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Economic and financial analysis of the implementation of a water-tube boiler in the process of grain drying using a column dryer

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The aim of this study was to carry out an economic and financial evaluation of the use of a dryer column with steam system replacing a conventional furnace. Seeking an energetic and economic evaluation of the process of grain drying, a research was carried out on the drying of corn kernels using a dryer column (Comil CM 150 DR, double reuse) and a water-tube boiler (CW 40). In order to perform economic and financial analysis, the net present value (VPL), internal rate of return (TIR), profitability index (PI), rate of return (RR) and discounted payback were calculated. In the economic analysis, an investment of US$ 155,258.84 and a minimum acceptable rate of return (MARR) of 3.5% per year were considered. The VPL within 15 years was US$ 200,612.85. The TIR was 17.89% per year. The project presented a PI of 1.29% and RR of 29%, which were considered acceptable. The payback period, considered as the time required to recover the capital invested in the project was 7 years, which indicates economic feasibility.

Key words: Energy, firewood, storage.

INTRODUCTION

The purpose of drying agricultural products is to ensure their quality. This is done by reducing the moisture content, biological activity, chemical and physical changes that occur (Oliveira et al., 2014). The drying study provides information on the heat and mass transfer occurring between the biological material and drying element (atmospheric air normally heated or unheated), which is crucial for the design, operation and simulation drying systems dryers (Corrêa et al., 2003).

According to Pacheco (2010), grain drying is defined as the unit of operation where liquid is removed from a solid to an unsaturated phase, by means of thermal

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Figure 1. AWD 40 water-tube boiler. Source: Picture taken by the authors (2013).

evaporation. It occurs at a temperature inferior to that at which that liquid boils in the system pressure.

As stated by Afonso (2011), high moisture content in the product during storage contributes to the loss of germination power and seed vigor. It affects the quality of starch and protein and also induces acidity. It may lead to microbial contamination and affect physical structures (whole grains). High moisture content also impairs a proper preservation of the product, causes loss of nutritional content, which is required by the industrial sector, and affects the average chemical compositions and energetic values of the species during storage or industrialization.

Therefore, drying is the stage of pre-processing of agricultural products whose main purpose is to remove part of the water contained in them. According to Bremm and Chiodelli (2012), drying is the post-harvest process that has the highest energy consumption, thus, it is primordial to use dryers that consume a minimal amount of energy to remove as much water as possible from the product to reach the desired final condition.

According to Groff (2002), the energy required in the drying process is an expensive and scarce input, as the energy consumed will always be higher than the latent heat of vaporization of water, which is around 540 kcal/kg H_2O.

Nogueira (1985) presented a viable alternative to the use of biomass as a source of heat, aiming to preserve the quality of the final product by installing a system consisting of a boiler associated with one or more heat exchangers and replacing the solid fuel furnaces. In this process, the steam supplied by the boiler flows through the heat exchanger, which is heated. The dryer fan forces the passage of ambient air through the heat exchanger, injecting it into the mass of grains, which causes the drying. Some advantages of employing this system are: the possibility of installing several dryers in parallel; fuel and labor economy; lower risk of fire; reduction of environmental pollution levels and uniformity of drying air temperature. As a major disadvantage, the cost of the initial investment for implementation and system maintenance is high.

Benecke (2013) and Sobrinho (2001) presented the water-tube boiler system, which consists of boilers with water walls or water tubes. The water flows through the tubes, which are heated by the flames of a furnace with indirect heating, and circulates in the heat exchanger.

Afonso (2011) indicates that the dryer column is the most recent equipment to be introduced in the drying process. It has a series of internal vertical modules (columns) through which the product flows. In order to carry out the economic and financial analysis of an energy project, the following factors must be calculated: net present value (NPV), internal rate of return (IRR), profitability index (PI), rate of return (RR) and discounted payback (Kassai, 2005).

The aim of this study was to carry out an economic and financial evaluation of the use of a dryer column with steam system replacing a conventional furnace, by analyzing the potential for reducing fuel consumption (eucalyptus firewood), with a system proposed for the drying of corn.

MATERIALS AND METHODS

The study was conducted in the grain storage unit of an agricultural cooperative located in the West of Paraná State, Santa Helena, at a latitude of 24°51'37" south, longitude of 54°19'58" west, and altitude of 258 m.

A complete boiler system was installed (Figure 1) with water pump for high temperature; a furnace induced for burning wood and other solid fuels was properly sized to a dryerwith capacity of 150 tons. A water-tube boiler with heat exchanger was used (Figure 2); there were three gas passages inside the furnace, which was dimensioned to ensure smoke tubes at the exit of gases, steam production of 4000 kg/h, working pressure of 8 kgf/cm^2 (7.845 bar; 113.79 psi), hydraulic test pressure of 12 kgf/cm^2 (11,768 bar; 170.68 psi), heating area of 160 m^2, fuel wood and other solid fuels, maximum temperature of 446°F (230°C), corresponding to a thermal efficiency of 85%. The control panel is fully automatic with manual option.

