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REDUCTION OF THE ENERGY COST AND ENVIRONMENTAL IMPACT IN THE PROCESS OF ARTIFICIAL AGING OF RICE FROM SOLAR THERMAL ENERGY IN THE COMPANY RICE MOLICAS S.A.C.

Reducción del costo energético y del impacto medioambiental en el proceso de añejado artificial del arroz a partir de energía solar térmica en la empresa Rice Molicas S.A.C.

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ABSTRACT

During the last 20 years, Peruvian rice production has increased by 2.8% annually, increasing the number of rice mills and their energy consumption, generated mostly by fossil fuels. Studies have shown that artificial aging and polishing processes require more electricity. Therefore, the objective of this study was to demonstrate the monetary savings in electricity consumption and the reduction of environmental impact in the artificial aging of rice by developing a proposal based on solar thermal energy in the case of the company Rice Molicas S.A.C. First, the company's current situation was studied through its electricity consumption monetized in soles, and the carbon footprint based on a production batch calculated using a multimeter, the unit price per kWh and using the SEIN conversion factor. Then, the materials and equipment for the design of the proposal were determined, where the referenced articles were consulted and evaluated with the technical specification sheets. The proposal was then simulated in CHEMCAD software version 1.7.5. Finally, the design was validated with a physicist and the simulation with a metallurgical engineer. As a result, savings of 12.11 s/ton of electricity consumption and a reduction of 0.03651 tonCO2eq of the carbon footprint were obtained. This study contributes to the dissemination of the use of environmental resources, it should be noted that the proposal was not chosen for implementation or monetization, and it is possible to develop more efficient designs.

Palabras clave:
energía solar térmica, alternativas de energía, granos de arroz, añejado, energías renovables.

RESUMEN

Durante los últimos 20 años la producción peruana de arroz se ha incrementado un 2.8% anualmente, aumentando así la cantidad de molinos arroceros y su consumo energético, generado mayormente por combustibles fósiles. Estudios demostraron que los procesos de añejado artificial y pulido demandan más electricidad. Por esto, el objetivo de este estudio fue demostrar el ahorro monetario del consumo eléctrico y la disminución del impacto ambiental en el añejado artificial del arroz al desarrollar una propuesta basada en la energía solar térmica en el caso de la empresa Rice Molicas S.A.C. Primero, se estudió la situación actual de la empresa mediante su consumo eléctrico monetizado en soles, y la huella de carbono en base a un lote de producción calculados mediante el uso de un multímetro, el precio unitario del kWh y utilizando el factor de conversión del SEIN. Luego, se determinó los materiales y equipos para el diseño de la propuesta donde se consultó con los artículos referenciados y fueron evaluados con las fichas de especificaciones técnicas. Después, se simuló la propuesta en el software CHEMCAD versión 1.7.5. Finalmente, se validó el diseño con un físico y la simulación con un ingeniero metalurgista. Como resultado, se obtuvo un ahorro de 12.11 s//ton del consumo eléctrico y una reducción de 0.03651 tonCO_2eq de la huella de carbono. Este estudio contribuye a la difusión del uso de recursos medioambientales, cabe resaltar que no se optó por la implementación ni la monetización de la propuesta, y es posible elaborar diseños más eficientes.

Introduction

In all countries, it is the responsibility of the authorities to ensure the protection of environmental components, including flora, fauna and natural resources, since they are the basis for the production of various goods that drive the national economy, generating jobs and the circulation of currency. In Peru, rice production has increased by an average of 2.8% per year over the last 20 years, leading to a substantial increase in the number of rice mills (Ministerio de Agricultura and Riego [Midagri], 2020) this has led to a substantial increase in the number of rice mills. Most of these mills consume electric power and fossil fuels to operate. This results in the emission of environmentally harmful gases that add to the pollution already existing from the planting of the rice. Although there are mechanisms, both preventive and controlling, and multiple legislative compendiums to prevent violations of the ecological system, they are often not complied with, either by omission or negligence.

