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Adaptation and Performance Evaluation of Small-Scale Solar Beeswax Extractor

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***Abstract*—Beeswax is one of the most valuable and oldest bee products primarily used to construct foundations in beekeeping. It is also still used in developing new products in various fields, such as the foundation for beehives, cosmetics, foods, pharmaceuticals, engineering, and industry. Apiculture in southwestern 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 was 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 1kg and 5kg of honeycombs, 190g and 980g of beeswax were respectively extracted. But the maximum efficiency of 25.01 % was obtained when the extractor was loaded with 3kg of honeycomb and placed under the sun for four days (seven hours per day). The color of the extracted beeswax also varies with the amount of honeycomb loaded. The best recommended quality of the beeswax was obtained in a light yellow color at a temperature of 63 ºC.**

***Keywords*—Solar beeswax, Extractor, Hives, Foundation sheet, and Honeycombs**

1. INTRODUCTION

Beeswax is one of the most valuable and oldest bee products, primarily used to construct foundations in a beehive. Besides, it is still used in various fields such as cosmetics, foods, pharmaceuticals, engineering, and industry [1]. Therefore, beeswax is a valuable and helpful by-product of beekeeping, and so knowing how to handle it is an essential beekeeping skill [2]. Ethiopia is one of the few countries in the world with a long tradition of beekeeping. The country is estimated to have the largest bee colonies in Africa, with over ten million bee colonies (Honey and Wax Potential Study, Southern nation nationalities and people's regional state, Regional Export Products Promotion Agency [3]. The most crucial honey and beeswax production regions in Ethiopia are Oromia (about 46 percent of total production), Southern nation nationalities and people's regional state 22%), Kaffa (9%), and Tigray (5%). In more detail, the principal supply areas in the country include places like Sidamo, Jimma, Gondar, Wollega, Illubabor, Bale, and Gojjam. The first three sources are reputable for the best quality of crude beeswax. Ethiopia produces about 24,000 tons of honey and nearly 32,000 tons of wax [4].

The proportion of honey to wax produced is 1:6; therefore, wax appears to be a huge wastage rate [5].

Apiculture in southwestern 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. Despite severe deforestation throughout many regions of Ethiopia, the landscape, especially in the southwest, still contains many nectars and pollen-producing plants ideal for bees [6].

Beekeeping enables a large number of citizens to engage in the trading of honey at different levels and selling of honey wines (local beverage Tej) which create job and self-employment opportunities. Traditionally, the demand for honey in Ethiopia is based on the consumption of honey in alcoholic "tej" and non-alcoholic "birz" beverages. The honey processing for such drinks occurs in households and specialized "tej" houses. This is often operated by women and creates income [7].

The utilization of beeswax for foundation sheets currently creates a local demand [1] due to the introduction of improved frame hives. Different rendering techniques can be employed to get pure beeswax [8]. Beeswax is collected mainly from honey produced from traditional hives rather than modern hives. The bulk of the supply of beeswax is obtained as residual from "Tej" production, a mildly alcoholic beverage popular throughout Ethiopia. The quality of beeswax obtained from tej by-product does not seem pure, and its color is not light as that of beeswax extracted directly from crude honey. This may be due to ingredients used in tej like Gesho (Raminus prinodes) stem and leave, fermentation periods, or way of storing natural beeswax (sefef); the color and the quality of beeswax processed and marketed are varied. Moreover, beeswax obtained from different processing methods affects its quality [11].

Jimma and Iluababor zones were the southwestern part of the Oromia region, known for natural resources, specifically forests. Due to its intensive presence of forests and different flowering plants, various wild and domestic animals such as honey bees migrate to the zones to improve their life condition. As a result, the honey produced from the areas was high, but there were no sufficient technologies which develop this product. Therefore, there was a problem like; less quality of honey, less technology to use honey by-products (beeswax), and less income from produced honey and beeswax; therefore, solar beeswax extractor was a good technology to minimize these problems.

