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FEASIBILITY STUDY OF BURNING CENTRIFUGED SLUDGE GENERATED IN A POULTRY SLAUGHTERHOUSE

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Abstract. *Brazil is among the world's top producers and exporters of poultry protein, responsible for 14% of global production in 2022. However, the production process generates substantial solid waste, which is traditionally composted after treatment with an average humidity of 65% (m/m). In order to find a more valuable use for this waste, researchers have been investigating the possibility of co-incinerating it for steam generation. In this context, this study evaluates the feasibility of dehydrating poultry waste in a slaughterhouse, taking into account the moisture content for co-combustion and composting. The aim is to decrease expenses and enhance the waste's compatibility with these two destinations. The results suggest that a moisture content of 56% (m/m) is optimal for the drying method and would result in lower operating costs. Ultimately, the choice between burning and composting dried poultry waste would depend on various factors, such as energy costs, environmental impact, and cost for composting.*

Keywords: *steam generation, industrial waste, waste drying.*

1. INTRODUCTION

Brazil is a top global producer and exporter of poultry protein, with its poultry industry accounting for 14% of global production in 2022 according to the Brazilian Association of Animal Protein (ABPA, 2023). The high production levels result in the generation of significant waste, which must be efficiently managed.

Poultry slaughterhouses generate large amounts of waste at various stages of the production process. Most of the waste is processed by the industry, and the organic solid fraction from the Effluent Treatment Stations (ETS) undergoes composting. This disposal technique is ecologically sound; however, there are possibilities for reutilizing this waste within the industry.

The combustion of industrial sludge for steam generation in boilers is an attractive alternative due to its high calorific value. Co-burning this residue with the main fuel in boilers has been studied extensively. Sena (2005) examined the burning of waste to produce energy with varying moisture contents of 20% and 15% by mass. Virmond (2007) analyzed the technical feasibility of utilizing waste as an energy source. The study compared the output from burning eucalyptus chips alone to burning a mix of the chips and dry residue (with 15-20% humidity) at a 9:1 ratio, respectively. The results demonstrated a decrease in biomass acquisition expenses, but failed to consider the costs associated with waste drying. Meanwhile, Mantovan (2022) examined the joint burning of slaughterhouse sludge (with 65% humidity) and eucalyptus chips for process steam generation in a boiler. The author conducted a sensitivity analysis on equipment efficiency using the indirect method, in accordance with the ASME PTC4 (2013) standard, by varying the mass content of sludge in the mixture. Results indicated an efficiency increase up to a mass percentage of 15%. However, for higher sludge shares, a minor decrease occurred, and at 20%, problems arose with sludge feeding in the mixture. Finally, the impact of scale formation and corrosion in a boiler resulting from the burning of industrial sludge and eucalyptus chips was evaluated by Burin et al. (2022). The obtained results showed that co-burning of the residue did not adversely affect the formation of encrustations in the furnace of the equipment. Nevertheless, the findings concerning corrosion were not definitive.

The cited works have evaluated the incineration of residues, but additional aspects deserve to be explored, including the financial analysis of incineration, the economic viability of residue drying, and the determination of the optimal moisture content after drying.

In this study, scenarios of waste drying and burning were evaluated to understand the process behavior under varying moisture content, observing the variation in operating costs and mass variation in waste disposal. The study relied on Resolution No. 42/2008 of the State Secretariat for the Environment and Water Resources (SEMA) to establish the criteria for waste burning in boilers. The resolution limits the burning of waste in boilers by prohibiting the use of more than 20%

of waste by mass or energy content in collective burning. This action aims to prevent the main fuel from being mischaracterized.

2. METHODOLOGY

The study was conducted at a poultry slaughterhouse situated in the western region of the state of Paraná, specifically in the city of Palotina. The facility generates saturated steam from a mixed-type boiler, which is fueled by eucalyptus chips biomass purchased from suppliers and associates in the region. The steam generator has a declared output of 40 tons/hour of steam at 1.5 MPa.

As per its operational parameters, the boiler operates below the nominal level producing saturated steam at 0.9 MPa pressure, with an average demand of 23 tons per hour mainly intended for heating and cleansing. The thermal efficiency of the boiler is at 87%, calculated by Mantovan (2022).

The plant requires a steady amount of steam to cater to the slaughtering of approximately 615.000 birds daily, producing an average of 60 tons/day of centrifuged floating sludge. The industry has adopted composting as the primary destination, which costs approximately BRL 275 per ton.

