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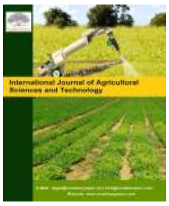

Research Paper

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Adaptation and Performance Evaluation of Small-Scale Solar Beeswax Extractor

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Abstract

Ethiopia is one of the few countries in the world with a long tradition of beekeeping. Honey is the most important primary product of beekeeping both from a quantitative and an economic point of view. Apiculture in eastern Ethiopia allows impoverished or low-income people to supplement their earnings by selling harvested bee products such as honey and beeswax at a suitable market. Due to the lack of technology, knowledge, and skill in honey production, honey and beeswax extraction is still very traditional in Ethiopia. This study aimed to adapt, manufacture, and evaluate the performance of the small-scale solar beeswax extractor. Temperature and Extracted beeswax weight recording were undertaken for extractor efficiency during the evaluation of loading different kg of honeycomb. The result shows the amount of beeswax extracted was increased with the honeycomb placed on the extractor. From 2kg and 6kg of honeycombs, 270g and 970g of beeswax were respectively extracted. However, the maximum efficiency of 20.05 % was obtained when the extractor was loaded with 4kg of honeycomb and placed under the sun for five hours. The color of the extracted beeswax also varies with the amount of honeycomb loaded; the best quality of the beeswax was obtained a light-yellow color at a temperature of 61.2ºC – 64.3ºC.

Keywords: *Beeswax, Extractor, Honeycombs, Solar*

1. Introduction

Ethiopia is one of the few countries in the world with a long tradition of beekeeping. Honey is the most important primary product of beekeeping both from a quantitative and an economic point of view. Ethiopia produces about 24,000 tons of honey and close to 3200 tons of wax (S, 2015). It was also the first bee product used by kind humankind in ancient times. The history of the use of honey is parallel to the history of man and virtually every cultural evidence that can be found of its use as a food source and as a symbol employed in religious, magic and therapeutic ceremonies is an appreciation and reference to it owes among other reasons to its unique position until very recently, as the only concentrated form of sugar available to man in most parts of the world. The same cultural richness has produced an equally colorful variety of uses of honey in other products (Hulamani *et al.*, 2014).

Beeswax is a unique, natural product produced by bees to make the cells they use to store honey and raise brood. Beekeepers accumulate beeswax in various forms as they work their bees and extract honey. Beeswax is a valuable and useful by-product of beekeeping so knowing how to handle it is an essential beekeeping skill. Beeswax is a natural wax

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secreted from the bodies of worker bees. The wax is produced from 8 wax glands under the abdomen. Like most other tasks in the hive, wax production is related and is one stage in the bee's life cycle. Wax is usually produced by bees up to 17 days of age (Fasasi and Amund, 2016). When producing wax, bees hang motionless in long clusters and the tiny scales of wax appear from their wax glands. The bees scrape the scales off with their mandibles and shape the soft wax into comb. Wax production has been identified as the most destructive action to honeybee nests.

Bee wax is obtained from three primary sources: honey capping's; bits of burr comb scraped off from hive bodies and frames, and from old combs removed during the hive management or trapping swarms and need to be recycled. The first type is light yellow and is the best-grade commercial bee wax. Bee wax must be processed in a separate room outside the honey building due to the general clutter and fire hazard generated by the wax melting procedure, but wax capping can be normally processed in the honey extracting room at the time of comb uncapping.

To produce beeswax bees must consume about eight times as much honey by mass. It is estimated that bees fly 150,000 miles to yield one pound of bee wax (Fasasi and Amund, 2016) . So, our center Apiculture researchers and Beekeepers around Hararge accumulate beeswax and founding combs in various forms as they work their bees and extract honey. But the method they used for melting wax was by using a wood fire for the comb foundation which means conventional energy. So, this study focuses on how to melt wax for a comb foundation using solar energy.