According to Ferre (2010), the United Nations confirmed that rice is considered the second most produced cereal in the world. Within the agricultural sector, rice is responsible for 4.19% of Peru's greenhouse gas (GHG) emissions. The most energy-intensive processes in this industry are artificial aging and polishing or bleaching. Rice aging consists of causing irreversible changes in the physicochemical, sensory, cooking and textural properties that depend on time and temperature (Saikrishna et al., 2018). These changes are mostly beneficial, as they provide the added value desired or preferred by consumers.

Due to industrial improvements, aging has gone from being a natural process to an artificial one where the consumption of fossil fuels is higher. For this reason, many companies have opted for the use of clean energies such as solar thermal energy that seeks the concentration of heat generated by the sun to be transferred to some material as a fluid and to use it as heating for this process (Carbonell, 2021).

The question for this research will be the following: To what extent is a proposal for the use of solar thermal energy capable of reducing energy costs while reducing the negative environmental impact for the rice artificial aging process at Rice Molicas S.A.C.?

Likewise, the objective is to demonstrate the savings in electricity consumption costs and the reduction of the environmental impact in the artificial aging of rice by developing a proposal based on solar thermal energy.

Justification of the Study

Theoretical: According to Ekasilp and Soponronnarit (1995) the total electrical energy consumption in a mill is approximately 190 MJ (megajoules) per ton of paddy rice. However, the optimization of a cogeneration system can help reduce the excess steam generated during the rice production process, especially in the soaking and drying stages of the grains. These grains should reach a moisture content between 12% and 14% to avoid microbiological activity and minimize quality losses during storage, since there is a great risk when using natural drying methods due to sudden climatic changes (Salvatierra-Rojas et al., 2017). To calculate the percentage of moisture, Burbano (2005) the company states that currently it can be estimated by studying the thermal properties of the grains, one of them being the enthalpy or latent heat of vaporization. This property determines the amount of heat required to evaporate a certain volume of water in the product.

Methodology: There are different ways of using solar thermal energy, such as obtaining hot water using a thermosyphon, heating or hot air and generating electricity using a solar thermal system (Carbonell, 2021). Vijayaraju and Bakthavatsalam (2020) also comment that there are two ways to heat the air, one is by natural convection, where the air flow enters naturally through thermal conductors and the other is by forced convection where the air enters through a fan and is heated by a solar collector. On the other hand, Lovegrove and Dennis

(2006) they advise using a method of concentrating the radiation on an absorbing surface and, as a result, decreases thermal losses. This is by means of a linear Fresnel concentrator consisting of adapting linear absorbers and long mirror strips that are adjusted to direct solar radiation on an elevated surface. This method can take advantage of the mathematical properties of a parabola.

Environmental: According to Burbano (2005), there is a wide variety of agricultural products that can employ the use of solar thermal energy, but only those that generate a greater impact or have a national diversification will be analyzed. Because of this, Goyal et al. (2014) mention that the rice industry is considered one of the most energy consuming industries making the utilization of renewable energy a challenging task; however, such energy savings would lead to the reduction of fossil fuels and polluting electricity. Vijayaraju and Bakthavatsalam (2020) also found that each unit of rice processing accounts for between 5% and 10% of global methane emissions. Therefore, they recommend using a thermal system that utilizes renewable energies to be used for all energy requirements in the rice industry to maximize the heat from the system.

Based on the above, the objective of this research was to describe and validate a proposal for the use of solar thermal energy more convenient for the reduction of fossil fuels in the process of artificial aging of rice in the company Rice Molicas S.A.C.

Other Studies on Rice Aging

According to the systematic approach of Ekechukwu and Norton (1999) on the economic impact on the use of thermal energies in the rice drying process compared to the traditional method, cost savings are demonstrated for farmers in rural areas who do not have large capital by resorting to resources such as air or land. Also, a study in a rice mill located in the Tambo Valley, Arequipa, demonstrated an economic benefit for the owners and farmers in the area with the redesign of the processes and changes in the technology and energies used to improve the flexibility and efficiency of production (Najar & Alvarez, 2007).

Lee et al. (2014) used three drying methods from different heat sources: UV irradiation, autoclave sterilization and convection heating. All showed changes in the physicochemical properties of milling and cooking rice without showing a clear tendency to accelerate the aging process. However, Peinado et al. (2013) developed a proposal for a dehydrator with thermal energy that provided the desired results in less time than direct sun dehydration. Also, a proposal for aging using a microwave obtained results very similar to natural aged rice without using clean energy (Zhong et al., 2020).

