Photovoltaic acai (*Euterpe oleracea* Mart.) berry juice extractor machine

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Abstract. This project is about the development of a product called the photovoltaic acai (*Euterpe oleracea* Mart.) berry juice extractor machine, which comes as a technological alternative to solve one of the problems resulting from the lack of commercial supply of electricity in remote areas of the Amazon. It is a utility model patent, which employs equipment available in the local market, designated initially to operate in conventional electrical supply however operationally configured for photovoltaic solar power systems. This machine configuration consists of an "acai mixer", a three-phase induction motor, a three-phase variable-speed drive and a photovoltaic generator. The photovoltaic acai (*Euterpe oleracea* Mart.) berry juice extractor machine is characterized as a photovoltaic system isolated from the conventional power grid and it is of the type of direct coupling. The results of the tests performed in the lab revealed that the prototype could produce up to 126 L/day of acai berry juice in a single day. However, the production of only 28 L/day is able to amortize the investment within two years.

1. Introduction
The access to electricity is a major challenge for public policies and a great hope for the thousands of families living in the Amazon. The lack of electricity aggravates social inequality, which already exists in the region [1]. This scenario affects not only life’s quality but also the production of the main income sources and meal for this population, the acai. These questions lead us to a creation of a model that implements an alternative sustainable energy based on a small scale of photovoltaic (PV) solar power use and non-integrated in the national electric distribution power system for the production of this berry juice. The main particularity of this system is the absence of battery banks and the use of a variable-speed drive to control the motor speed, especially those with three-phase induction motors. Another particularity of this system is that all the power produced by the PV generator is used at the exact time of its conversion. Thus, the PV acai (*Euterpe oleracea* Mart.) berry juice extractor machine has intermittency as characteristic. Which means that the power delivered to the induction motor varies accordingly to the levels of solar radiance during the machine’s operation, which also means that this motor will operate with
variable speed. So, adjustments with the variable-speed drive were made in order to this motor’s speed variation does not interfere with the quality of the final product.

2. Methodology
The PV acai berry juice extractor machine was designed in the direct-coupled configuration where a variable-speed drive is used as a power-conditioning device as pumping PV systems applications [2]. The diagram in figure 1 illustrates the system configuration of the PV acai berry juice extractor machine.

![Diagram](image)

**Figure 1. PV acai berry juice extractor machine components.**

The assembly is made of an acai berry juice mixer which contains a barrel of 17 cm of diameter and a three-phase motor of 1 HP (746 W) and 80.5% efficiency driven by a variable-speed drive (VSD) with same power, 1 HP and 0.95% efficiency. It is important to the variable-speed drive to have a controller derivative integral proportional embedded [3]. Thus, for this project the objective was to keep the variable-speed drive operating in a closed loop in order for the system to receive a voltage feedback signal from the PV generator and the controller derivative integral proportional enabled to maintain that voltage signal in a desired value based on the setpoint value chosen by the user. At last, the sizing of the PV generator was performed using equation 1.

\[
\text{Input Power} = \frac{P_{\text{out}}}{\text{Efficiency of motor} \times \text{Efficiency of VSD}}
\]

Therefore, a 1045 Wp PV generator was installed using 19 PV modules of 55 Wp each connected in series, with an objective to reach the variable-speed drive operating voltage level.

3. Results and discussion
3.1 Acai making process
The prototype test made in February 2021 had the help of a professional from the area who carried out the entire pulp extraction process. The process started at 10:13 am, where the first acai berries were placed in the mixer (process with load) and finished at 10:20 am, when the leftovers from the seeds were removed (process without load). The process of making acai juice does not have an exact guideline. Thus, the acai maker do the process intuitively adding more water and more berries if needed. In addition, the result of the process in liters can also vary accordingly to the acai juice’s viscosity wanted. In figure 2, we can observe the beginning of the process of making acai juice. The test lasted 7 minutes using 9 kg of acai berries and produced a total of 1.5 L of acai juice.
3.2 PV generator analysis
To analyze the tests results, power curves (P vs V) of the PV generator were simulated with the assistance of the Crearray Software v1.0 (http://www.solar.ufrgs.br/#softwares). This software was used as an aid to the results interpretation, the variation in irradiance and module cell temperature shown in figure 3. Also, power variation of the PV generator over a day with some cloudiness shown in figure 4. Since it is necessary to identify at which instant the irradiance level would be sufficient for the PV acai berry juice extractor machine to operate at the nominal frequency of 60 Hz. Data collection from figure 3 and figure 4 was performed after the test with the juice extractor machine.

![figure 3](image)

**Figure 3.** Irradiance and cell temperature variation throughout the day – measurement performed on 05.24.2021.

Figure 4 shows that for days with this profile, there are about 9 hours and 13 minutes of irradiance above 400 W m$^{-2}$, which is sufficient for PV generator to supply the power demanded by extractor machine (380 W) at its point of nominal frequency operation, as will be observed in the following analyses.
In figure 5, we can see the power curves plots recorded with current and voltage values during the test. It is possible to observe that the operating points are displaced from the region delimited by the simulated curves (blue curve and black curve). A possible reason for this could be an incorrect measurement of the temperature the back of the PV modules that integrate the PV generator during the test.