2. Methods and Materials

2.1. Description of Study Areas

The experiment was conducted at the Fedis Agricultural Research Center (FARC) workshop, Oromia Agricultural Research Institute (OARI), the center is found in Harari Peoples National Regional State and located between 42°03'– 42°16' N and 9°11'- 9°24'E. The region shares common boundaries with the Jarso district in the North Babile district in the East; the Fedis district in the South and the Haramaya district in the West. The city of Harar is located in the East at a distance of 510 Km from Addis Ababa. The region is mainly categorized into two agroecological zones, highland, and lowland or kola. The mid-high land (1400-2200 m.a.s.l) which is called weynadega constitutes 90% of the land area of the region while the low land (<1500 masl) which is called Kola constitute constitutes 10% of the total land area of the region. The mean annual temperature of the region varies from18-27 °C. The mean annual rainfall of the region ranges from 700 mm to 900 mm (Biri *et al*., 2019).

2.2. Materials

The materials used for manufacturing solar beeswax extractors are; sheet metal (aluminum), lumber, double glass pane (glazing), wire mesh, drip pan (aluminum container), screws, nails, black and white paint, plastic brush, handles, and honeycomb.

Instruments used (Figure 1)

- Ambient temperature using Digital thermo hygrometer
- Black body solar absorber using thermocouples of K-Type thermocouple
- Sky temperature using Infrared thermometer
- Relative Humidity using Digital hygrometer
- Wind speed using Anemometer
- Weight of Honeycomb before and after using Digital balance
- The internal temperature in terms of millivolts using a multi-meter
- Moisture contents of biomass using Oven-dry

Design and construction of solar beeswax extractor consideration

- Portability
- Cost effectiveness
- Easily operation
- Environment friendly

Figure 1: Instruments Used During the Data Collection

Figure 2: The Manufactured Small-Scale Solar Beeswax Extractor

2.3. Working Principle of Solar Beeswax Extractor

The beeswax extractor should be positioned in a location with the box tilted to catch the sunlight. It is important not to paint the metal sheet where the combs are placed as paint may contain lead and contaminate the wax. The Melter is used to melt down combs, capping, and other hive scrapings. The melted wax flows into a collection container through a wire mesh taking on the shape of that container. The collected wax should be very clean. Once melted the wax must undergo filtration to purify it. A sieve can be used at the outlet of the melting tank to remove any debris. After this process it can be stored in containers, for making sheets of wax or directly used in cylinders that produce continuous sheets of multipurpose wax.

Parameters that have been considered and measured for the experiment work

- Ambient temperature and the temperature within the solar bee's wax extractor
- Weight of honeycomb and beeswax extracted.
- Time for experiment
- Efficiency and quality (color) of the extracted beeswax moisture content

A substance's moisture content (Mw) is expressed as a percentage by weight on a wet and dry basis. The moisture content wet basis was calculated as follows:

$$\%MC = \frac{Mw - Md}{Mw} \times 100 \quad (1)$$

where *Mw* is the mass of the wet material and *Md* is the mass of the dry materials

Solar beeswax extractor efficiency

$$\varepsilon e = \frac{We}{Wbe} \times 100\% \quad (2)$$

where εE is the extracting efficiency (%), we, are the weight of beeswax produced (kg), Wbe is the weight of honeycomb before extracting (melting), kg

2.4. Data Collection Method

The data was taken by testing the performance evaluation of a solar beeswax extractor. The test was conducted using honeycombs collected from the beehive users of the Meta and Kersa districts of East Hararge Zone of Oromia, Ethiopia. The moisture content sample of the honeycomb before being used was taken by oven dry. Different amount of honeycomb-weight samples (2kg, 4kg, and 6kg) were loaded into a solar beeswax extractor at different times for experimental evaluation of the technology.

2.5. Data Analysis Methods

The solar beeswax extractor performance was evaluated at Fedis Agricultural Research Center (FARC), and the collected data were analyzed using descriptive statistics.

3. Results and Discussion

3.1. Experimental Results

The result of the moisture content of the honeycomb collected from different sources before and after wax extraction is shown in the above Figure 3. The maximum moisture content before extraction was 39%, and the minimum moisture content after extraction was 2.42%.

This result also related with (Kole, 2022) which the maximum moisture content before extraction was 42.91%, and the minimum moisture content after extraction was 2.48%.