Many people believe that the quality level of a product decreases when it undergoes artificial processes, however, Saikrishna et al. (2018) it has been demonstrated with various aging methods that, although it does not provide the same effect as naturally aged rice, the quality parameters are improved when artificially processed, and that is why the aging method should be carefully selected according to the desired attributes. On the other hand, Jebur et al. (2019) propose the design of aging systems that combine the natural and artificial methods in order to take advantage of solar thermal energy and thus reduce costs. In the same way, Karaca et al. (2019) showed the benefits using a PV/T system, which consists of a combination of a solar thermal and a photovoltaic system, for the long-term production and feeding of the population.

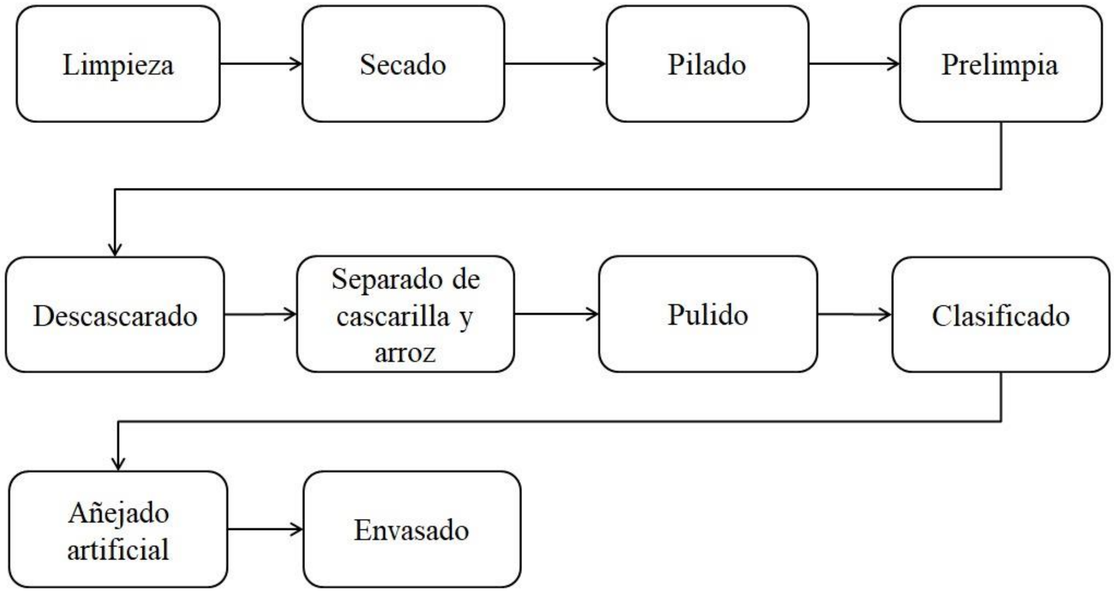
As for the final product, in order to ensure the required quality and properties of the rice, the researchers and Diao et al. (2019) and Mahakham et al. (2017) recommend the use of reducing agents and silver nanoparticles to improve the production of a good quality aged rice by evaluating the germination and metabolism of the seeds for this process.

Method

Rice Molicas S.A.C. has been operating for three years in the city of Lambayeque, located in northern Peru, and its main products are husked, selected and aged rice. The following is a block diagram detailing the rice production process in the company.

Figure 2. 1

Block diagram of the production process



The aging process has the highest energy consumption per ton of the company. The tool used to arrive at this statement was a survey of information during a visit to the company, which consisted of measuring with a DT830L multimeter a motor for each machine in operation to obtain its voltage and amperage.