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2. METHODS AND MATERIALS

2.1. Description of study areas

The experiment was conducted at Jimma Agricultural Engineering Research Center (JAERC) workshop, Oromia Agricultural Research Institute (OARI), Ethiopia. The center is located at 7° 18′N and 8° 56′N latitudes and 35° 52′E and 37° 37′E longitudes, having an elevation of 1772 meters above sea level (masl). Jimma zone was found in the Oromia region 353 km southwest of Addis Ababa. For 8 to 10 months receives an average annual rainfall of 1000 mm. The main rainy season stretches from May to September, and there is a minor rainy season in February, March, and April. Jimma zone temperatures range from 8 to 28°C. The average temperature is 20°C annually.

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), screw, nails, black and white paint, plastic brush, handles, and honeycomb.

2.2.2 Instruments used

- ✓ Ambient temperature using Digital Thermometer and 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

The Instruments used:

Figure 1. Instruments used while the data was collected

2.3 Methods

Design consideration of solar beeswax extractor

- Portable
- Low cost
- Easy operation
- Environment friend

Figure 2. The manufactured small-scale solar beeswax extractor

2.3.1 Working principle of solar beeswax extractor

The beeswax extractor was placed in a sunny spot. The box was tilted at an angle to catch the sun. Combs placed on the metal sheet should not be painted, as paint contains lead, which can contaminate the wax. The melter can be used to render old combs, capping, and other hive scrapings. The wax melts were run into a collecting container through a wire mesh were formed wax blocks according to the shape of the collecting container. The collected melt wax was very clean. A sieve (wire mesh) has been used to keep any debris at the exit of the melting metal pan. After that, it was dropped into containers to produce individual wax sheets or directly liberated into a container that made continuous sheets of wax, which will be used for multi-purposes.

2.3.2 Parameters that have been considered and measured for the experiment work

- ➢ Ambient temperature and the temperature within the solar bees 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:

$$\% MC = \frac{M_w - M_d}{M_w} \times 100 \qquad (2.1)$$

Where M_w is the mass of the wet material and M_d is the mass of dry materials

Solar beeswax extractor efficiency

$$\varepsilon E = \frac{We}{Wbe} \times 100 \qquad (2.2)$$

Where εE is the extracting efficiency (%), We is the weight of beeswax produced (kg), Wbe is the weight of honeycomb before extracting (melting), kg

2.3.3 Data collection method

- The data was taken by testing the performance evaluation of a solar beeswax extractor.
- The test was conducted using honeycomb collected from the beehive users of the Gera and

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Gomma districts of Jimma zone, Oromia, Ethiopia.

- The moisture content sample of the honeycomb before being used was taken by oven dry.
- Different amounts of honeycomb weight samples (1kg, 2kg, 3kg, 4kg, and 5kg) were loaded into a solar beeswax extractor at different times for experimental evaluation of the technology.

2.3.4 Data analysis methods

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

3. Results and Discussion

3.1 Experimental results

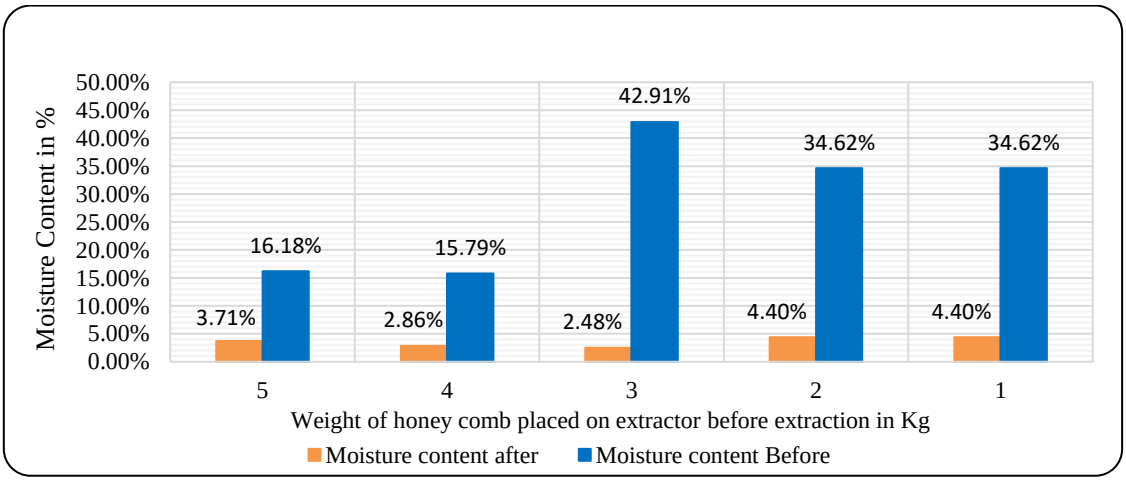

Figure 3. The moisture content of honeycomb before and after used

The result of moisture content of honeycomb collected from different sources before and after wax extraction was shown in the above figure. The maximum moisture content before extraction was 42.91%, and the minimum moisture content after extraction was 2.48%.

