Economic evaluation of solar drying process for washed coffee in mixteca region of Oaxaca state, México

Evaluación económica del proceso de secado solar para café lavado en la región mixteca del estado de Oaxaca, México

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Abstract

Solar drying is an alternative innovation to process where product is exposed to direct sunlight and outdoors and where final quality is not always optimal. Solar dryers are installations that require little capital and low maintenance costs, are easy to build and use any locally available material. Objective of this work was to evaluate economic efficiency of drying process of washed coffee beans using a solar dryer built with regional materials. Study was carried out during 2022 coffee harvest, in a passive semi-parabolic greenhouse solar dryer, with an external cover of 36 m^2 as a collector. Results showed a unit cost of $11.29 MXN on average to dry a kilogram of washed coffee and transform it into parchment coffee; the benefit/cost ratio was 1.40 and the investment recovery period was determined in one months, values that make solar drying unit a highly profitable option.

Unit cost of drying, B/C ratio, Payback period

Resumen

El secado solar es una innovación alternativa al proceso donde se expone el producto a los rayos solares de manera directa y a la intemperie y donde la calidad final no siempre es la óptima. Los secadores solares son instalaciones que requieren de poco capital y bajos costos de mantenimiento, son de fácil construcción y se utiliza cualquier material disponible localmente. El objetivo del presente trabajo fue evaluar la eficiencia económica del proceso de secado de grano de café lavado mediante un secador solar construido con materiales regionales. El estudio se realizó durante la cosecha de café 2022, en un secador solar de invernadero semiparabolico tipo pasivo, con una cubierta externa de 36 m^2 como colector. Los resultados mostraron un costo unitario de $11.29 MXN en promedio para secar un kilogramo de café lavado y transformarlo en café pergamino; la relación Benéfico/Costo fue de 1.40 y el periodo de recuperación de la inversión fue determinado en un mes, valores que hacen de la unidad de secado solar, una opción altamente rentable.

Costo unitario de secado, Relación B/C, Periodo de recuperación

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Introduction

Sun drying is perhaps one of the oldest methods in which solar radiation is used for food preservation, the traditional way being to extend it under the sun for periods that vary according to the product, but there are serious limitations, as the product in the drying process is affected by rain, dust, insects, rodents or domestic animals.

Drying with the help of solar radiation is a very economical procedure for agricultural products and on the other hand it is very environmentally friendly (Shimpy *et al*., 2019). However, to increase the efficiency of material drying by solar radiation, a suitable innovation or application is needed (Hii *et al*., 2019; Upadhyay and Singh, 2017; Yoo *et al*., 2017).

The alternative innovation to solve this problem has been the development of technology to maximise the use of solar radiation potential in the drying process, referred to as solar drying. There is now a wide variety of designs and sizes of solar dryers that can be used for drying a variety of foods of agricultural origin. They are low capital and low maintenance cost installations, are easy to construct and any locally available material can be used (El-Hage *et al*., 2018).

The tendency of the designs is towards simplicity, as there is no significant difference in the results obtained with more primitive designs compared to more sophisticated ones (Sharma *et al*., 2018). They are generally low-capacity equipment, mainly used for drying various foods of agricultural origin, either for family use or for marketing some surplus (Belessiotis and Delyannis, 2011).

In recent years, solar dryers have become popular in the agricultural sector, due to their cost-effectiveness and the use of a clean energy source (Ahmadi *et al*., 2021), because when the different economic parameters, such as break-even point, net present value, payback period, cost-benefit ratio, annuity and internal rate of return, are calculated, they are highly profitable, so their economic viability is high (Mohana *et al*., 2020; Singh *et al*., 2020).

Solar dryers are highly effective devices with low investment to produce good quality dry products (Mathew *et al*., 2018).

However, factors such as production capacity for drying, drying time, climatic conditions depending on the time of year, cost of dryer components and accessories, labour costs and variable or miscellaneous costs need to be taken into account for economic calculations (Mohana *et al*., 2020). In all cases, the capital cost of the dryer is used, however, the operating cost of the dryer is not included in the total cost of the solar dryer (ELkhadraoui *et al*., 2015).