Table 2. 1

Energy consumption per ton with motors

Process	No. of machines	No. of motors	Voltage (V)	Amperage (A)	Hours/ton	Consumption (kWh/ton)
Pre-clean	1	1	380	4.2	0.167	0.262
Shelling	1	2	380	4.15	0.25	0.798
Husk and rice separator.	1	2	380	4.15	0.167	0.532
Polishing	4	1	380	5.05	0.333	2.609
Classified	1	1	380	5.3	0.333	0.671
Artificial aging	1	4	380	3.75	0.125	0.713

Table 2. 2

Energy consumption per ton with resistors

Process	No. of resistors	Voltage (V)	Amperage (A)	Hours/ton	Consumption (kWh/ton)

Artificial aging	18	380	5.3	0.125	4.532

To obtain the consumption expressed in kWh for one hour of work on one ton of rice to be processed, the number of machines, the number of motors, the voltage, the amperage and the hours per ton were multiplied and divided by 1000 and, in the case of aging, the consumption of the resistors was added, resulting in a total consumption of 5,244 kWh. This is because the aging machine uses four motors and eighteen resistors when it is in operation compared to the other machines in the other processes that only have one or two motors and no resistors at the time of operation.

This case study is oriented to a technological improvement proposal with an experimental design and a descriptive scope. The instruments and techniques used to collect and analyze the information in this case study will be:

Table 2. 3
Table of research techniques and instruments

Techniques	Instruments
Process analysis	Block diagram
Field study	Multimeter and data logging
Improvement design	Flowchart
Operations	Simulation of processes

The case to be investigated is Rice Molicas S.A.C., a company dedicated to rice processing, starting with the storage of paddy rice and ending with the packaging of granulated rice ready for cooking. In order to obtain adequate information when using the techniques and instruments (See Table N°1), the object of study was dimensioned in 2 fields: environmental management, which will contain information about the negative energy impact on the environment, and the electrical energy used in the process, including energy costs and the duration of the process.

In turn, these variables are subdivided into indicators, which are distributed as follows:

Table 2. 4
Table of variables and indicators

Variables	Indicators	Instruments
Environmental impact	Carbon footprint reduction ($TonCO_2eq$). Aging energy savings (kWh).	CO_2 conversion factor in the SEIN. Multimeter GOLD POWER DT830L.
Energy costs	Variation in energy consumption for aging (kWh/ton) and (S/ton).	Multimeter GOLD POWER DT830L.
Duration of the process	Difference in the time of use of the resistors (h/batch).	Flexzion D-113 stopwatch.

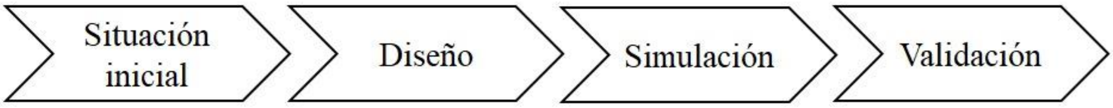
- Carbon footprint reduction: The electricity consumption of the process in MWh had to be found and multiplied with the factor of the National Interconnected Electrical System (SEIN) equal to 0.4521 tonCO2/MWh (see Annex 2) to obtain the value of $tonCO_2eq$.

- Aging energy savings: The current energy consumption of the company was taken in such a way that after the simulation of the improvement, a difference of values is made to demonstrate the negative impact compared to the environmental improvement.
- Variation in energy consumption during aging: It consisted of the difference between the current energy consumption with respect to the energy consumption with the implemented improvement. The energy consumption for one ton to be processed was obtained with the total consumption of the aging process multiplied by the thirty hours of work of the motors and the resistors, the result was expressed in kWh/ton. In the case of energy cost, this consisted of multiplying the aforementioned energy consumption by the tariff, which had a value of 0.15 S/kWh, expressed in S/ton.
- Difference in the time of use of the resistors: Measured by a stopwatch in units of hours for each batch entering the machine for processing.

The information obtained in this stage will be necessary to know the initial situation of the company and to propose an optimal improvement proposal to be validated by the general manager. In addition to the above, the multimeter is currently calibrated, the chronometer is new, so it does not need to be calibrated, and the SEIN conversion factor was obtained from the Ministry of Economy and Finance (MEF). In order to prepare this proposal, the following phases were followed in general:

Figure 2. 2

Methodology



A simulation of the proposal to be developed will be carried out in order to avoid resorting to economic losses for the company and to obtain data in advance of the real process, being validated by three specialists in the field. They will consist of a physicist with expertise in clean energy, a metallurgical engineer with experience in unit operations and processes, and the general manager of the organization.