The boiler AWD, model CW 40 Water tube type, operated with a working pressure of 8 kg/cm^2 (7,845 bar; 113.79 psi); it used wood Eucalyptus (45% moisture content and higher calorific value of 16 082 kJ/kg^{-1} and 3,842 kcal/kg firewood) as a solid fuel, and operating temperature varying from 185°F (85°C) to 221°F (105°C) (Oliveira, 2014).

Water-tube boilers

In the water tube boiler, the water passes through the tubes, which

Figure 2. Heat exchanger. Source: Picture taken by the authors (2013).

in turn are heated by the flames of a furnace with indirect heating circulating in the heat exchanger.

Column dryers

Column dryers are drying towers made up of panels and intercalated ducts. It is where the grain mass moves vertically and receives the flow of hot air from the furnace, providing the drying of grains. They have shutters for air intake, which enable the ambient air to mix with the air from the furnace, thus providing the ideal mixture for drying.

The monitoring of the drying air temperature is held at three points of the tower, using sensors located at the entrance to the first drying stage, at the second stage and at the outlet for the fan.

The volumetric discharge is a system consisting of a set of trays in a galvanized steel plate that oscillates horizontally and moves up to the grain column, loading up a specific volume and then unloading it to the lower funnel. The discharge and the lower funnel are modulated, fitted with inspection covers and devices that allow better access for maintenance and cleaning.

Economic analysis of the investment

For the economic analysis, it was considered the calculations of discounted payback, net present value (NPV) and internal rate of return (IRR) (Kassai et al., 2005). These alternatives are the most consistent for investment analysis.

In the analysis of economic and financial indicators, the first step is to determine the cost structure, selling price and the breakeven point. It was analyzed the system of financing, the projection of cash flow and the projection of the Profit and Loss Statement (P&L). Braga (1989) cites the following as the most widespread methods for evaluating investment proposals: accounting rate of return, payback period, net present value and internal rate of return. According to Oliveira (2005), in a projection of investments, the residual value of the investment should be taken into account in the last year. This value is 30% for buildings (civil works) and 10% for machinery and equipment. Thus, in the financial calculations for the last year (15th year) in this study, it was added an extra revenue to the income concerning the residual value. In the structure of expenses, it was developed a cost structure in order to observe more clearly what happens with the development of the business. Fixed costs are expenses that are independent of the quantity produced. They do not vary and are recorded at each production period, that is, they remain constant in a certain period of time and do not increase due to the volume of production and sales (Braga, 1989).

Costs of repairs and maintenance of assets and facilities are the expenses necessary to preserve the buildings, improvements, facilities, machinery and equipment in working condition (Ocepar, 2003). Maintenance of equipment should always be carried out in order to preserve proper functioning and long life cycle. Maintenance expenses must be counted.

Variable costs are expenses that happen according to the amount produced, in other words, they represent the inputs used in the production process (raw materials, sales commissions) and other expenses (Hoji, 2003).

For calculation purposes, it was considered net revenues as the price differences between the installation of the steam drying system and the conventional system of furnaces.

The total cost is the sum of fixed costs and variable costs, that is, the revenue that can be achieved with a reduction in the consumption of firewood.

According to Matarazzo (2003), cash flow is the discrimination of amounts of money being transferred into and out of a business during a specified period of time, thus leading to the assessment of the cash balance and enabling several economic analyses. The main goals of the discrimination of cash flow include: assessing alternative of investments; assessing and controlling important decisions that have monetary consequences taken by the company; assessing the current and future cash flow situation in order not to achieve a liquidity situation; certifying that the current cash excesses are being correctly applied.

Braga (1989) states that in the forecast of the profit and loss statements, the profit and loss of the fiscal year can be verified by the difference between the revenue and expenses incurred.

According to Hoji (2003), in order to achieve economic and financial results based on a budget framework, one should analyze the financial transactions of several equity accounts, as well as profit and loss accounts. The economic indicators of investments are described below.

Setting a minimum acceptable rate of return or hurdle rate is necessary for the financial analysis of a project as a source of comparison for the investment to be made. That is, in case this rate is not acceptable, the project should be rejected (Kassai, 2005).

The net present value is a sophisticated and useful tool to assess proposals of capital investment as well as to show wealth of the investment in monetary values. It is measured by the difference between the present value of cash inflows and the present value of cash outflows, discounted by a determined sum (Kassai, 2005).

The values for calculation refer to the net results of each year obtained from the P&L statement, which are considered as positive flows, and to the investment, which is the negative flow. The following equation was used for the computation of the NPV:

$$NPV = \left[\sum_{t=0}^{n} \frac{CF_t}{(1+i)^t} \right.$$

where: NPV, Net present value; t, Time (months or years); n, Project lifespan (total of months or years); i, minimum acceptable rate of return; CF, net cash flow at time t.

