Modification and Performance Evaluation of Manually Operated a Screw Press Beeswax Extractor

By

Mesay Sermolo Degefu

A Thesis Submitted to the Department of Mechanical Engineering, School of Mechanical, Chemical and Material Engineering

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Agricultural Machinery Engineering

Office of Graduate Studies

Adama Science and Technology University

October, 2023

Adama, Ethiopia

Modification and Performance Evaluation of Manually Operated a Screw Press Beeswax Extractor

By:

Mesay Sermolo Degefu

Advisor:

Amana Wako (Ph.D.)

A Thesis Submitted to the Department of Mechanical Engineering, School of Mechanical, Chemical and Material Engineering

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Agricultural Machinery Engineering

Office of Graduate Studies

Adama Science and Technology University

October, 2023

Adama, Ethiopia

DECLARATION

I hereby declare that this Master Thesis entitled "Modification and Performance Evaluation of Manually Operated a Screw Press Beeswax Extractor" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

_____	_____	_____
Name of the Student	Signature	Date

Recommendation of Advisors/ Supervisors

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "Modification and Performance Evaluation of Manually Operated a Screw Press Beeswax Extractor" submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Agricultural Machinery Engineering.

Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

_____	_____	_____
Major Advisor	Signature	Date
_____	_____	_____
Co-advisor	Signature	Date

APPROVAL

I, the advisor of the thesis entitled "Modification and Performance Evaluation of a Manually Operated a Screw Press Beeswax Extractor" developed by Mesay Sermolo, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Major Advisor	Signature	Date
Co-advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Mesay Sermolo have read and evaluated the thesis entitled "Modification and Performance Evaluation of a Manually Operated a Screw Press Beeswax Extractor" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Agricultural Machinery Engineering.

Chairperson	Signature	Date
Internal Examiner	Signature	Date
External Examiner	Signature	Date

Finally, approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

Department Head	Signature	Date
School Dean	Signature	Date
Office of Postgraduate studies Dean	Signature	Date

ACKNOWLEDGEMENT

I praise the Creator of all things for leading, maintaining, and offering everything needed for the fruitfulness of this work.

I would like to take this opportunity to express my sincere thanks to my advisor, Dr. Amana Wako, for his professional and trustworthy support in the completion of this research task. I would like to express my deep appreciation to everyone who contributed in making this work possible, especially the technical staffs of the School of Mechanical, Chemical and Material Engineering and the Department of Mechanical Engineering.

I also want to extend my thanks towards my mentor and brother, Yinebeb Seyoum (Ing), for every bit of his guidance and encouragement throughout my academic endeavors. I would like to acknowledge my mom, my parents, and friends of mine, Mrs. Elsabete Kashahune, and all of the others in my family for their affection, assistance, and support. I respect you all very much.

Furthermore I am filled with appreciation for everyone who has played a part in my academic journey. Their guidance encouragement and support have been invaluable and I am truly grateful for their contributions to my growth and development.

Finally, I'd like to express my gratitude to Mr. Goshu Yami, a particular buddy. Whose support and advice I deeply valued during the course of my task. Thank you for being there for me constantly.

CONTENTS

CHAPTER **PAGE**

DECLARATION ii
APPROVAL iii
ACKNOWLEDGEMENT iv
LIST OF TABLES viii
LIST OF FIGURES ix
ACRONYMS xi
ABSTRACTS xii
CHAPTER ONE 1
1. INTRODUCTION 1
1.1. Background and Justification 1
1.2. Statement of the Problem 5
1.3. Objective of the Study 6
1.3.1. General objective 6
1.3.2. Specific objective 6
1.4. Significance of the Study 7
CHAPTER TWO 8
2. LITERATURE REVIEW 8
2.1. Beeswax 8
2.2. Chemical and Physical Characteristics of Beeswax 8
2.3. Production and Trade of Beeswax 10
2.4. Beeswax Quality 14
2.5. Methods of Beeswax Rendering 16
2.5.1. Those employing only heat 17
2.5.1.1. Solar beeswax extractor 17
2.5.2. Those employing both water and heat 19
2.5.2.1. Manual extraction method (simple extraction method) 19
2.5.2.2. Submerged beeswax extraction method 20
2.5.2.3. Steam beeswax press extractor 21
2.5.3. Those employing presses and hot water 22
2.5.3.1. Hot water beeswax-press extractor 22

2.5.3.2. Steam beeswax press extractor 24
2.5.3.3. Unheated press beeswax extractor 25
2.6. Some of the Works Done on Screw Press Extractor 26
CHAPTER THREE 38
3. MATERIAL AND METHODS 38
3.1. Study Site Description 38
3.2. Materials 39
3.3. Modification of the Manually Operated Screw Press Beeswax Extractor 39
3.3.1. Design considerations 40
3.3.2. Working principle of the screw presser 41
3.3.3. Design specification 42
3.4. Modification of the Components of the Screw Presser 44
3.4.1. Modification of the perforated and cylinder of the presser 44
3.4.2. Modification of press plate or piston 46
3.4.3. Modification of the vertical supporting columns of the presser 46
3.4.4. Modification of the top and bottom frame of the presser 47
3.4.5. Modification of the bottom or main frame 48
3.5. Manufacturing of Main Parts 49
3.5.1. Manufacturing of bottom press plate of the presser 50
3.5.2. Manufacturing of pressing chamber of the presser 51
3.5.3. Manufacturing of perforated inner cylinder 51
3.5.4. Manufacturing of pressing plate (Piston) 52
3.5.5. Manufacturing of lower frame (Stand) 53
3.5.6. Manufacturing of plunger or threaded screw 54
3.5.7. Manufacturing of top frame 55
3.5.8. Manufacturing of vertical columns or frame 55
3.6. Assembly of the Screw Presser Components 56
3.7. Performance Evaluation of a Screw Presser 58
3.7.1. Materials 58
3.7.2. Test procedure 59
CHAPTER FOUR 61
4. RESULTS AND DISCUSSIONS 61

4.1. Results 61
4.1.1. The modified screw pressers performance 62
4.2. Discussion 67
4.2.1. Extraction efficiency 67
4.2.2. Extraction capacity 70
4.2.3. Extraction time 71
CONCLUSION AND RECOMMENDATION 73
Conclusion 73
Recommendations 73
REFERENCES 75
APPENDIXES i

LIST OF TABLES

TABLES **PAGE**

Table 1.Quality Criteria for Beeswax 15
Table 2. Ethiopian Standard Specification for Beeswax 16
Table 3. List of Materials Used 39

LIST OF FIGURES

FIGURES **PAGE**

Figure 1. Solar Wax Melter 18
Figure 2. Solar Melter 19
Figure 3. Traditional Squeezing Method 20
Figure 4. Immersion or Sisal Sack Press Method 21
Figure 5. Steam Wax Extractor 22
Figure 6. Beeswax Press 23
Figure 7. Steam Beeswax Press 25
Figure 8. Presses: (a) spindle press, (b) hydraulic press 26
Figure 9. Manually Operated Palm Oil Extractor 29
Figure 10. Power Screw Type Spindle Oil Press 30
Figure 11. Study Area Map 38
Figure 12. Beeswax Screw Presser Prototype 42
Figure 13. Isometric View of the Screw Presser 42
Figure 14. Bottom Pressing Plate 51
Figure 15. Pressing Chamber 51
Figure 16. Perforated Cylinder 52
Figure 17. Pressing Plate (Piston) 53
Figure 18. Lower Frame 54
Figure 19. Threaded Screw 55
Figure 20. Top Frame 55
Figure 21. Vertical Columns 56
Figure 22. Front, Side, Isometric Views and Beeswax Presser Assemble 58
Figure 23: The Modified Beeswax Extractor 61
Figure 24: Extraction Capacity Vs Extraction Efficiency of the Screw Press 63
Figure 25. Extraction Capacity of Screw Press Methods 64
Figure 26. Extraction Efficiency of Screw Press Methods 64
Figure 27: Extraction Capacity Vs Extraction Efficiency of the Traditional Method 65
Figure 28. Extraction Capacity of Traditional Methods 65
Figure 29. Extraction Efficiency of Traditional Methods 66