Phase 1: Initial situation.

The artificial aging works from 28 to 30 hours per batch to be processed and goes through four manual changes of temperature increasing during the process starting at 40 °C. The first change occurs after the first 3 hours rising to 51 °C; the second change occurs after 3 hours rising to 62 °C; the third change is 2 hours after the second one and rises to 73 °C. Finally, the last change occurs 2 hours after the third and rises to 83 °C. The purpose of these changes is to give the rice the desired graininess.

To obtain the data for this phase, a personal communication was conducted with the company's general manager and the operator of the study machine during which they answered the following questions.

Table 2. 5

Personal conversation data

Questions	Responses
what is the amount of kW consumed by the aging machine?	Per motor it consumes 380 volts, about 4 amps, which is 0.15 kW. By resistance it consumes 380 volts, about 5 amperes, that would be 0.19 kW.
what is the temperature required in the artificial aging process for the rice to meet the necessary qualities? (°C)	It has four manual temperature changes starting at 40 °C. After the first 3 hours it rises to 51 °C; 3 hours later it changes to 62 °C; 2 hours later it rises to

	73 °C. After another 2 hours it rises to 83 °C.
Do you have any value on the recent unit cost of energy?	The rates we pay are attached to the ENSA invoice.
How long is the aging process? (days, hours)	Aging lasts 30 hours, after which the rice is left to cool for about 8 hours.
What is the processing capacity of the aging machine? (input bags/hour)	175 bags/hour.
What is the weight per bag of processed rice?	49kg/sack.
What is the percentage of moisture required in rice before and after the aging process?	Before: 12% - 13% Afterwards: 8% - 9%

Note: F. Castillo & T. Quesada (personal communication, September 8, 2021)

The data obtained are based on a batch that is equivalent to eight tons based on the methodology previously described.

Table 2. 6

Initial situation data.

Data	Value
Carbon footprint	0.07112 TonCO2eq
Aging energy	1258.56 kWh/lot
Aging energy consumption	157.32 kWh/ton 23.60 soles/ton
Time of use of the resistors	30 h/batch

Based on the data obtained after gathering information on the current state of the company, the initial value of the carbon footprint emitted was 0.07112 tons of carbon dioxide equivalent for one ton of processed rice; the energy consumption for the aging process was 1258.56 kWh for each batch of rice to be processed; the energy consumption for the original aging process was 157.32 kWh and 23.60 soles per ton of processed rice. Finally, the time of use of the resistors was 30 hours per processed batch of rice.

Phase 2: Design

Solar irradiation in Lambayeque averages 5.38 kWh/m2 per year, transforming into a total annual energy of 1.96 MWh/m2, making the city where the company is located have a high solar potential for the generation of electricity from solar energy (Gastelo-roque et al., 2018).