To comprehend the benefits of waste drying, thermodynamic and financial simulations were carried out with the aim of making a comparative analysis between three scenarios adopted: the first considers the current operation of the complex (Scenario 1), the second considers the operation with joint incineration of wet waste, with 65% humidity, and eucalyptus chips to generate process steam (Scenario 2), and the third considers the drying of waste before sending it for joint burning, and composting (Scenario 3). Differences amongst the scenarios are depicted in Table 1.

Table 1. Differences between the scenarios.

Scenario	Fuel Burned for Process Steam Generation	Waste Destined for Composting
1	Wood Chips	Wet Sludge
2	Mixture of Wood Chips and Wet Sludge	Wet Sludge
3	Mixture of Wood Chips and Dry Sludge	Dry Sludge

2.1 Scenario 1

The initial proposed scenario, Scenario 1, currently utilized in the studied slaughterhouse involves the composting of waste after treatment, with high moisture content. Serving as the baseline for this study, it is schematically depicted in Figure 1, while the average reference values obtained from the industry directory are presented in Table 2.

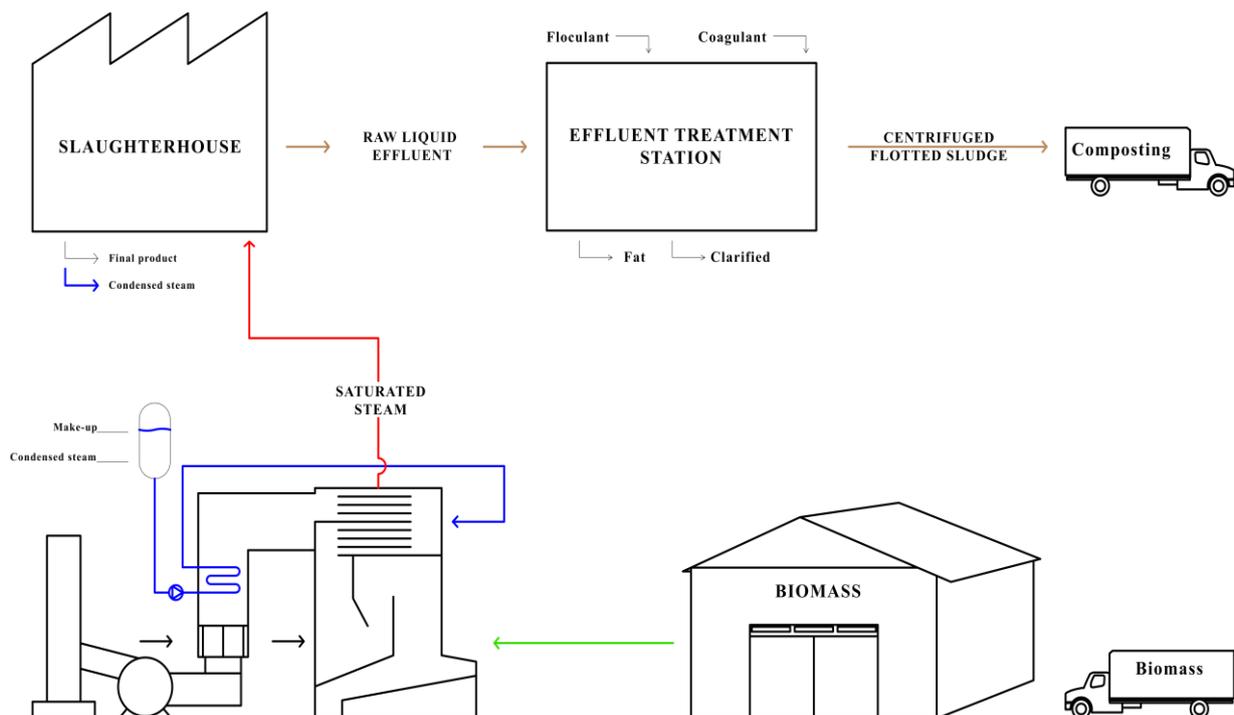


Figure 1. Scenario 1.

For the scenario presented in Figure 1, the liquid effluent from the slaughterhouse is directed to the effluent treatment station for physical-chemical treatment. The treated effluent is subsequently forwarded to an outsourced composting company with an average humidity of 65%. In Scenario 1, the monthly cost of composting amounts to BRL 346,477.