Figure 30: Extraction Capacity of the Screw Press Vs Traditional Method 67
Figure 31. Extraction Efficiency of Screw Press Vs traditional Method 67

ACRONYMS

CSA	Central Statistics Agency
ETB	Ethiopian Birr
E_E	Extraction Efficiency
E_C	Extraction Capacity
GDP	Gross Domestic Products
HBRC	Holleta Bee Research Center
MoA	Ministry of Agriculture
QSAE	Quality and Standards Authority of Ethiopia
USD	United States Dollar

ABSTRACTS

In Ethiopian beekeeping, there is a unique traditional method of beekeeping that presents an opportunity for significant beeswax production. However, the current beeswax processing techniques are outdated, resource-intensive, time-consuming, and inefficient. These traditional methods result in substantial annual wastage of beeswax. To address these issues, there is a need to develop an automated beeswax pressed separator. The objective of this thesis was to modify and evaluate the performance of manually operated a screw press beeswax extractor. A prototype of the screw press extractor was constructed and tested both on the production field and in a controlled testing environment to find a viable solution. The selection of components for the construction of the presser was based on the requirements and estimates of the concept. The presser demonstrated an extraction yield ranging from 29.7% to 60.3% with an average of 44.5%. This is a significant improvement compared to the traditional squeezing method, which had an extraction efficiency ranging from 19.1% to 32.5% with an average of 25.8%. The newly developed screw press extractor is capable of processing 0.64 kg of crude beeswax per hour while also improving the color of the beeswax. However, there is still room for improvement in the presser's throughput by modifying the designs of a few key components. Overall, this study highlights the need for innovation in Ethiopian beekeeping to enhance the efficiency and productivity of beeswax processing. The prototype screw press extractor demonstrates promising results and provides a foundation for further advancements in this field.

Keywords: Effectiveness, efficiency, modification, pressing plate, perforated cylinder, performance evaluation, Screw presser.

CHAPTER ONE

1. INTRODUCTION

1.1. Background and Justification

In Ethiopia, agriculture plays a vital role in the economy, with over 80% of the population depending on it for their livelihoods (IMF, 2016). The agriculture sector, according to MoA (2019), has not only contributed a substantial amount of 27.5 billion dollars, equivalent to 34.1% of the GDP but has also employed approximately 79% of total workforce. Furthermore, it has been responsible for generating 79% of the country's foreign revenues and serves as the primary provider of essential resources and capital for market growth and investment (IMF, 2016). It additionally provides 70% of the inputs needed for the agriculture and food industry as well as more than 90% of the country's overall earnings from exports (Atsbaha G/Selassie & Tessema Bekele, 2012), although it remains dominated by small-scale farmers, who generate over 95% of the nation's entire agricultural earning (HSIOB, 2013). As reported by (Louhichi et al., 2019), the remaining 5% are supplied by a fairly small percentage of (former) government-owned or private agricultural enterprises (commercial farms) (HSIOB, 2013). According to official figures, 12.6 million hectare of agricultural land had been cultivated by 17.4 million producers in (CSA, 2016/17).

The livestock subsector in agriculture provides the potential for economic development (Shapiro et al., 2017). Approximately 15% of the GDP is accounted for by the animal husbandry sector (Demisew Wakjira, 2016; Atsbaha G/Selassie & Tessema Bekele, 2012). LSIPT estimates that livestock directly contributes ETB 150.7 billion, or 17% of the nation's GDP, and 39% of the revenue from agriculture to the economy each year. Without accounting for the costs of processing, marketing, and its indirect investments in the form of organic fertilizer and traction, the amount rises to almost 21% of the country's GDP and 49% of agricultural output (Shapiro et al., 2017).

Beekeeping generates 1.3% of the agricultural gross domestic product and constitutes an important portion of the livestock industry (Teshome Kassa & Guta Regasa, 2020). Beekeeping is a popular hobby among rural residents and is performed at homesteads around the nation.

Despite the fact that beeswax is a more useful bee product as honey also offers a valuable income in addition to honey, most people mistakenly believe that honey is the product most commonly associated with bees (Teshome Kassa & Guta Regasa, 2020). Beeswax is more valuable than honey by an amount of one kilogram (Bradbear, 2009).

A kilogram of blocks of processed beeswax nowadays rates in between 250 and 300 ETB (25 and 30 USD) in the town's marketplace (HBRC, 2020). Bees utilize beeswax, which possesses a creamy look, for constructing a comb which serves as the foundation for where they lived. The hexagonal-shaped comb acts as a structure for the bees' place of living and serves for each of the several storage tasks required in the bees' nest, including honey storage, pollen storage, egg laying, and larvae In addition, beeswax continues to be utilized on a daily basis in a wide range of occupations, including engineering, medicine, food, personal care products, and manufacturing (Gemechis Legesse, 2014). Beeswax is a versatile product that is utilized in both domestic and foreign markets. Globally, it is primarily used for beauty products (25-30%), medications (25-30%), candles (20%), and various other purposes (10-20%) (Yeshitela Eshete et al., 2018). Ethiopia holds a prominent position as one of the top four producers of beeswax. This achievement can be attributed to the traditional beekeeping system practiced in the country, which yields a higher production of beeswax byproducts per hive compared to other methods (Yeshitela Eshete, 2018; Nuru Adigaba, 2007; Ayalew Kassaye, 2008; Gemechis Legesse, 2014).

In improved or modern colonies, beeswax is generated at a rate of 1.5 to 2% of the total amount of honey, according to the profitability of beeswax in relation to various types of hives. The yield, however, is 10 to 15 of the total volume of the honey in typical hives (Weidmann & Kilcher, 2011). According to CSA (2021), the country's rural and remote agricultural areas are inhabited to an anticipated 6.99 million bee hives. Of this figure, traditional hives represented the majority (95.89%) of the total hives in the nation, being followed by transitional hive systems (1.47%) and modern hive systems (2.63%), accordingly. Traditional (10 to 15 kg of the weight of honey) hives, as opposed to contemporary frame hives, are where the majority of beeswax is obtained. According to the aforementioned evidence, over 90% of beekeepers in Ethiopia maintain traditional beehives, suggesting that the nation has an immense possibility for beeswax production. Ethiopia has enough resources to provide 50,000 tons pure beeswax yearly

as a result (Johannes Agonafir, 2005). The country currently producing fewer beeswax than it could. Regardless of possessing the means of producing as much as 50,000 tons of pure beeswax annually, the nation only produces less than 10,000 tons (Tewodros Kassa, 2020; Yeshitila Eshete & Tekeba Eshetie, 2018).

Since a great deal honey is traded packed with wax, it is projected as approximately one quarter of the total quantity of wax resulted in is "thrown away" due to a lack of processing tools (Ayele Gezahegn et al., 2006). The aforementioned estimate excludes into account most of the beeswax that comes from geographically remote areas, where it is typically squandered unharvested. Moreover, almost all of the beeswax used locally and internationally has been processed manually in an extraordinarily conventional manner, which has been speculated to be a contributing factor to the loss reported. A study conducted by Nuru Adgaba & Eddosa Negara, (1995) identified that 33.1 kg of pure beeswax goes unused for each 100kg of crude beeswax that is traditionally converted. The lack of effective tools for processing crude beeswax in Ethiopia results in a significant waste of approximately 9,900 quintals (990 tons) of beeswax annually. This wasted beeswax is valued at 30 million Birr. The majority of the locally produced beeswax, which amounts to 3,000 tons, is processed manually, further exacerbating the inefficient utilization of this valuable resource.