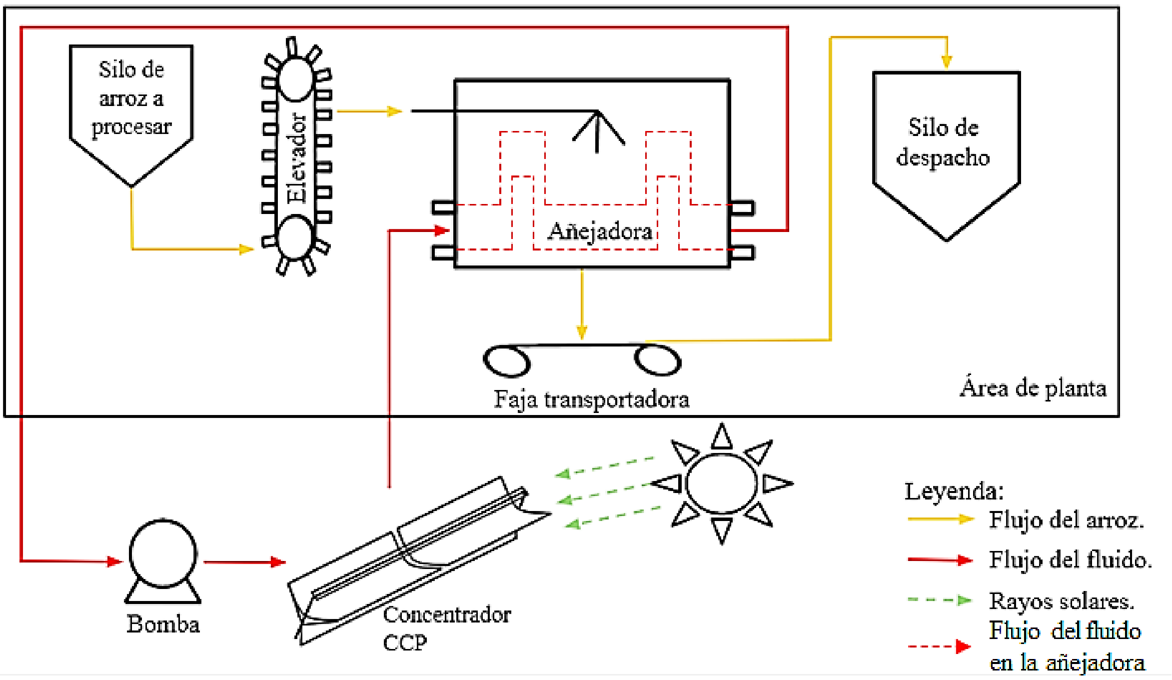
The design of the proposal consisted of a pump, two parabolic-cylindrical thermal concentrators (PCC), a steel pipe to transport the fluid from the concentrator outlet to the inlet of the aging machine. For the interior of the machine, a copper pipe was chosen as it is a better conductor of heat, in addition, a foam covering was added to the steel pipe except for the heat absorption area (CCP concentrator), this is to reduce heat losses.

Both the steel and copper tubes carry a thermal fluid that carries the heat absorbed by the sun. Once inside the aging machine, the fluid releases the absorbed heat by heating the air, which is mobilized by the fans located inside the machine.

The flowchart of the process with the added improvement was presented in this way:

Figure 2. 3

Flowchart with the improvement included



Equipment dimensions:

Steel absorber pipe with selective coating of 0.048m diameter and 40m long.

Glass tube with anti-reflective treatment of 0.058m diameter and 10m long.

Copper tube of 0.048m diameter and 10m long.

Solar thermal concentrator of approx. 20m^2.

Solar tracking system.

1HP centrifugal pump.

Thermal oil (Therminol 66)

Phase 3: Simulation.

The program used in this phase was CHEMCAD, which specializes in preparing chemical process simulations showing a close-to-reality view of the equipment used in the various production processes. The version used for the simulation was 7.1.5, to obtain it, first we went to the Chemstations page, selected this version and, finally, proceeded to download it. It should be noted that this design can be supported for any version of the software and it is recommended to create a separate folder before downloading the program. Likewise, the requirements used in this program were:

Pump: A mineral oil outlet pressure of 3.4 atm was required and for machine efficiency 80 % was set.

Heat exchanger #20: It was used as a replacement for the CCP concentrator, it was necessary to know the initial temperature of the mineral oil, which was 25 °C.

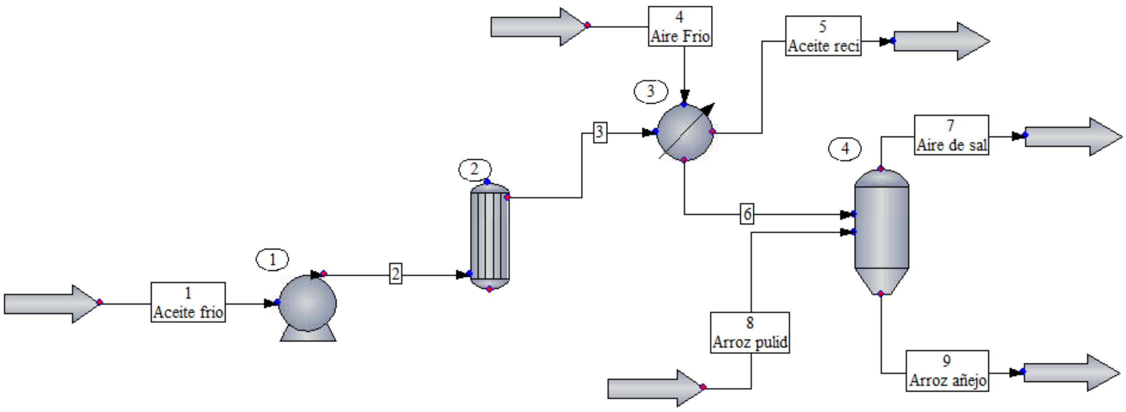
Heat exchanger #1: In this equipment, an air stream will be heated with the oil previously heated in heat exchanger # 20. The hot air will come into contact with the rice inside the aging machine.