Kesavan *et al* (2019), performed an economic analysis of a solar dryer in a very simple way, determining the cost of the material dried inside the dryer annually, the net profit obtained annually from the dryer, the payback time of the dryer investment. El-Hage *et al*. (2018) conducted an economic study to evaluate the monetary savings due to the application of dryers, they used as parameters the percentage of time the solar dryer is used, the mass of dry feed and the type of feed. Keke *et al*., (2014) report the economic evaluation of low-cost direct and indirect passive dryers using fixed cost - construction and maintenance cost indicators and a qualitative performance evaluation.

Another approach to economic analysis is the incorporation of cost/benefit analysis. It involves comparing the total expected cost of each option with the total expected benefits, to see if and by how much the benefits outweigh the costs taking into consideration the size, construction materials, efficiency, operation, sophistication and sustainability of the dryers (Dhanushkodi *et al.*, 2015; Desa *et al*., 2020). To determine the payback period, the capacity of the dryer must be considered and is calculated by dividing the initial investment by the annual cash flows and measures the time period between the investment and its payback (Mohana *et al*., 2020; Singh and Gaur, 2020; Dhanushkodi *et al*., 2015).

When performing the economic evaluation of solar drying, drying costs are a function of time and the total investment cost of dryer construction, equipment depreciation, volume of product to be dried, wages per load and administration costs. On the other hand, it is necessary to determine the unit cost of solar drying, which is the ratio between the total annualised cost of the solar dryer and the annual amount of product dried in the solar dryer (Tripathy, 2015).

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The objective of the present work is to determine the economic efficiency of the solar drying process of washed coffee using a solar dryer constructed with regional materials.

Materials and method

The economic evaluation of the drying process was carried out in a dryer classified as a passive type direct semi-parabolic greenhouse, with an external cover of 36 m2 considered as a solar energy collecting surface. It was built with materials from the region: wood and bamboo, covered with greenhouse plastic.

The dryer is located in the following geographical location: 16°40'33" N and 97°47'15" W, at an altitude of 1677 m above sea level, in Zaragoza Itundujia, located in the coffee-growing area of the Oaxacan Mixtec region.

For the economic evaluation, it was determined:

1. The drying cost to obtain a kilogram of parchment coffee (Intawee and Janjai, 2011; Singh and Gaur, 2020), using the following equations:

$$C_{us} = \frac{C_{an}}{P_{sa}}$$

Where:
C_{an} Total annual cost of solar dryer.
P_{sa} Total amount of product dried in the solar dryer solar dryer annually.

To obtain the above, it is necessary to determine the following values:

A. The annual cost of the solar dryer (Cas) is given as

$$C_{as} = C_{ca} + C_{mt} - V_r + C_{oa}$$

Where:
C_{ca} Annual capital cost, including initial infrastructure initial cost of infrastructure,
C_{mt} Annual maintenance cost of the dryer solar
V_r Recovery value
C_{oa} Annual operating cost of the dryer

B. The total amount of products dried annually in the solar dryer (Psa) is given by:

$$P_{sa} = \frac{M_{ps} D_u}{D_n}$$

Where:
M_{ps} Mass of product dried per batch in a solar dryer solar dryer,
D_u Number of days during which the dryer is used in the year, D_u dryer is used in the year,
D_n Number of days needed to dry the material per batch material per batch.

2. Payback period (Pr) is the period of time needed to recover the cost of the investment and was calculated using the following formula (Yelmen *et al*., 2019; Krungkaew *et al*., 2020)):

$$\mathrm{Pr} = \frac{I_{ss}}{B_{na}}$$

Where:
C_{an} Investment in the solar dryer,
B_{na} Annual net profit or income.

Results and discussion

The results presented are related to the drying of coffee in a passive semi-parabolic direct greenhouse solar dryer, with an external cover of 36 m2, from a volume of 200 kg (19.5 kg/m2) of coffee beans dried per load.