Beeswax has a strong market both at home and abroad. Although not yet tangible, it is argued that the traditional spiritual routine of the Ethiopian Orthodox Church's believers burning candle sticks called "tuaf" produced with purified beeswax consumes an immense amount of the beeswax produced domestically. Furthermore, Ethiopian beeswax has emerged as highly regarded and is frequently blended with beeswax from other parts of the world. As a result of its suppleness and malleability (Yeshitela Eshete, 2018; Bogdanov, 2006). Despite the fact that Ethiopia has the capability to produce top-quality beeswax (Yeshitila Eshete & Tekeba Eshetie, 2018; Yeshitela Eshete, 2018), fewer than 10% of it is exported. Currently, certain quantities of shipped beeswax have failed to meet the minimum requirements for beeswax quality.

Under the local context, poor knowledge of the procedure for rendering and a lack of effective techniques and technologies for crude beeswax processing would result in the principal causes of beeswax waste (Nuru Adgaba & Eddosa Negara, 1995). For the reason that some processing

facilities' inability to maintain the ideal temperature during processing, beeswax quality deteriorates locally as a result of overheating (Yeshitila Eshete & Tekeba Eshetie, 2018). Yeshitela Eshete et al., (2018) confirmed that longer heating times or higher temperatures result in substantial hydrocarbon loss and degradation in beeswax, which also affects the wax's chemical and physical characteristics. Overheating during rendering or other processing impacts the wax's structural makeup and its advantageous properties.

In Ethiopia, the handling and processing of unprocessed beeswax have a significant impact on the quantity and quality of the wax produced. Different methods can be employed to render wax, tailored to specific needs and situations. Solar wax melters, boilers with water and filters, or specialized presses with steam or boiling water can all be utilized for beeswax extraction. However, the prevailing wasteful beeswax extraction systems in Ethiopia, particularly among small and medium-sized farmers and processors, are believed to contribute to the wastage of beeswax. The manual beeswax rendering method currently employed is highly inefficient, with only a 50% efficiency compared to mechanical pressers (Nuru Adgaba & Eddosa Negara, 1995). This inefficiency exacerbates the loss of valuable beeswax resources in the country.

By developing low-cost and effective crude beeswax refining technologies, we can address the inefficiencies and labor-intensive nature of the conventional rendering procedure. This would greatly benefit farmers, cooperatives, tej makers, and small-scale beeswax processors who rely on beeswax as a key raw material. Implementing these technologies would not only save time and reduce labor demands but also significantly decrease the annual loss of beeswax. By streamlining the refining process, farmers and processors can maximize the yield of beeswax, resulting in higher profits and increased economic stability.

Affordability is a key aspect to consider in developing these technologies. By ensuring that they are accessible and inexpensive, we can empower smaller-scale individuals and organizations within the beekeeping industry to adopt these refining techniques, enhancing their competitiveness and potential for growth. Moreover, these low-cost technologies would have a positive impact on the environment. By reducing the need for excessive manual labor and optimizing the extraction process, we can minimize wastage and energy consumption, leading to more sustainable production practices. Ultimately, the development and widespread use of

low-cost and effective crude beeswax refining technologies will contribute to the overall improvement of the beekeeping industry. It will empower small-scale processors, increase profitability, and reduce beeswax loss, thus benefiting the entire value chain from farmers to end-users.

1.2. Statement of the Problem

Ethiopia currently produces around 47,710 tons of crude honey, which translates to an average of 3,816.8 tons of beeswax at an 8% productivity rate. Out of this total beeswax production, Ethiopia exports approximately 302.34 tons, which accounts for only about 8% of its total production (Yeshitila Eshete & Tekeba Eshetie, 2018). This indicates that less than 10% of Ethiopia's beeswax production is being exported, despite the high demand and quality of Ethiopian beeswax (Gemechis Legesse, 2014). Ethiopian beeswax is often mixed with beeswax from other regions of the world. Despite its significant potential for producing high-quality beeswax, the country's current export levels are significantly lower compared to the average yield for Africa and the rest of the world.

To achieve its national agricultural policy objective of increasing export earnings from USD 210 million in 2015 to USD 4.8 billion by 2025, Ethiopia needs to focus on increasing beeswax production and productivity (Zewdie Habte, 2020). By addressing the limitations of the current manual extraction method and adopting more efficient and affordable extraction methods, such as the modified screw press beeswax extractor mentioned earlier, Ethiopia can increase its beeswax production and meet its export goals. This would contribute to the overall economic growth and development of the country's agricultural sector.

The current method of manual beeswax extraction used in Ethiopia has several limitations that result in a poor yield of beeswax per kilogram. These limitations include difficulties in controlling the temperature of the beeswax, challenges in squeezing the wax, a high requirement for human power, and filtration difficulties. To address these issues, it is necessary to consider and resolve them by using different types of beeswax extractors. However, the beeswax extractors available on the market are mostly imported, which requires the country's limited foreign exchange. Furthermore, these extractors are designed for modern box hive beekeeping

operations, whereas the majority of Ethiopian beekeepers use traditional hives. Additionally, these imported extractors tend to be expensive, making them unaffordable for most farmers with modest incomes. They are also unsuitable for the local circumstances of Ethiopian beekeeping.

Therefore, it is not economically feasible to use imported beeswax extractors under Ethiopian conditions. The complex challenges associated with these extractors further slowdown their adoption. As a result, the objective of this paper is to modify a screw press honey presser into a beeswax extractor that is affordable and efficient compared to currently available traditional and mechanical extractors. The modified extractor should be simple enough to be fabricated in a local machine shop, lightweight for easy manipulation by women, and adaptable to the local farm beekeeping experience. This manually operated, screw press beeswax extractor has been modified specifically to meet the requirements of extracting beeswax within the recommended melting temperature. The objective is to increase productivity and reduce the production cost of beeswax extraction in Ethiopia. By utilizing this modified extractor, the country can enhance its beeswax production and work towards achieving its national agricultural policy objective of increasing export earnings.

1.3. Objective of the Study

1.3.1. General objective

The general objective of the study was to modify the manually powered screw press honey extractor into a manually operated beeswax press and evaluate its performance.

1.3.2. Specific objectives

- To improve the current manually operated screw press's perforated cylinder, external chamber and handle.
- To construct an efficient prototype of a beeswax presser.
- To evaluate the presser's efficiency in terms of extraction capacity and productivity.

1.4. Significance of the Study

The importance of this study was to modify a screw press honey extractor into beeswax extractor so that it will increase production of best quality beeswax through pressing extraction by considering the physical, mechanical and biological properties of beeswax and operating the extractor in the optimum temperature of beeswax. Extracting beeswax that is not overheated and best quality, quantity, color beeswax increase the additional income of farmer's beekeepers. The quality beeswax creates a good opportunity for farmers to maximize their income and they will be a source of raw material for different industry that uses beeswax as main row materials. In general it saves resources and cost of production and hence benefitting the farmers. By successfully extracting beeswax, farmers and beekeepers could substantially increase their income. This added revenue stream could potentially transform their livelihoods and provide them with opportunities for growth and development. Lastly, the modification of a screw press honey extractor into a beeswax extractor established a practical solution for maximizing beeswax production. Through optimized extraction techniques, farmers could increase their income by extracting the beeswax that was wasted in small scale beekeepers house.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Beeswax

The beeswax is sweated through four pairs of glands on the lower part of the abdomens of bees (*Apis mellifera*). Eight wax scales are produced by a worker honeybee every 12 hours (Bradbear, 2009). Since a wax scale weighs around 1 mg, approximately one million scales are required to manufacture one kilogram of wax (Bogdanov, 2004). The amount of pollen the young bees consume after emerging from their cells and the worker's age both affect how the wax glands develop. According to Mutsaers et al., (2005) and Yeshitela Eshete, (2018), rich pollen feed during this first stage assures that the bees will eventually have the best ability to form comb.