Solids dryer: It represented the rice aging machine, the final temperature of the solid was 75 °C.

The graph that represented this simulation was as follows:

Figure 2. 4

Simulation diagram



In addition, the type of liquid and solid to be used had to be recorded in order to find the data of the components of each material that will enter the process and obtain the expected results. For mineral oil, its inlet temperature was set at 25 °C and a weight of 6000 kg/h. For rice, the same temperature and weight of 285.83 kg/h were used.

Results

Phase 4: Proposal validation

The design was validated by physicist Erich Saettone and the simulation has been validated by metallurgical engineer George Power. Likewise, the results obtained once the simulation was completed in the program were as follows:

Figure 3. 1

Results obtained from rice with the simulation

Stream No.	9
Stream Name	**Arroz añejo**
Temp C	**75**
Pres atm	**1**
Vapor Fraction	**0**
Enthalpy kW	**-566.001**
Total flow	**273.2747**
Total flow unit	**kg/h**
Comp unit	**kg/h**
Therminol 66	0
Air	0
Water	24.59472
Dextrose	225.81
Lysine	22.87

As a result, the enthalpy released by the system was 566 kW-h leaving the aged rice with a moisture content of 9% using an air inlet flow of 778 kg/h with a humidity of 5% at 141°C.

Figure 3. 2

Results obtained from the air with the simulation

Stream No.	7
Stream Name	**Aire de salida**
Temp C	**75.4765**
Pres atm	**1**
Vapor Fraction	**1**
Enthalpy kW	**-180.3625**
Total flow	**790.5652**
Total flow unit	**kg/h**
Comp unit	**kg/h**
Therminol 66	0
Air	739.1
Water	51.46527
Dextrose	0
Lysine	0

With respect to the air leaving the aging machine, the enthalpy is interpreted as the energy that was released once the process was completed, being 180.36 kW-h with a humidity of 6.5%. To obtain the data for the initial situation, the results obtained in the CHEMCAD program were used and the same steps were followed as in phase 1.

Table 3. 1

Data with modeled proposal

Data	Value
Carbon footprint	0.03464 tonCO2eq
Aging energy	606.02 kWh/lot
Aging energy consumption	75.75 kWh/ton 11.36 soles/ton
Time of use of the resistors	12 h/batch

With the simulated improvement, the new carbon footprint emitted was 0.03464 tons of carbon dioxide equivalent for one ton of processed rice, with regard to the energy consumption of aging the change was 606.02 kWh for each batch of rice to be processed, and for the energy consumption of aging the values of 75.75 kWh and 11.36 soles for each ton of processed rice were obtained. Finally, the time the resistors were used was 12 hours per batch processed.

Discussion and Conclusions

The results that were found with the implemented improvement were compared with the data found in the initial situation of the company, this variation is presented as follows:

Table 4. 1

Value of indicators

Indicator	Initial value (Vo)	Value final (Vf)	Δ (Vo - Vf)
Carbon footprint reduction.	0.07112	0.03464	0.03649 tonCO2eq

Aging energy savings.	1258.56	606.02	652.54 kWh/lot
Variation in energy consumption during aging.	157.32	75.75	81.57 kWh/ton
	23.6	11.36	12.24 soles/ton
Difference in the time of use of the resistors.	30	12	18 h/lot

According to the variation, the carbon footprint reduction indicator shows a reduction of 51.3%, while the indicators of aging energy savings and variation of aging energy consumption are 51.8%, finally, the indicator of difference in the time of use of the resistors was 60% compared to the initial situation. This demonstrates the high probability of a positive change through the use of CCP concentrators in the aging process of Rice Molicas S.A.C. without affecting the quality of the final product. For this reason Najar and Alvarez (2007) consider that this will allow the use of existing renewable resources with the scarce use of other types of non-renewable and more polluting resources, such as the natural gas currently used.