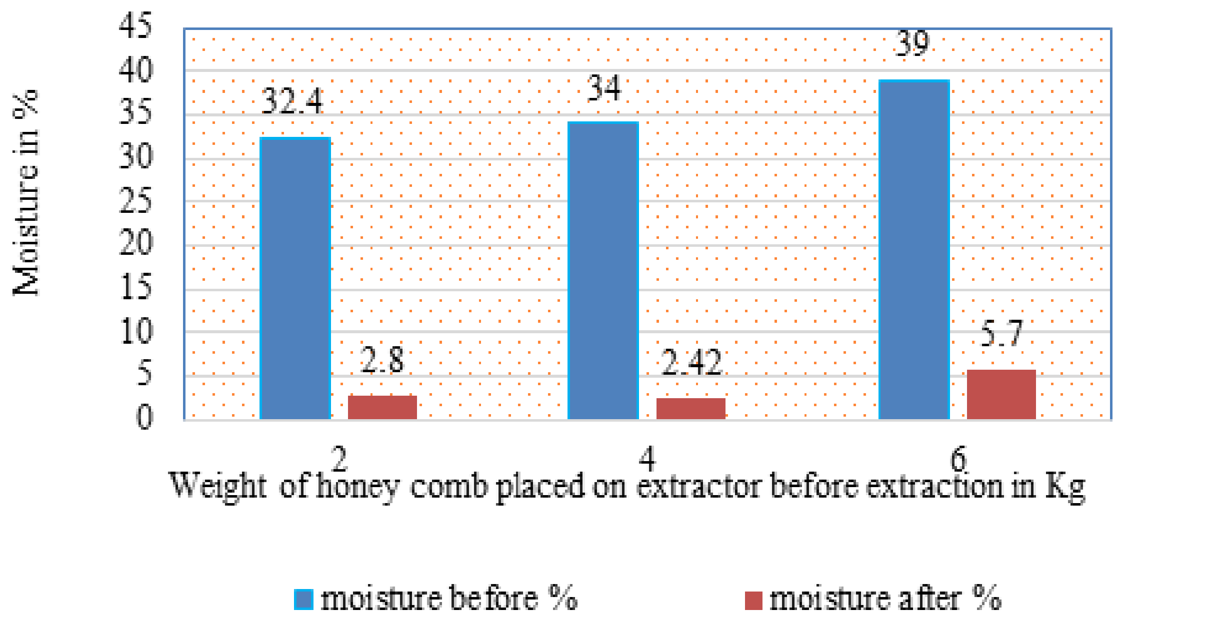

Figure 3: The Moisture Content of Honeycomb Before and After Used

3.2. Temperature Distribution

The quality of beeswax could deteriorate, and its natural composition could alter because of impurity and prolonged overheating. In addition, the melting point of beeswax is not constant since the composition varies slightly with its origin (Figure 4).

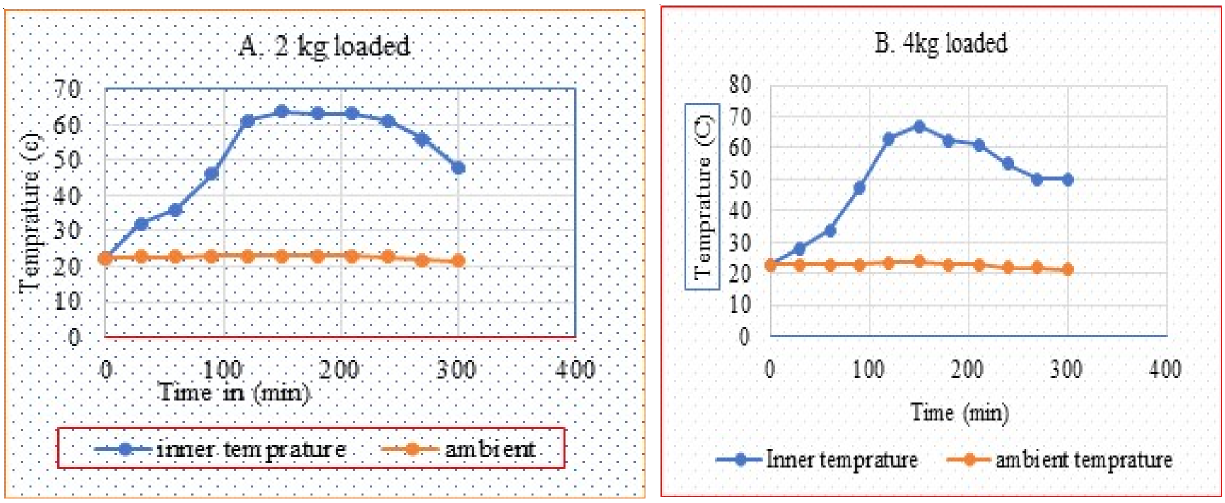

Figure 4: The Temperature Variation Internal The Melter When It Was Loaded with A = 2 kg and (B) = 4 kg