Bees use beeswax, a material with a creamy appearance, to construct the comb that serves as the framework for their nest (Bradbear, 2009;Yeshitela Eshete, 2018). The structure of the bees' residence, the comb, which has a hexagonal cross-section, is used for all the several storage purposes required in a bees' nest: to store honey, to store pollen, to serve as a location to lay eggs, and for the development of the young bees (Khan et al., 2019; Yeshitela Eshete, 2018; Bradbear, 2009). Two to four kilograms of honey can fit in a single Langstroth frame with only 100 g of wax (Bradbear, 2009). There is no unnecessary wax production in the bees' wax economy, which appears to operate according to the demand-supply paradigm (Bogdanov, 2004).

When there is an excess of honey that needs to be stored and there is a shortage of honeycomb to store and seal the matured honey, bees get inspired to produce wax. Bees need to consume about eight kilos of honey in order to generate one kilogram of wax when manufacturing and building with wax (Bradbear, 2009). In order to produce one pound of beeswax, it is thought that bees must collectively fly 150,000 miles, or about six times around the globe (Khan et al., 2019).

2.2. Chemical and Physical Characteristics of Beeswax

The melting point of beeswax is between 61.0°C and 63.9°C, the saponification cloud point is between 57.9°C and 65.0°C, and the ester value is between 66.4 and 98.0°C. The range of the

acid value is 18.0-32.7 (Bradbear, 2009). Since beeswax is chemically inert, its characteristics don't change much over time. Both spontaneous oxidation and hydrolysis do not affect it. It is a complicated substance made up of a variety of elements, but primarily higher fatty acid of esters and alcohol, pigments primarily derived from pollen and propolis, and very small amounts of bee material (Yeshitila Eshete & Tekeba Eshetie, 2018). Beeswax mostly consists of esters, which make up 72% of the total, free acids, which make up 14–15% of the total, and free alcohols, which make up 1% of the whole (Yeshitela Eshete, 2018).Very pure beeswax is white, but the presence of pollen and other substances causes it to become yellow (Bradbear, 2009). Beeswax has a characteristic odor originating from the bees, honey, propolis and pollen (Khan et al., 2019; Yeshitela Eshete, 2018).

Beeswax floats on the water and has a density of 0.95 kg/liter. At lower temperatures, it contracts as a result of an increase in density (Mutsaers et al., 2005). It is brittle once the temperature falls below 18°C (Bradbear, 2009), solid at room temperature, and highly plastic (pliable and flexible) at a relatively low temperature (about 32°C). Wax undergoes a physical change when heated. It turns into plastic at 30-35°C, a hard body's structure is shattered at 46-47°C, and it melts at 62-64°C (Yeshitela Eshete, 2018). The wax becomes discolored when heated above 85°C, and it becomes ruined when boiled. Beeswax is completely squandered if it is heated to a point where it burns. Beeswax shrinks by roughly 10% after cooling (Bradbear, 2009).

The research study presented above indicates that beeswax has a shape that is crystalline. Beeswax crystallization is influenced by how it is stored. Wax that has been stored for three to four months becomes more crystallized while also becoming stiffer and more elastic. The application of wax as "the house of the bees" largely depends on its mechanical qualities. Fresh "scale wax is less stiff than comb wax and has a greater strength and extends to a greater extent upon strain." These variations are brought about by the physical and chemical variances between these two types (Bogdanov, 2016).

Beeswax displays remarkable resistance to various acids and possesses insolubility in water. However, it readily dissolves in a multitude of organic solvents, including but not limited to acetone, ether, benzene, xylol, toluene, chloroform, and tetrachlormethane. Elevating the temperature above the melting point of the wax enables it to dissolve swiftly in these solvents,

as well as in ethanol. Nevertheless, complete dissolution is not achievable at normal ambient temperatures (Bogdanov, 2016). During the purification process, it is crucial to avoid heating beeswax in vessels composed of iron, lead, zinc, brass, or copper. These metals have a tendency to cause the wax to darken. Given that beeswax possesses a slightly acidic nature, caution must be exercised, ensuring that containers made from brass, copper, zinc, pewter, tinplate, or iron are not utilized. An adverse reaction between these materials and the wax could lead to discoloration (Bogdanov, 2016).

In order to safely work with beeswax, it is advisable to employ containers made of wood, enamel, stainless steel, nickel, or plastic. When it comes to the choice of water, soft and clean rainwater is highly recommended. The presence of lime in hard water has a detrimental effect on beeswax, causing it to react and saponify. Therefore, it is essential to avoid using well water, as it may cause the wax to turn brown in color. According to Cowan (2015), lime in water combines with the fatty acid present in wax, resulting in saponification and the formation of a spongy, grayish mass upon cooling. In the absence of rain or river water, a viable alternative is to add vinegar or a small quantity of sulfuric acid to the water, enough to neutralize the lime (Yeshitela Eshete, 2018).

2.3. Production and Trade of Beeswax

In some tropical regions, beeswax as an opportunity for making money is disregarded. Ethiopia and Angola are two examples of African nations where fixed-comb beekeeping is still common; in contrast, several nations neglect their beeswax export industries and simply discard the wax (Bradbear, 2009; Yeshitila Eshete & Tekeba Eshetie, 2018). Pieces of wax comb are frequently thrown away in situations where the majority of the honey produced is consumed locally and where beeswax has no local value (Bradbear, 2009).

In addition to honey, beeswax is a good commodity that can generate reliable income (Bradbear, 2009). Beeswax is the second most economically significant bee product after honey (Yeshitela Eshete, 2018). Its production is predicted to be between 1.5 and 2.5% when compared to honey (Bogdanov, 2004). A kilogram of honey is less valuable than a kilogram of beeswax. The cost per kilogram is ETB 371.21 (WAMUCII, 2022) in Ethiopian Birr. As a result, beeswax processing and commercialization are lucrative industries in Ethiopia. In order to meet market

demands and ensure the sustainability of beeswax, processors and exporters should be urged to handle it responsibly (Yeshitila Eshete & Tekeba Eshetie, 2018).

According to Bradbear, (2009), a lot of the beeswax produced around the world that beekeepers may harvest is wasted. Because beekeepers don't care to gather it and turn it into commercial blocks, the beeswax is left or thrown away. Because of this, only a small percentage of the world's beeswax production—possibly just half—reaches the market, with the remainder being wasted or lost (Bradbear, 2009).

Beeswax is primarily produced and exported by tropical nations, and developed nations need to import it. This is for the reason that both honey and wax can be harvested under local beekeeping practices (Yeshitila Eshete & Tekeba Eshetie, 2018). There are just a few significant producers of beeswax on the global market, including Ethiopia, India, Argentina, and Turkey. Ethiopia is one of the biggest producers of beeswax globally, and this success is mostly attributable to the country's predominately traditional method of production, which yields a significantly greater quantity of wax per hive (Yeshitila Eshete & Tekeba Eshetie, 2018). Assessments indicate that Ethiopia has potential for the production of beeswax because of the huge number of honeybee colonies being kept in traditional hives (Gemechis Legesse, 2014).