In the case of energy consumption, there are systems that can obtain up to 82% of their required energy, as is the case with Karaca et al. (2019). On the other hand, some authors such as Ekasilp and Soponronnarit (1995) found that the polishing process is the one with the highest energy consumption with 43%, while for our research this process reaches 27%. Likewise, in the simulation, there is a variation in the desired final moisture content as in the case of Vijayaraju and Bakthavatsalam (2020) whose objective is to have a range between 13% - 14%.

Table 4. 2

Identification of study limitations

Problems / limitations encountered	Did it affect the results?	Solutions used	Strengths
1. The improvement proposal could not be implemented.	Yes	The necessary data was collected using simulation software and validated with an expert.	Despite the fact that there was no implementation of the improvement in the company, the data obtained had to be analyzed with a low error rate.
2. Air capture is not used when heating the process.	No	-	-
3. The necessary project materials could not be afforded.	No	-	-
4. The project is tailored to a specific capacity.	Yes	The technical characteristics of the aging machine were used together with the size of the batch to be produced.	Working with a defined capacity of aged product facilitates the calculations to obtain the desired indicators in the research.
5. Consider the solar radiation intensity of the site to be implemented.	Yes	We consulted the NASA database to know the historical radiation of the Lambayeque site.	The site where the plant was located has high solar radiation, which is beneficial for the design of the improvement proposal.

In the second constraint, the proposed design, unlike other models such as the one described by Ekechukwu and Norton (1999)the second constraint is that the proposed design, unlike other models such as the one described by the company, applies a natural air circulation model since it focuses on the heating of the thermal oil, which heats the air trapped inside the aging machine. As for the third limitation, given the current circumstances in Peru, it was not possible to budget for the materials needed to implement the proposal, the opposite case being the research carried out by Placco et al. (2017).

The findings show the possibility of generating the heat quota required by the process using environmental resources to reduce the cost problem and the negative environmental impact generated by the aging process in the company by implementing solar thermal concentrators. This benefits the company and the environment, since the development of solar thermal energy is offered as an additional way to reduce the cost of electricity consumption, since the case study is one of the processes with the highest energy demand, which demonstrates the importance of opting for renewable and less polluting resources for the environment.

As for the conclusions, cost savings and a 51.3% reduction in environmental impact were calculated using the indicators when simulating the improvement proposal. Likewise, it was possible to demonstrate that the artificial aging process consumes more energy than other production processes in the company. As for the design, it was deduced that the choice of materials will vary according to the requirements of each type of aging machine and the preferences of the entrepreneurs. Thus, with the simulation and validation of the improvement proposal, it was concluded that it satisfies the aging requirements.

Although the benefits of the proposal were demonstrated, it could not be implemented and the materials could not be afforded because the company limited staffing due to the current pandemic situation. On the other hand, authors such as Ekechukwu and Norton (1999) used at the time of designing their proposals the air induction method as a thermal agent; however, the aging machine had internal fans, so this method was not necessary. In addition, the operation of the CCP concentrator will depend on the solar radiation in the area, as this is an important factor for the CCP concentrator. Bearing in mind that this approach can also be adapted to a specific industry and not necessarily to a case study leading to the heating of a system.

While the design of the proposal is not a fixed model, future research should explore the development of new, more practical and efficient designs that meet the same objective. It is essential to adhere to programs and processes for the use of renewable energy, because, with the objective of reducing the environmental impact generated, it is possible to promote long-term monetary savings for the company, being one of the applicable instruments the ecological planning, which implies the evaluation of alternatives for the use of natural elements, trying not to alter the ecosystem too much, and ensuring its conservation.

Finally, it is important to emphasize that it is necessary to constantly and periodically evaluate the environmental impact generated by the companies, and thus control and supervise the levels of generation of polluting agents. At the same time, it is of great relevance to point out the need to promote the speed in the sanctioning processes that are promoted by the competent authorities to the polluting companies that violate environmental regulations, considering that it implies a possible irreversible damage to society.

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