Based on the ambient temperature’s measurement, it was possible to estimate that the most likely value for temperature would be 40 °C, at the time of the test. Therefore, the simulation was rerun for this new temperature value. The result was more consistent for values recorded as observed in figure 5. It is noteworthy, however, that this detail does not influence the performance analysis of the extractor machine.

The figure 5 also shows the voltage versus power curve (gray), simulated for irradiance of 390 W.m⁻², illustrating that the PV generator provides the power demanded by the acai mixer at their nominal frequency point the machine operates with full load. It is important to emphasize that the machine keeps operating with values below 380 W, but with an operating frequency lower than
60Hz, with 40Hz being the minimum frequency necessary for its operation but with a reduced motor shaft speed. In addition, it is important to note that the derivative integral proportional controller embedded in the variable-speed drive performs this control.

The test results revealed that the PV generator is oversized for the 1 HP motor used. The reason is that the acai mixer demands 379.4 W (peak power recorded). In this sense, the following adjustments can be made: 1) increase the barrel capacity, thus increasing the production capacity; 2) replace both, variable-speed drive and induction motor, with a ½ HP (368 W) capacity or 3) replace only the induction motor with a ½ HP, however, using two acai mixers in parallel, also increasing the production capacity.

Analyzing all the three (3) possibilities, the first and third ones appear to be the most practicable because it avoids reducing the power of the PV generator, which would raise the cost of Wp. The explanation is that power modules below 55 Wp have the highest Wp cost. In addition, there are shortages in the market.

3.3 Economic and financial analysis

The economic and financial analysis of this project considers that the prototype is ready for commercial purposes. Therefore, it is necessary to know all the costs involved in building the prototype. Table 1 shows this cost (initial investment).

| AMOUNT | ITEM                                | VALUE (USD) |
|--------|-------------------------------------|-------------|
| 01     | PV generator + structure            | 915 + 110   |
| 01     | Variable speed-drive + command board| 240 + 257   |
| 01     | Acai mixer + induction motor        | 165         |
|        | Wiring + installation accessories   | 159         |
|        | Total (USD)                         | 1846        |

There is also a sequence of information that had to be considered in the economic analysis:

- On the day of the test, February 2021, the can of acai was quoted at $12. It is a low season price. At the harvest season, or high season, this price can be reduced by up to 60%.
- According to laboratory tests, a can of the fruit produces up to 7 L of medium-thick acai (viscosity, neither “thin” nor “thick”).
- According to the tests carried out in the laboratory, the prototype is capable of processing (pulping) up to three cans of the fruit per hour, thus producing 21 L of acai juice.
- The places that sell acai are generally managed by the family itself, without the participation of salaried employees.
- The system will work 23 days a month and 4 hours a day (operationally very suitable for the period of maximum irradiance on a typical day in the Amazon).
- Fixed monthly costs such as cleaning materials, packaging and transport for the purchase of fresh fruit are around $158.
- The useful life of the components of the prototype consisting of the PV generator, variable-speed drive and “acai mixer” are respectively 25, 10 and 5 years.
- 5 possible variations are used for the discount rate referring to the Selic rate (Copom/Bacem): 5%, 7.5%, 10%, 12.5% and 15%.
- Fixed costs for operation and maintenance of the prototype (O&M) are 2% of the initial investment.
- Three scenarios are considered for analysis:
  1. Low season, where a can of fruit costs $12 and the sale price of a liter of average acai is $2.56.
2. High season, where a can of fruit costs $6.41 and the sale price of a liter of average acai is $1.83.

3. Intermediate value (seasonal transition or off-season), where a can of fruit costs $9 and the sale price of a liter of medium acai is $2.

The economic-financial analysis was evaluated according to the net present value (NPV), the internal rate of return (IRR) and the capital recovery time (payback). The IRR shows which value of the discount rate is capable of nulling the NPV, that is, how many cans of acai must be processed in order to recover the investment, taking into account a discount rate, or for the prototype to pay for itself, without generating losses.

The results showed that for the three scenarios evaluated from the knocking of two cans of acai, the value of the IRR is much higher than the value of the rates currently used (ranging from 5% to 15%), concluding that it is difficult to have a loss using the machine to produce at least two cans of acai per day. The payback in each case for processing two cans of acai per day showed that the prototype pays for itself in less than 2 years and the higher the discount rate, the longer the return on capital will be. The NPV from the second year to the end of the machine's 25-year lifespan is positive and the profit margins in the three cases vary little, regardless of the discount rate used. Therefore, the prototype is economically viable and is paid for in less than two years after its implementation in any of the analyzed scenarios. This analysis reveals that the prototype can produce up to 126 L/day. However, the production of only 28 L/day (28%) is capable of paying off the investment in less than two years, depending on the local production capacity and the operating system installed.

4. Conclusion

This research evaluated the patent of the utility model type called PV acai berry juice extractor machine. The results revealed that the prototype could be improved to increase its production capacity. However, even in the initial stage the technology proved to be technically and economically feasible, with great potential for technology transfer from the model to the productive sector where remote communities in the Amazon live. Therefore, this knowledge and technology can be easily adopted as a sustainable and profitable enterprise that favors the productive arrangement of populations that depend on the sale and consumption of acai juice. In particular, riverside communities living without any conventional supply of electricity, which is very common in the Amazon region.

5. References

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