According to Gemechis Legesse (2014), Ethiopian honey farming is distinguished by an old-fashioned system of production that fosters the possibility of high beeswax yield potential. Beekeeping, which is with hives made locally yields more beeswax since the delicate honeycomb must be shattered in order to harvest the honey and cannot be put back together again. Using either fixed-comb or movable-comb hives, the ratio of honey and beeswax production is roughly 10:1 (Bradbear, 2009). According to CSA, (2021), a total of 6.99 million bee hives are thought to be present throughout the nation's rural and pastoral sedentary areas. From this total, the majority of hives (95.89%) were traditional, followed by transitional (1.47%) and modern (2.63%) hive systems, respectively (CSA, 2021). Traditional hives are where beeswax is mostly collected, as opposed to movable frame beehives, and the total quantity of beeswax produced is estimated to be 8–10% and 0.5–2% of the crude honeycomb produced in conventional and mobile frame hives, respectively (HBRC, 2020; Yeshitila Eshete & Tekeba Eshetie, 2018; Johannes Agonafir, 2005).

Ethiopia, known for its high-quality beeswax, is a significant player in the global market, ranking as the second-largest producer after India (Mohammed & Hassen, 2021). Annually, the country produces an estimated 5,790 metric tons of beeswax, generating substantial foreign exchange revenues and boosting the national economy. According to Mohammed & Hassen (2021), the value of beeswax exports amounts to over 325 tons, resulting in a profit of approximately 560 million ETB. Despite its immense potential, Ethiopia's beekeeping industry falls short of reaching its full capacity. With the capability to produce over 50,000 tons of beeswax per year (Shegaw & Edimew, 2021), the actual production remains limited to 5,742 tons (Tesfu Shegaw & Tewabe Edimew, 2021; Mohammed & Hassen, 2021), accounting for just 10% of its potential. In 2018, Ethiopia's production accounted for only 8.2% of the global total, equivalent to 5694 tons (Gratzer et al., 2021).

The demand for beeswax in both domestic and international markets is exceptionally high. African beeswax, particularly from Ethiopia, is renowned for its low pesticide content and is often used to blend with lower-quality wax from other sources. Due to its unique production environments and favorable climate, Ethiopian beeswax commands a higher price in the European Union and experiences greater demand. Even with improved beekeeping practices, the local beeswax market consistently struggles to meet demand, which leads to continuously rising prices (Yeshitila Eshete & Tekeba Eshetie, 2018; Weidmann & Kilcher, 2011). The majority of beeswax produced is dedicated to the traditional production of candles known as "twaf" (Gemechis Legesse, 2014). Studies conducted by IPS indicate that around 750 tons of beeswax are utilized for the production of "twaf," mainly serving the needs of approximately 25,000 Ethiopian Orthodox Churches. In addition more than 220 tons of wax is consumed by existing candle producing enterprises. The reliable data on the domestic production of beeswax are not available since it is produced at small-scale levels, mostly homemade (Gemechis Legesse, 2014).

In 2018, the value of Ethiopia's beeswax exports reached 3.48 million USD, marking a 19.54% increase from the previous year's total of 2.8 million USD. However, the annual growth value of Ethiopia's beeswax industry between 2017 and 2018 experienced a decline of 6%. The country sold 402 tons of beeswax in 2018, with a notable increase in demand for processed beeswax compared to the previous year, witnessing a 20.15% change. Over the period of 2015

to 2018, beeswax exports from Ethiopia decreased by 3.48%, generating 3.48 million USD in revenue for 2018 (https://www.selinawamucii.com/insights/prices/ethiopia/beeswax/). The top-performing markets for Ethiopia's beeswax in 2019, based on exports per kilogram, were Canada, the Netherlands, China, the US, and Germany. The export values for beeswax in Ethiopia were 2,798 thousand USD, 1,951 thousand USD, and 2,885 thousand USD in 2017, 2018, and 2019, respectively (https://www.selinawamucii.com/insights/prices/ethiopia/beeswax/). In 2022, the estimated average price for one ton of Ethiopia Beeswax in the international market is 8,849.69 USD (https://www.indexbox.io/store/world-beeswax-market-report-analysis-andforecast-to-2020/).

A study conducted by Nuru Adgaba & Eddosa Negara (1995) revealed that for every 100 kg of crude beeswax traditionally rendered, there is a loss of 33.1 kg of pure beeswax. Considering that the estimated annual production of crude beeswax in Ethiopia is around 3,000 tons, it is estimated that the country loses 9,900 quintals of beeswax annually, amounting to a value of 30 million Birr, due to the absence of efficient crude beeswax refining technology. In Ethiopia, the main causes of beeswax wastage are the consumption of honey in its crude form and the discarding of crude beeswax at each consumer's home or "tej" (a local honey wine) maker, alongside the lack of efficient crude beeswax extraction technologies. Furthermore, the existing beeswax processing methods in the country are limited and traditional, resulting in low efficiency. Due to a lack of awareness about the value and processing techniques of beeswax, a significant amount of crude beeswax is wasted in beekeepers' backyards and in "tej"-making houses (Gemechis Legesse, 2014). Lack of awareness, small production, market problems, lack of processing skills, lack of processing materials, According to Poku (2002), the major constraints for beeswax collection in the studied areas, ranked in order of importance, are lack of awareness, small production, market problems, lack of processing skills, lack of processing materials, lack of knowledge about the economic benefits of beeswax, and lack of interest. This lack of awareness and knowledge about beeswax and its potential economic benefits has led to a limited market and low production levels in Ethiopia.

The majority of exported and locally used beeswax in Ethiopia is processed manually in a traditional way, as highlighted by Nuru Adgaba & Eddosa Negara (1995). This traditional processing method is believed to contribute to the loss of beeswax mentioned earlier. The

inefficient beeswax extraction technologies currently available in Ethiopia are also considered a factor that contributes to the wastage of beeswax, particularly for small and medium-scale producers and processors (Gemechis Legesse, 2014). The lack of efficient processing technologies further hampers the efforts to maximize the utilization of beeswax and minimize waste in the country.

2.4. Beeswax Quality

Due to the huge amount of species of plants which provide honeybees both nectar and pollen, Ethiopia has a favorable environment for the production of high-quality bee hive products. Although there is a considerable market for these products, the farmers who keep bees and processors of honey and beeswax are less accustomed to meeting the requirements for quality needed in national or world markets, which results in low costs. Light wax (from new combs) is frequently significantly more valued than dark wax (from old combs), as beeswax is valued according to its purity, as well as its color. Beeswax can turn yellow whenever pollen, propolis, and contaminants are present. It is best utilized or sold as soon as possible because it will darken with time (Yeshitila Eshete & Tekeba Eshetie, 2018).

Wax that has just been produced is clear white, but after being utilized by bees, it rapidly turns pale yellow. If new honeycomb is simply used for preserving honey, it will maintain its nearly-white tint. The longer the comb is utilized for brood, the darker it becomes. The reason for this is because the larvae's cocoons spin inside the cell before to pupation. Additionally, some larval feces is sealed inside the cells (Bradbear, 2009). Beeswax is colored in varying degrees of yellow, orange, and red all the way to brown as a result of the presence of various materials, particularly pollen. Although the variation in hue has no impact on the wax's quality, light-colored wax is perceived as having higher value than dark-colored wax. Wax has a substantially lower value if it is dark because it has been overheated (Yeshitila Eshete & Tekeba Eshetie, 2018).

The Ethiopian government developed standards of quality for all beeswax produced, irrespective of the type of hives used; if managed properly, Ethiopian beeswax has been accepted as having the potential to be of excellent quality on a global scale. Sensory and physicochemical criteria are needed for quality standards. Beeswax with excellent quality

should have a yellow to yellowish brown color and a nice, honey-like aroma when heated. It should also cut easily and not adhere to teeth or the knife (Table 1).