Steam is generated solely from burning eucalyptus chips with a biomass consumption rate of 169 tons per day and a cost of BRL 270 per ton. No combusted residues are utilized. In this scenario, the monthly cost of purchasing eucalyptus for combustion is BRL 959.690.

Table 2. Average operational values of the slaughterhouse.

Operational Characteristics	Values
Steam Flow, tons/hour	23
Boiler Operating Pressure, MPa	0,9
Boiler Feed Water Temperature, °C	70
Eucalyptus Chip Moisture Content, m/m	0,40
Eucalyptus Chip Hydrogen Content, m/m ⁽¹⁾⁽²⁾	0,0723
Superior Calorific Value of Eucalyptus Chips, MJ/kg ⁽¹⁾⁽²⁾	18,707
Centrifuged Floated Sludge Flow, tons/day	60
Centrifuged Floated Sludge Moisture Content, m/m	0,65
Centrifuged Floated Sludge Hydrogen Content, m/m ⁽¹⁾⁽²⁾	0,0863
Superior Calorific Value of Centrifuged Floated Sludge, MJ/kg ⁽¹⁾⁽²⁾	25,936

⁽¹⁾ dry base

⁽²⁾ ash free

2.2 Scenario 2

The scenario in question seeks to understand the benefits of partially burning wet residue in the boiler. This approach is a low-cost option as it only requires studies and the implementation of a feed hopper. The avoided costs include both wood chip savings and sludge disposal savings for composting.

Scenario 2, illustrated in Figure 2, closely resembles the original scenario (Scenario 1). The distinction lies in the fact that damp sludge is partly disposed of by being burned in the boiler accompanied by eucalyptus chips. According to SEMA Resolution N°. 42/08, the residual amount blended with the primary fuel may not surpass 20% on a mass or energy basis.