From the Figure 5, the average ambient temperature during the experiment test was 22°C and the average inner temperature of the solar bee's wax extractor was 62.7°C. Based on the above figure 5, the maximum efficiency of 20.5 % was obtained when the extractor was loaded with 4kg of honeycomb and placed under the sun for five hours. The minimum extraction efficiency of 13.5% was obtained by loading with 2kg honeycombs.

Based on the above-obtained results, the recommended solar beeswax extractor color (light yellow) was obtained at 61.2ºC-64.3ºC. According to (Kole, 2022), maximum efficiency of 25.01 % was obtained when the extractor was loaded with 3kg when it was placed under the sun for seven hours and the average inner temperature of the solar bee's wax extractor was 63 °C.

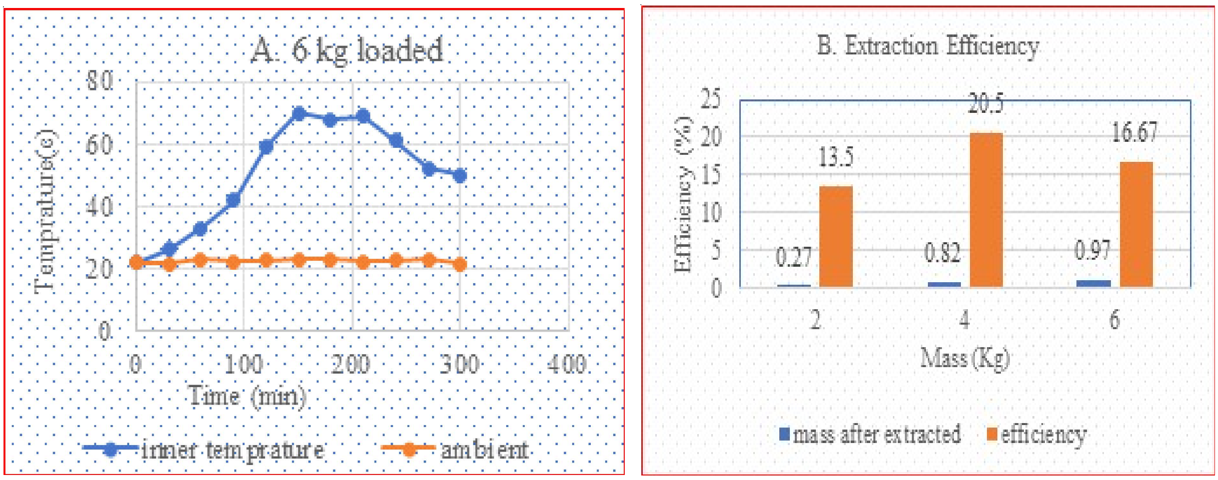

Figure 5A: The Temperature Variation Internal The Melter When It Was Loaded With A 6kg; (B) Weight of Extracted Beeswax Versus Extraction Efficiency

4. Conclusion

The solar beeswax extractor was fabricated and evaluated. Based on the conducted experiments to evaluate the performance efficiency of the extractor using amounts of honeycombs, such, as 2 kg, 4 kg, and 6 kg were used. The results indicated that the amount of beeswax extracted increased, as more honeycombs were placed in the extractor. For instance, when using 2kg and 6kg of honeycombs they obtained 270g and 980g of beeswax respectively. However, the highest efficiency of 20.05% was achieved when they loaded the extractor with 4kg of honeycomb and exposed it to sunlight for five hours. The color of the extracted beeswax also varies with the amount of honeycomb loaded. The best quality of the beeswax was obtained in a light-yellow color at a range of a temperature of 61.2 -64.7 ºC. Based on the obtained result, the adapted solar beeswax extractor will be recommended for communities with small and medium beehive technologies.

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