Table 1. Financial indicators overview.

Investment	R$ 350,000.00
Repayment	15 years
MARR	3.5% per year
NPV	US$ 200,612.85.
IRR	17.89%
PI	1.29
RT	29%
Discounted payback	7 years

Source: author (2013).

For the minimum acceptable rate of return, any investment with NPV equal or above zero is considered acceptable. The internal rate of return is used in capital budgeting to measure and compare the profitability of an investment. It is the discount rate at which the net present value of costs (negative cash flows) of the investment equals the net present value of the benefits (positive cash flows) of the investment (KASSAI, 2005).

$$\text{IRR} = \text{i when } \left[\sum_{t=0}^{n} \frac{CF_t}{(1+i)^n}\right] = 0$$

where: IRR: Internal rate of return.

Any investment that presents an IRR superior to the MARR is economically viable (KASSAI, 2005).

The profitability index and rate of return refer to the ratio of payoff to investment of a proposed project. That is, a PI greater than 1.0 indicates that the profitability is positive (Neto, 2000).

So:

$$\text{PI} = \frac{\text{PV (positive cash flow)}}{\text{PV (investment)}}$$

The profitability index of the proposed project is larger than 1, what is considered acceptable. The rate of return of an investment is represented by relative values, that is, percentage. Every investment with a rate of return above zero is considered acceptable. The rate of return of the investment is given by the following equation:

$$\text{RR} = (\text{PI} - 1) \times 100$$

The discounted payback period is considered the exact time period required to recover the capital invested in a project (Gitman, 2002). With analysis of financial index, it is easy to ascertain the period of time that a company will need to recover what was invested before, having a better view of the business that is proposed.

RESULTS AND DISCUSSION

According to Silva (2004), the decisions about investments refer to the application of assets, as well as to the expected return and the risks posed by these assets.

The price quoted for the supply of the boiler and the two radiators described above, properly dimensioned for the dryer, was US$ 155,258.84. The Storage Incentive Program for National Grain Companies, known as BNDES *Cerealistas*, provides financial support with repayment periods from 12 to 15 years and annual interest of 3.5% (BNDES, 2013).

In the cost structure, the National Bank for Economic and Social Development (BNDES) will finance US$ 155,258.84 through the net of financial agents associated with the development bank. The budget will be part of the investment support program (ISP), which finances the construction and expansion of silos and auxiliary structures. The loans will last for 180 months (15years) at an annual interest of 3.5%. The investment of US$ 155,258.84 will be made by the company AWD Metalúrgica em Geral Ltda. The annual maintenance of the boiler costs US$ 6,210.35, according to the Ocepar (2003).

The variable cost for the drying system (annual value of electric energy) will be US$ 3,619.39. The total annual value, represented by the sum of fixed and variable costs, will be US$ 9,829.75. For calculation purposes, the revenue will be the difference of price between the installation of a steam drying system and the installation of the conventional firewood boiler system, according to the projections for reception and drying of 18,000 tons of soybean, 48,000 tons of maize and 3,000 tons of wheat (Oliveira, 2014). Considering an average price of US$ 19.96 for the cubic meter of firewood, it is possible to achieve an annual revenue increment of US$ 39,923.70, with an average reduction of 40% in the consumption of firewood (= 5,000 m^3/year) for the parameters obtained for corn kernel drying, using a tube dryer in a water-tube boiler system. The financial indicators are summarized and depicted in Table 1.

The cash flow forecast presented a net present value of US$ 200,612.85 considering an investment of US$ 155,258.84 and annual gross revenue of US$ 39,923.70, with capital return and revenue at the 15th year of US$ 55,449.58. The minimum acceptable rate of return was considered 3.5% per year; the same value for the line of credit (according to the BNDES) for financial investments supported by the Harvest Plan (Plano Safra) 2013/2014 (Mapa, 2013). All economic index shows that the proposed project is feasible (NPV larger than zero, IRR larger than MARR, PI larger than 1 and RT larger than zero).

The discounted payback period is considered the exact period of time necessary to recover the costs of the investment, considering the annual cash inflow (Gitman, 2002). Based on the cash flow forecast, the discounted payback period was reached in the 7th year, as the annual positive cash flow was able to return the invested capital.

Conclusion

According to the analysis of the economic indicators, based on the cash flow and revenue growth forecasts, the project requires an investment of US$ 155,258.84 (approximately R$ 350,000.00). Considering a minimum acceptable rate of return of 3.5% per year, the net present value for a period of 15 years will be US$ 200,612.85. The internal rate of return is 17.89 per year. The project presented a profitability index of 1.29% and rate of return of 29%, which is considered acceptable. The payback period is 7 years, which indicates economic feasibility.

Conflict of Interests

The authors have not declared any conflict of interests

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