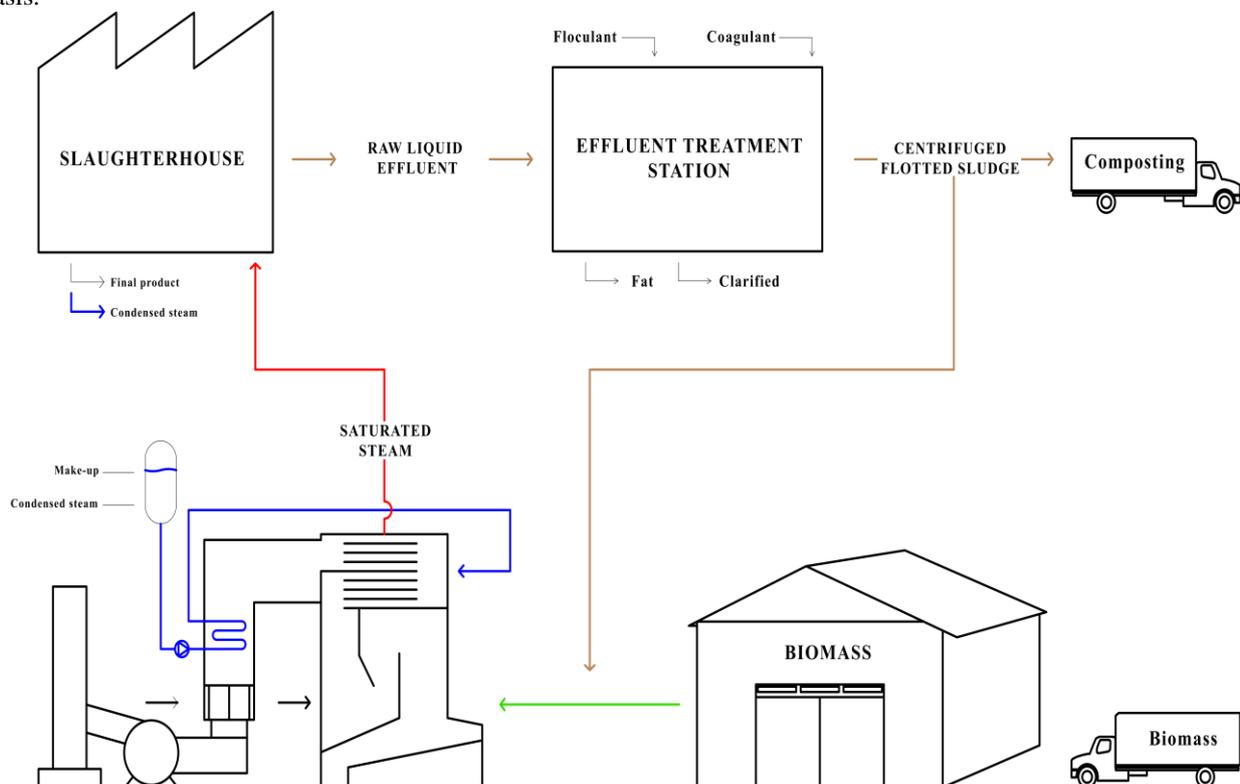


Figure 2. Scenario 2

2.3 Scenario 3

In Scenario 3, the sludge is partially incinerated after being dried, and the leftover volume is designated for composting. The modification from Scenario 2 involves incorporating a sludge dryer post-physical-chemical treatment that takes place at the effluent treatment facility, as depicted in Figure 3.

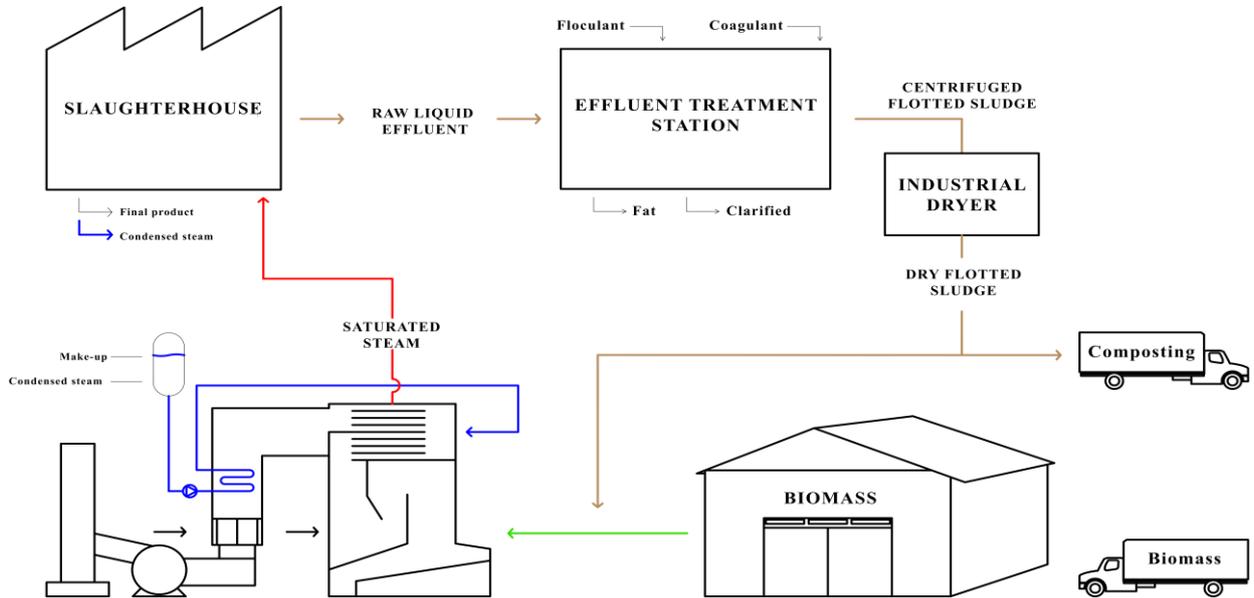


Figure 3. Scenario 3

In scenario three, as depicted in Figure 3, two distinct industrial dryer models were examined: a steam dryer and a hot gas dryer. The steam dryer utilizes steam for drying, while the latter employs the hot combustion gases generated from a furnace that burns eucalyptus. Figure 4 displays the steam dryer's model, while Figure 5 depicts the hot gas dryer's model.

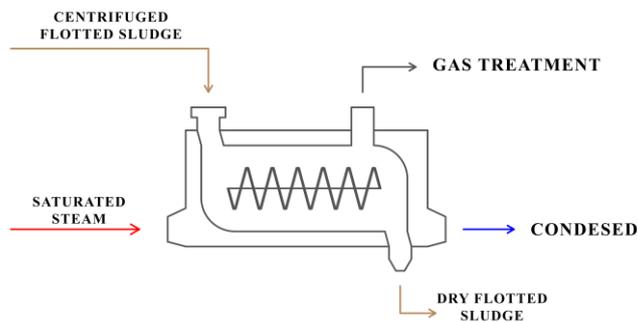


Figure 4. Steam dryer.