3.1.1 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.

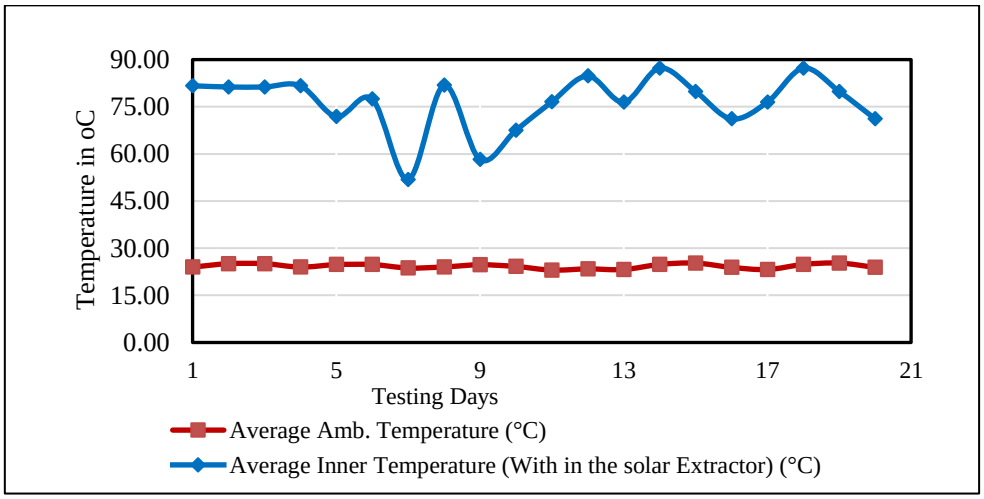

Figure 4. The temperature of solar beeswax extractor versus testing days

From the above figure, the average ambient temperature during the experiment test was 22°C the average inner temperature of the solar bees wax extractor was 63 °C.

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3.1.2 The Effect of loading densities