Table 1.Quality Criteria for Beeswax

Parameters	Sensor Characteristics
Color	Yellow to Yellow brown
Odor	Pleasant & honey like when heated
Chewing test	Should not stick to teeth
Breakage test	Should have a fine granular, blunt, not crystalline structure
Cutting test	Should not stick to knife upon cutting
Consistency	Workable with fingers, should not stick to them
Splinters test	Scratch with nail(knife), splinter should have a spiral form

Source: Addisu Bihonegn, (2017)

After conducting thorough evaluations of the physical and chemical features of beeswax samples from various locations in Ethiopia, including farm gates, retailers of beeswax processors, and outlets of beeswax exporters, Ethiopia established its specifications for beeswax (Nuru Adgaba, 2007). These specifications were developed based on the testing protocols outlined by the American Beeswax Importers and Refiners Association INC, 1968, as described by Gemechis Legesse (2014).

The tests conducted on the beeswax samples focused on key physical and chemical characteristics that determine the quality of beeswax. These characteristics include melting point, saponification cloud point, acid value, ester value, and the ratio of ester to acid values.

The results of the tests indicated that the purified beeswax collected from various locations across Ethiopia met the international standards for quality (Gemechis Legesse, 2014). The melting point of the beeswax ranged from 61.0°C to 63.9°C, while the saponification cloud point varied from 57.9°C to 65.0°C. The ratio of ester to acid values was found to be between 4.2 and 4.0, with the acid value ranging from 18.0 to 32.7 and the ester value between 66.4 and 98.0 (Gemechis Legesse, 2014).

Table 2. Ethiopian Standard Specification for Beeswax

S/No.	Characteristics	Crude beeswax	Refined beeswax
1	Specific gravity at 20°C	0.9500-0.9800	0.9550-0.9800
2	Melting point (°C)	58-64	61-66
3	Ash, % by mass max.	0.60	0.20
4	Total volatile matter, % by mass, max.	1.0	0.75
5	Acid value, max.	17-24	17-24
6	Saponification value min.	80.0	85-105
7	Ester value	63-84	70-80

Source: QSAE, (2005)

2.5. Methods of Beeswax Rendering

Once beeswax products have been taken out of the hive, their quality cannot be significantly improved, but it can be compromised during various stages of harvesting, extraction, processing, and storage (Mutsaers et al., 2005). However, additional processing can improve the shelf life of the wax (Yeshitela Eshete, 2018).

If old combs are not treated before storage, particularly in tropical regions, they can be consumed by wax moths within a few weeks. Additionally, these old combs can harbor honeybee diseases and spread them from one colony to another. Too safely store or transport used combs, they should be broken down, cleaned, and solidified into a wax block (Bradbear, 2009). Before beeswax can be used, it needs to be rendered or melted to remove physical contaminants like propolis, moldy pollen, larval moults, and chalkbrood mummies. Beeswax for rendering can come from various sources, including old combs, sefef (a tej residue), and crude honey (broken comb or cappings). The best sources of beeswax are broken combs and cappings crude honey, although older honeycombs and brood combs may yield less wax due to being impaired by propolis. Dark combs that are removed from hives due to their age are the least useful and potentially produce the least beeswax (Yeshitela Eshete, 2018). The cappings removed during honey extraction, which result in high-quality, light-colored wax, can also be

used as a source of raw beeswax for rendering. Light colored broken combs provide the next quality of wax, whereas old black brood combs yield the smallest proportion and lowest quality of wax (Suparyanto & Rosad, 2020).

To extract wax from combs Methods that employ only heat involve melting the combs using steam, boiling water, or the heat of the sun. The heat causes the wax to melt and separate from impurities due to its lighter specific gravity (Yeshitela Eshete, 2018). Methods that employ both water and heat often involve boiling the combs in water to facilitate the separation of wax from impurities. The water helps to remove impurities such as propolis and moldy pollen, allowing the wax to float to the surface for collection (Yeshitela Eshete, 2018). Methods that employ presses and hot water typically involve using mechanical presses to extract wax from the combs. The combs are first melted in hot water, and then the hot mixture is pressed to separate the wax from the remaining impurities (Yeshitela Eshete, 2018).

These different rendering methods provide various options for separating wax from impurities, and beekeepers can choose the most suitable method based on their resources and preferences.

2.5.1. Those employing only heat

2.5.1.1. Solar beeswax extractor

Beeswax The solar wax extractor is indeed an effective and eco-friendly method for melting and purifying beeswax. It utilizes the heat of the sun to melt the wax, providing a clean and high-quality final product. The solar wax extractor can be easily made at home, typically consisting of a double-glazed glass lidded insulated timber box. Inside the box, there is a metal tray that holds the combs and can be tilted to maximize exposure to the sun's rays. The heat from the sun melts the wax, which then drips into a detachable container for collection (Gimlet, 2014).

One advantage of the solar wax extractor is that it has minimal operating costs since it relies solely on the sun's heat. However, it should be noted that the solar extractor may only extract around 20 to 50% of the wax present in the combs (Gimlet, 2014). Overall, the solar wax extractor provides an easy, efficient, and environmentally-friendly method for separating impurities from beeswax and producing high-quality wax blocks.

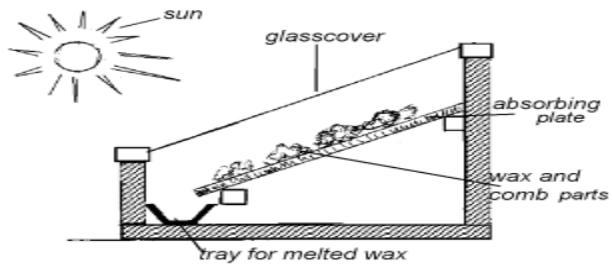


Figure 1. Solar Wax Melter (Mutsaers et al., 2005)

The solar wax separator consists of a rectangular box equipped with a heat-absorbing metal sheet positioned inside. On top, there is a lid made of either glass or transparent plastic, allowing for observation. As the honeycomb pieces are melted, the wax droplets are directed down the metal slope into a container. To guide the wax towards the container, the metal sheet is cleverly bent at the corners. A wire mesh screen prevents any trash or comb fragments from falling into the container, ensuring the purity of the collected wax.

Although a few imperfections may cling to the final block of hardened wax, the majority adheres to the metal sheet. The temperature within the solar wax separator can reach 68 to 70°C, effectively melting the components of the honeycomb. Gradually, the melted wax seeps into the container, which is only partially filled with water. The size of the extractor depends on the dimensions of the container used in its construction. A larger container allows for higher internal temperatures to be achieved (Cowan, 2015).

It is important to note that only fresh combs or cappings can be melted using this innovative technology. Old combs, which harbor multiple generations of cocoons from brood-raising activities, yield minimal, if any, wax separation when processed with a solar-powered extractor. However, the extractor proves to be highly effective in clarifying previously rendered wax cakes, obtained through alternative methods. It easily handles various forms of wax, including burr and bridge combs, cappings, broken new combs, and even serves as a convenient tool for manipulating cut-out comb sections amidst bees (Cowan, 2015).

When left to run its course, this extraction procedure effortlessly melts the wax for the beekeeper. It stands out as one of the finest methods due to the partial bleaching process that occurs, as a thin film of melted wax gracefully flows into the receiving pan. Furthermore, this

method eliminates any concerns regarding chemical contamination or color deterioration caused by excessive heating. The outcome is pure, high-quality wax, free from impurities and unsightly blemishes (Suparyanto & Rosad, 2020).

Due to the longer melting time and lower recovery rate (50–75%), this approach is not employed for old or combs used for brood rearing. This is particularly true for older combs as the buildup of cocoon debris from earlier brood serves as a sponge, absorbing the wax and limiting the flow. (Chhuneja & Bhowmick, 2018). The solar extractor, however, can only be used in bright conditions. Other downsides include the necessity of frequently tilting the pan toward the sun and the lack of yield in cloudy or low-light situations (Chhuneja & Bhowmick, 2018).