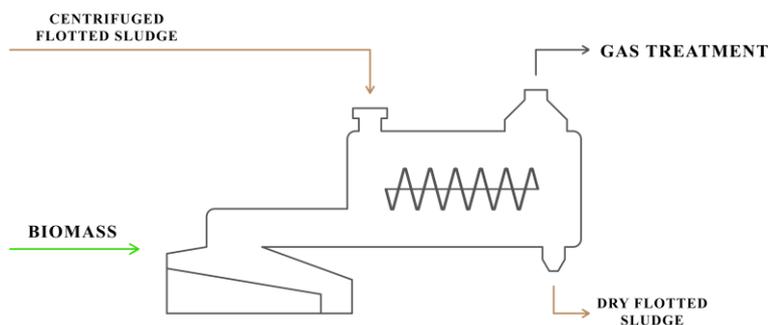


Figure 5. Hot gas dryer.

The dryers examined in this analysis exhibit different operating and energy consumption characteristics. The steam dryer provides energy through indirect contact with the residue, while the hot gas dryer supplies energy through direct contact. Manufacturers state that it demands 900 kcal of energy for the steam dryer to vaporize one kilogram of water, while the hot gas dryer requires 1.100 kcal. The installation of the steam dryer and hot gas dryer totals BRL 3.700.000 and BRL 3.000.000, respectively.

The steam required for drying in the steam dryer (Figure 4) is produced by the complex's feed boiler, which results from the combined combustion of eucalyptus chips and previously dried sludge, while the hot gas dryer (Figure 5) uses only eucalyptus chips in its kiln, with no energy contribution from sludge in this model.

3. RESULTS AND DISCUSSION

An initial sensitivity analysis was performed to determine the optimal moisture content for the process studied after the waste drying process. Figure 6 displays the average mass flow rates of sludge designated for composting and burning for the two different dryers, as well as the amount of chips required for burning in the boiler to satisfy the steam demand.

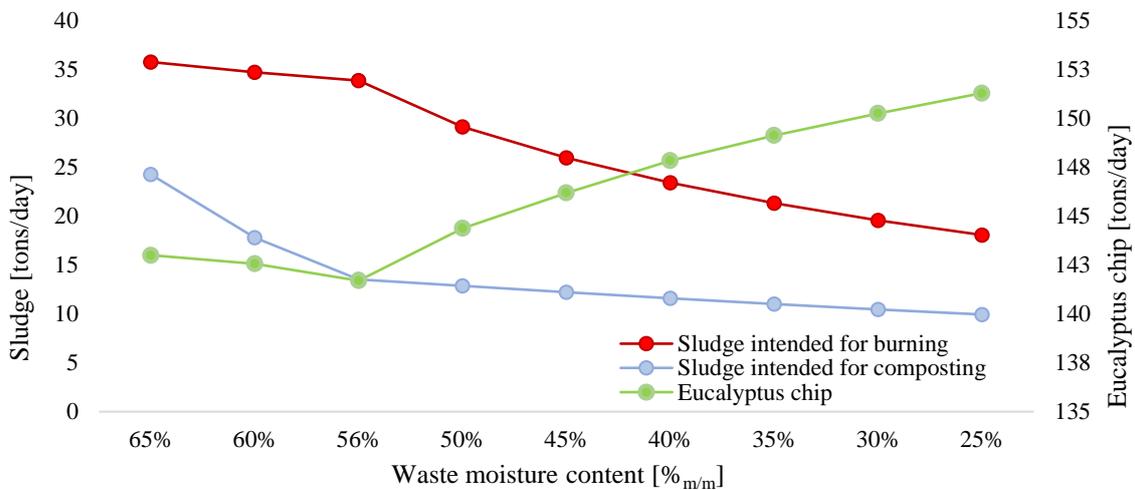


Figure 6. Waste moisture content sensitivity analysis.

For moisture contents between 65% and 56%, the mass residue limit is assumed to be 20% of the mixture. At 56%, both the mass and energy limits are reached. Below 56%, the energy content of the sludge in the mixture assumed to be 20%.

In an effort to reduce process costs, an analysis of moisture sensitivity was also carried out in relation to the cost of purchasing chips for incineration and the cost of disposing of sludge for composting, where the graph in Figure 7 expresses the values for the two dryer models.