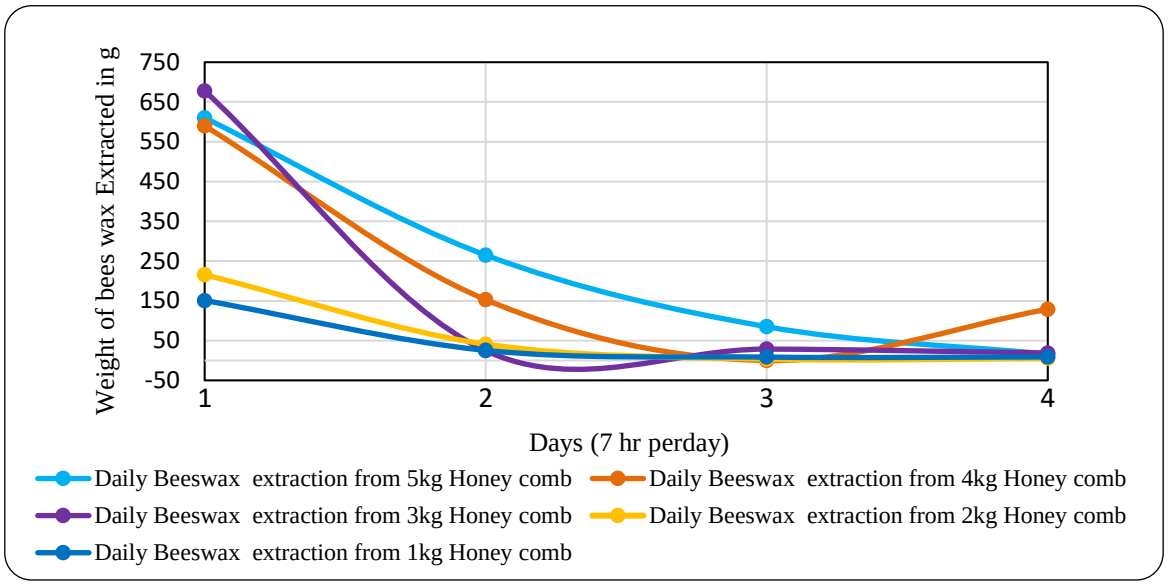

Figure 5. Weight of the extracted beeswax versus testing days

Based on the above results, from 1kg and 5kg of honeycombs, 190g and 980g of beeswax were extracted.

3.1.3 Extraction Efficiency

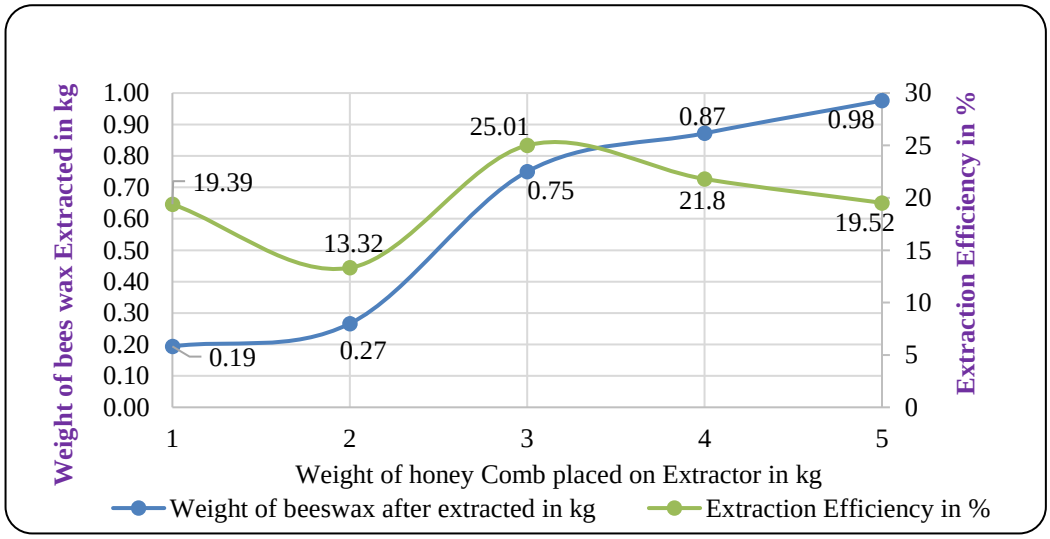

Figure 6. The weight of extracted beeswax versus Extraction efficiency

Based on the above figure, the maximum efficiency of 25.01 % was obtained when the extractor was loaded with 3kg of honeycomb and placed under the sun for four days (seven hours per day). The minimum efficiency of 13.01 % was obtained by loading with 2kg honeycombs.

The beeswax extraction:

Figure 7. The wax extraction during the experiment

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Figure 8. The bees wax that was produced and prepared for the beehive frame

Based on the above-obtained results, the recommended solar beeswax extractor color (light yellow) was obtained at a temperature of 63 ºC.

4. CONCLUSIONS AND RECOMMENDATION

The solar beeswax extractor was fabricated and evaluated. Based on the experimental result, the solar beeswax extractor performance efficiency was evaluated by considering different loading weights of honeycombs, i.e., 1kg, 2kg, 3kg, 4kg, and 5kg. The result shows that the amount of beeswax extracted was increased with the honeycomb placed on the extractor. For example, from 1kg and 5kg of honeycombs, 190g and 980g of beeswax were extracted, respectively. But the maximum efficiency of 25.01 % was obtained when the extractor was loaded with 3kg of honeycomb and placed under the sun for four days (seven hours per day).

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 temperature of 63ºC. Based on the obtained result, the adapted solar beeswax extractor will be recommended for communities with small and medium beehive technologies. Solar beeswax extractor technology is not well known in Sab-Saharan countries like Ethiopia. Therefore, promoting or demonstrating the technology in honey production areas is better.

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