Figure 2. Solar Melter (SANFORD & DIETZ, 1976)

2.5.2. Those employing both water and heat

2.5.2.1. Manual extraction method (simple extraction method)

To effectively eliminate any impurities such as honey, sheath, or liquid-soluble substances, the raw beeswax obtained from different sources underwent a specific process. Firstly, the beeswax was individually placed in clean water and left to soak for a period of 24 hours in a plastic basin or bucket. This soaking process was repeated twice to ensure thorough dissolution of impurities. After the soaking period, the wax was strained to remove any solid impurities that may have settled. Subsequently, the wax was melted by immersing it in an adequate amount of hot water. Once the wax was completely liquefied, it was poured into sisal, a type of fabric, for extraction.

The sisal cloth containing the melted wax was then manually squeezed by twisting and pinching it, while also gradually sliding it between two horizontally positioned sticks. This squeezing process allowed for complete removal of the wax from the cloth. Once the wax had ceased flowing through the cloth, the water-wax mixture was left to cool. After the mixture had cooled down, the wax solidified into a block, which was then extracted and its quality, color, and quantity were carefully measured. The remaining byproduct, known as slum gum, which consists of extracted and dried impurities, was weighed and recorded (Meseret Gemeda & Deressa Kebebe, 2019).

Figure 3. Traditional Squeezing Method (Meseret Gemeda & Deressa Kebebe, 2019)

2.5.2.2. Submerged Beeswax Extraction Method

To facilitate the dissolving of any residual honey, the beeswax sourced from different origins underwent a specific procedure. First, it was placed in separate plastic buckets filled with clean water and left to soak for a duration of 24 hours. Afterward, the wax was meticulously cleansed and wrapped in fresh fabric sacks known as abujedi. These sacks were tightly tied, and the wax-filled bags were immersed in clean water twice the capacity of the sacks.

Next, the setup was heated to temperatures ranging from 70 to 80°C, ensuring the complete melting of the wax. A stirring stick was employed to agitate the bag, causing the melted wax to rise to the surface. Once the wax had reached the top, it was carefully poured out of the boiler. To extract every bit of wax from the cloth, two sticks were utilized to squeeze the material after passing the heated water and wax mixture through either a strainer or a clean cloth.

Subsequently, the water and wax mixture were allowed to cool, enabling the formation of wax cakes. These cakes were then extracted from the mixture, and comprehensive data regarding the extraction process were diligently recorded (Meseret Gemeda & Deressa Kebebe, 2019).

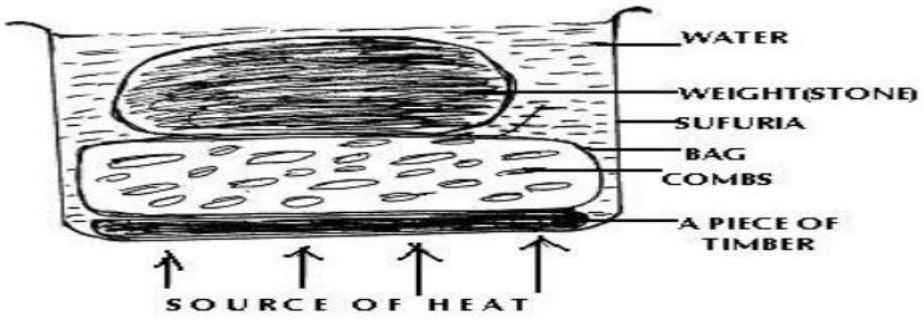


Figure 4. Immersion or Sisal Sack Press Method (SANFORD & DIETZ, 1976)

2.5.2.3. Steam Beeswax Press Extractor

A steam wax extractor operates similarly to a vegetable steamer, with separate chambers for the wax and water. The water is heated to produce steam, which is then forced up into the chamber containing the wax, melting it. The melted wax is expelled through a vent into a container, while any impurities or rubbish are collected in a basket. This method is effective for processing large quantities of comb and yields pure, aesthetically pleasing wax that is ideal for capping or making new combs. However, it typically only yields around 80% of the wax and may not be the best approach for melting down old combs.

Old comb presents challenges because the wax is still constrained and difficult to remove due to the presence of multiple layers of cocoons from brood-rearing cells. Simply melting old combs in hot water or steam can cause the cocoons to become soaked with wax, resulting in significant waste. Constructing a steam wax extractor locally can be challenging, unlike a wax melter that can be made using hot water and the sun.

When using steam extraction, it is crucial to avoid exposing the wax to live steam. This can lead to partial saponification of the wax, causing minerals like calcium to react with the wax and produce a soap-like material, which reduces the quality of the beeswax. Care must be taken to prevent this. Overall, steam extraction is a viable method for obtaining pure wax, especially for

capping or new comb production, but careful attention is needed to ensure high-quality beeswax (Mutsaers et al., 2005; Yeshitela Eshete, 2018; Moderator, 2016).

In addition, using steam extraction for old combs requires extra caution due to the presence of multiple layers of cocoons in the brood-rearing cells. If the old comb is melted in hot water or steam, the cocoons will become soaked with wax, resulting in significant loss (Moderator, 2016). Therefore, while steam extraction is effective for capping and producing pure, high-quality wax, it may not be the ideal method for melting down old combs.

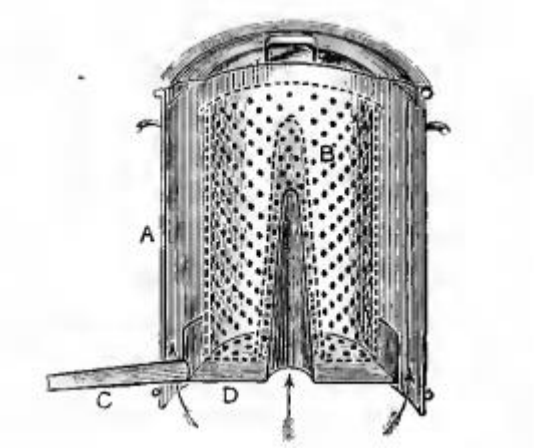


Figure 5. Steam Wax Extractor (Cowan, 2015)

2.5.3. Those employing presses and hot water

2.5.3.1. Hot water beeswax-press extractor

When According to the information provided, using a hot water beeswax-press extractor is an effective method for extracting wax from combs. This method involves melting and pressing the residue multiple times (Mutsaers et al., 2005), as the leftover material still contains 30% beeswax after the initial melting process. The wax press, which applies pressure combined with heat, is considered the most effective wax extractor, with only 1-3% of wax remaining in the waste. Professional beekeepers commonly employ this method due to its efficiency (Moderator, 2016).

Wax presses can be categorized into two types: heated presses, which apply heat during the pressing process, and unheated presses, which do not. The most commonly used rendering

media for wax presses are steam and hot water. Hot water beeswax-press extractors can be manufactured in two variations: one where combs are subjected to intense pressure in hot water, and the other using steam. It is important to note that the information provided is based on studies, testing, and observations from beekeepers, suggesting that the wax press is the most effective wax extractor. Different approaches and equipment may yield varying levels of effectiveness, and individual circumstances may also play a role (Cowan, 2015).