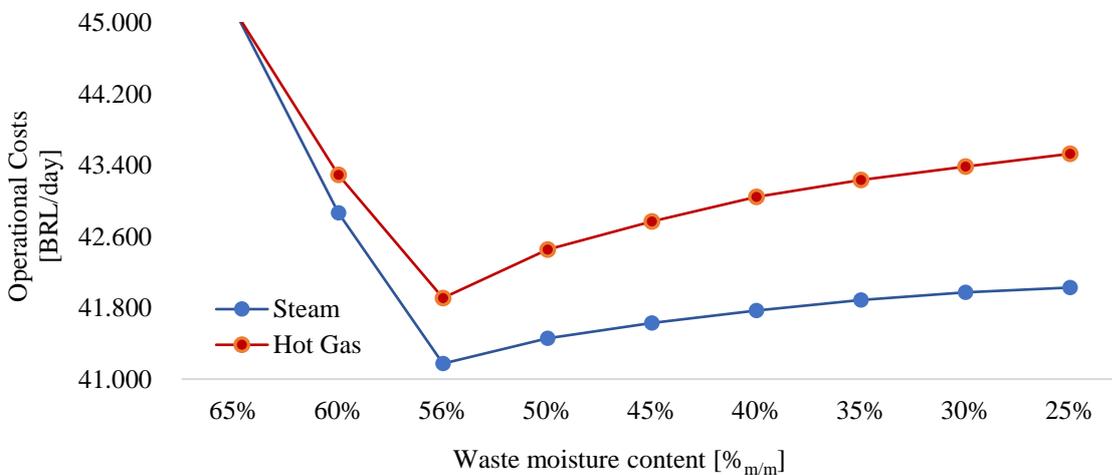


Figure 7. Waste moisture content sensitivity costs analysis.

It can be seen in Figure 7 that the operating costs are also lower at the point of 56%, which is adopted in this paper as the ideal humidity for incineration and destination for composting.

After determining the optimal point for the moisture content of the residue for scenario 3, it is necessary to make a comparison between scenarios 1 and 3 to understand the benefits of incineration and drying for the process, and between scenarios 2 and 3 to understand the benefits of carrying out only drying in a process where co-firing already occurs.

In this sense, Figure 8 provides a comparative analysis between the demands for chips and sludge disposal for scenario 1 compared to scenario 3, for the two different models of dryers.

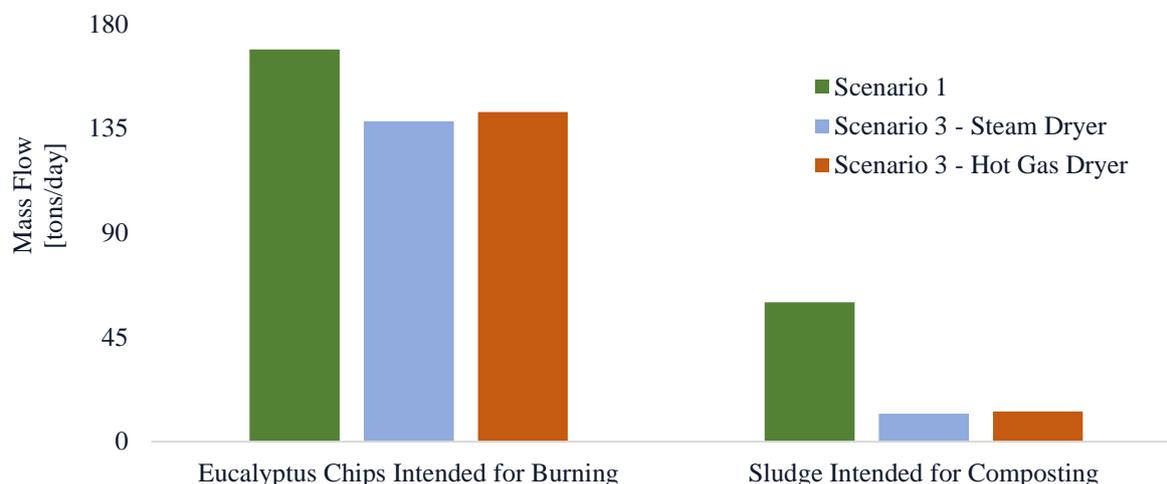


Figure 8. Comparison between scenario 1 and scenario 3.

