleaner production, enabling the company to operate in a socially and environmentally responsible manner, consequently resulting in economic and technological improvements, applying a precautionary approach to Environmental Management (Medeiros et al., 2007).

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