In relation to the results regarding the cost of drying one kg of material, the initial cost of the dryer was $8,817.00 pesos (Table 1), where 34.2% corresponds to the cost of materials obtained from the region, 25% to the cost of labour to build it and the rest corresponds to complementary materials for its construction. In addition, the annual maintenance cost was $3,000.00 with no recovery cost.

The total amount of coffee dried annually is 1400 kg per season, starting from 200 kg per drying batch, with an average drying time of 10 days, as it depends entirely on the weather, which during the coffee harvesting season is humid and foggy most of the day. Even though the approximate time of use of the dryer is 90 days, which corresponds to the duration of the harvest, it is only feasible to carry out seven loads or drying processes of coffee per season.

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Materials	Cost ($)	%
Materials from the region		
Polines, bamboo, wood	3,020.00	34.2
Materials purchased externally		
Greenhouse plastic, metal mesh, screws, staples, nails, hinges, wire, raffia, etc.	3,597.00	40.8
Labour		
12 jornales	2,200.00	25
Total:	8,817.00	100

Table 1 Composition of the total cost of the solar dryer

The results of the economic indicators are presented in Table 2, from evaluating the solar drying process to obtain parchment coffee from washed coffee beans in the coffee-growing area, in the Mixtec region of the state of Oaxaca.

Economic indicator	Value
Annual unit cost of drying	$11.29
B/C ratio	1.40
Payback period	1 mes

Table 2 Economic indicators of the process of solar drying of washed coffee beans

The unit cost of drying one kg of washed coffee into parchment coffee was $11.29 on average for the 2022 harvest season. This result reveals that the solar drying process is quite simple and the unit cost of drying one kg of product depends mainly on the initial investment for construction, the operating cost for labour, maintenance cost, as well as the cost of the volume of product to be dried and the drying time, which ultimately determines the usage time of the dryer (Sharma *et al*., 2018; Poonia *et al*., 2019).

On the other hand, the Benefit/Cost ratio was 1.40 for the case study, higher than the value of 1.21 reported by Mohod *et al*. (2011), but lower than the value reported by Dhanushkodi *et al*. (2015) when drying 40 kg of cashew nuts in a solar dryer, which was 5.23. Also lower than the economic indicator value of benefit/cost ratio of 2.09 (Poonia *et al*., 2019). Results showing the potential of using solar dryers for drying different agricultural products.

With the net income of the harvest season where the dryer was used and applying the equation of the payback period of the investment, we have a value of 0.15, which implies the proportion of time corresponding to the period of use, so the payback period is less than three months and to know in which load it will be, the following operation is performed:

Pri = 0.157*7 = 1.1

This means that the recovery takes place at the end of the second drying run, but as the drying period must be completed, then it is in the second drying run, i.e. in approximately one month.

Thus, the payback period for the dryer studied was determined to be only one month, which is less than that reported by El-Hage et al. (2018), who report a payback period of 10 months when using a dryer with a capacity to dry 120 kg of carrots. Also lower than that reported by Prakash et al. (2016), who determined a recovery period of 1.11 years for a modified greenhouse solar dryer when drying sliced potato, and well below the values reported by Fudholi et al. (2015), who reported an average period of 2.6 years and by Mohod et al. (2011), who reported a recovery period of 2.84 years.

On the other hand, ELkhadraoui et al (2015) mention that a payback period of 1.6 years is very small compared to the lifetime of solar dryers, which on average is 20 years. These low payback period values, which average between 1 to 2 years approximately (Singh and Gaur, 2020), make a solar drying unit very cost-effective (Poonia *et al*., 2019).

Conclusions

– The unit cost of drying was $11.29 MNX on average for the 2022 harvest season, and is a good benchmark for comparison for drying processes in different solar dryer designs, as it depends primarily on the initial investment with low maintenance costs.

– The Benefit/Cost ratio was 1.29 for the case study, which makes it feasible to use solar drying for drying washed coffee.

– The payback period for the dryer studied was determined to be two months, less than the average values of approximately 1 to 2 years reported in the literature, which makes the solar drying unit very profitable.

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