From Figure 8, it is possible to observe a drop in the demand for chips destined for burning in scenario 3 in relation to scenario 1, with absolute values of 31 ton/day for the steam dryer and 27 ton/day for the hot gas dryer, representing an average drop of 17% at this point for scenario 3.

As for the savings resulting from not disposing of waste to composting, the values are relatively more attractive, with a reduction of up to 80% in the case of the steam dryer and 78% for the hot gas dryer.

Financially, the monthly savings with not purchasing chips and not disposing of sludge for composting resulting from the implementation of burning and drying the waste is approximately BRL 453.500 for the steam dryer, and BRL 424.600 for the dryer hot gases.

Observing only the implementation of drying in relation to an industry that already burns the waste, Figure 9 brings the comparison between scenario 2 and scenario 3.

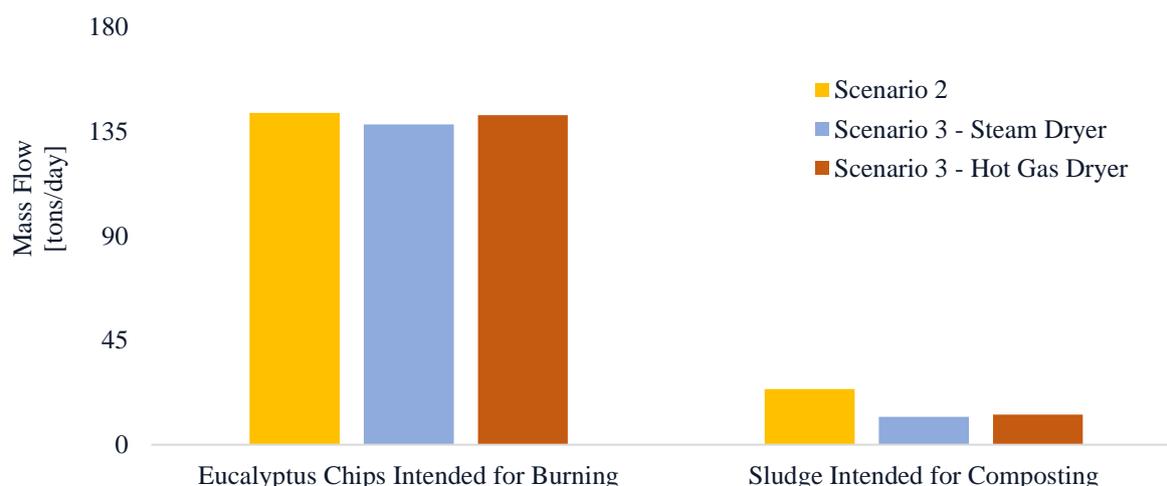


Figure 9. Comparison between scenario 2 and scenario 3.

For this analysis, the savings values become smaller, since a good part of the reduction is related to the implementation of firing, however, the values are still attractive, with an average reduction in chip acquisition of

approximately 0,7%, about of 3 ton/day, and for the purpose of composting, the value is close to 50%, with a reduction of 12 ton/day.

Economically, the returns from the implementation of drying alone return monthly to the agroindustry approximately BRL 98.127 for the steam dryer and BRL 69.219 for the hot gas dryer.

A general comparison between the three scenarios can be observed in Table 3, where the mass values of sludge disposal and wood chip burning are presented, as well as the operational costs of the scenarios and the implementation costs adopted.

Table 3. Differences between the scenarios.

Parameters	Scenario 1	Scenario 2	Scenario 3	
			Steam Dryer	Hot Gas Dryer
Monthly Operational Costs (BRL)	1.306.167	961.302	863.175	892.083
Implementation cost (BRL)	-	250.000	3.950.00	3.250.000
Sludge intended for composting (tons/day)	169	143	138	142
Sludge intended for burning (tons/day)	-	36	35	34
Eucalyptus Chips intended for burning (tons/day)	60	24	12	14

4. CONCLUSION

The study of the drying process in an agro-industry has shown that it is an interesting process to give a nobler destination to the waste and to save the acquisition of biomass for heat generation. However, it is important to carry out an analysis to determine the optimal humidity, since an unnecessary reduction in the moisture content of the residue will lead to unnecessary energy expenditure.

The study has also highlighted the advantages of implementing drying for the process studied, in terms of high returns despite the costs associated with the investment.

Overall, the study has shown that the drying process can be a valuable tool for the agro-industry, providing a number of economic and process benefits.

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