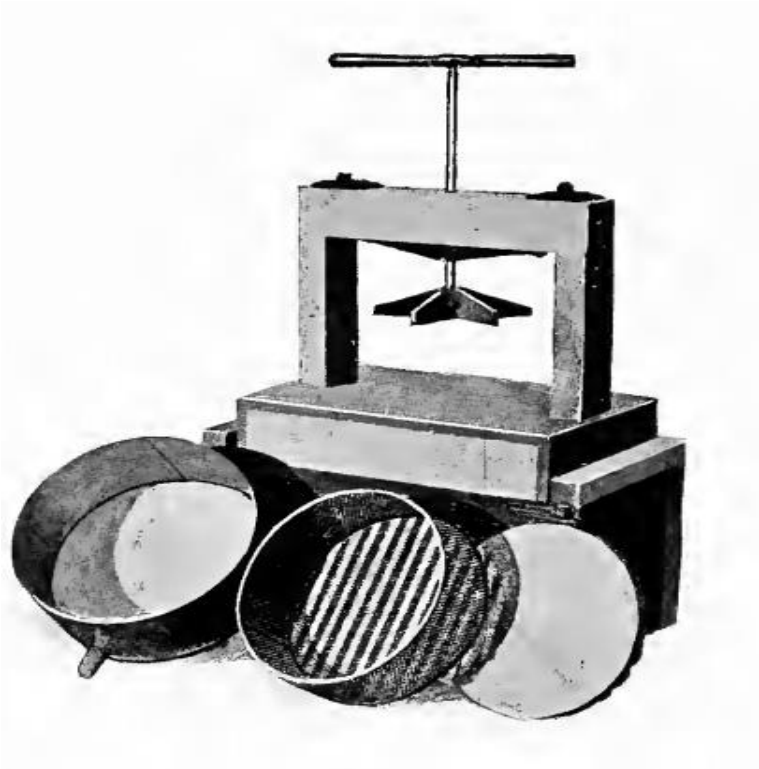


Figure 6. Beeswax Press (Cowan, 2015)

After the initial filtration and collection process, some wax may still be present in the scales or cocoons of the bees that remain. This is especially noticeable with used combs. To remove as much wax as possible from these scales, a wax press is employed. The process involves wrapping pieces of an old comb's wax scale in a cloth bag. These bags are then placed in a large pot with boiling water, which is filled to approximately one-third of its capacity. As the wax melts, it is forced through the bags and floats on top of the water. Pressure is applied by rotating the screw of the wax press.

When dealing with multiple used combs, the wax press proves to be effective. However, the color of the wax obtained from such presses may not be optimal due to the continued high

temperature. It tends to be darker in color. This issue can be overcome by introducing hot water frequently during the process. By doing so, the wax can be run off at short intervals, and the color of the wax is not compromised. It is important to note that the information provided here is based on the insights shared by Cowan in 2015. Different beekeepers may have their own variations in the wax press process, and individual circumstances can also affect the outcome (Cowan, 2015).

2.5.3.2. Steam Beeswax Press Extractor

A steam beeswax press extractor is a machine used to extract beeswax from the honeycomb using steam. This method is commonly used by beekeepers to efficiently separate beeswax from the honeycomb and other impurities. The extractor consists of a large steaming chamber, typically made of stainless steel, and a press mechanism. The process begins by placing the honeycombs or wax scales inside the steaming chamber. Steam is then introduced into the chamber, which helps to soften the wax and facilitate its removal.

Once the wax has melted and become more malleable, pressure is applied to extract the wax. This can be done using a manual press mechanism that compresses the softened wax against a fine filter or mesh, allowing the molten wax to flow through while capturing any impurities or debris. The extracted wax is collected in a container or tray positioned below the press. It can later be refined or further processed to remove any remaining impurities, resulting in pure beeswax. The steam beeswax press extractor is known for its efficiency in obtaining large quantities of beeswax from honeycombs or wax scales, making it a popular tool among beekeepers and commercial wax producers.

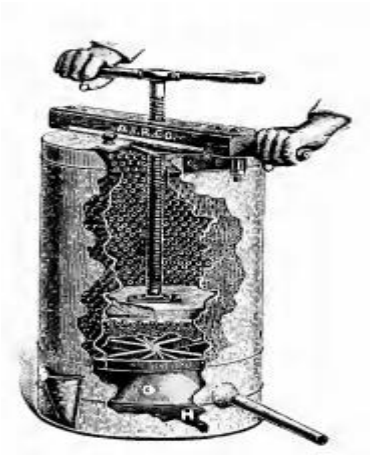


Figure 7. Steam Beeswax Press (Cowan, 2015)

2.5.3.3. Unheated Press Beeswax Extractor

With An unheated press beeswax extractor is a device used to extract beeswax from honeycomb without applying heat. These extractors typically consist of a cylinder or container with perforations to allow the wax to escape, and a mechanism to apply pressure and squeeze out the wax. The process with an unheated press typically involves placing the combs soaked in water inside the press. Pressure is gradually applied, using a handle or screw mechanism, to compress the combs and release the beeswax. The wax is then collected as it is forced out through the perforations (Cowan, 2015)**.** .

The advantage of using an unheated press is that it preserves the natural characteristics of the beeswax. Since no heat is applied, the wax retains its original color, scent, and other qualities. This can be desirable for those who value the natural properties of beeswax for various purposes, such as candle making, cosmetics, or furniture polish. However, it's important to note that unheated press extractors may not be as efficient as steam or heat-based methods, as the wax may not flow as rapidly. The pressure and time required for extraction may be higher compared to heated methods. Additionally, unheated extraction may not fully remove impurities or residual honey from the beeswax (Cowan, 2015)**.**

Ultimately, the choice between a heated or unheated press extractor depends on individual preferences, the desired quality of the wax, and the specific applications for which the beeswax will be used. Each method has its benefits and drawbacks, so beekeepers should consider these factors when selecting an extractor (Cowan, 2015)**.**

2.6. Some of the Works Done on Screw Press Extractor

It appears that the provided information discusses the principles and types of presses used in oil extraction processes. These presses are specifically designed for batch production, where small quantities of material are continuously processed (Poku, 2002). In batch operations, the material to be processed is placed into a cage made of heavy metal. A metal piston is then used to press the material, extracting the oil. The pressure is generated by the action of the piston, forcing the oil out through holes in the cage. Layer plates may be employed to ensure consistent pressure distribution throughout the materials (Bhargavi et al., 2018).

Various types of presses have been developed over the years for this purpose. These include manual vertical screw presses, motor jack presses, spindle presses, hydraulic presses, and combination screw and hydraulic presses. Among these, the screw press principle is considered more reliable, efficient, and adaptable for small and medium-sized producers compared to hydraulic presses. Hydraulic presses are more expensive, require more maintenance and labor, and there is a risk of oil contamination due to the presence of potentially toxic hydraulic fluid (Aremu & Ogunlade, 2013; Olaniyan & Aremu, 2012; Moses, 2014; Olaniyan et al., 2012; Kiggundu & Jjagwe, 2021).

Figure 8. Presses: (a) spindle press, (b) hydraulic press (Kiggundu & Jjagwe, 2021)

In batch press designs, the mechanism used to move the piston and apply pressure varies. It can be powered by a motor or operated manually by a human being (Poku, 2002). Screw presses, specifically, can be powered by electric motors, diesel engines, or even photovoltaic cells (Pighinelli & Gambetta, 2012). Researchers have discussed the benefits of utilizing an electric motor-driven oil press over a manual-driven one. These advantages include high processing speed, high oil press output, easy operation, and time savings (Mekonnen Addisalem, 2013).

However, it is worth noting that existing extractors are often laborious and complex in terms of maintenance and operation. Additionally, issues such as epileptic power supply and the high purchase cost of foreign-made machines can limit the usability of motorized extractors, particularly for local or small-scale processors (Odewole et al., 2018). Several studies support the conclusion that the adoption of different technologies in oil extraction should consider factors such as the availability of equipment and spare parts, the complexity of the equipment, maintenance requirements, and the need for a reliable power supply (Sheikh & Kazi, 2016).

It is emphasized that for an extraction method to be successful, it should offer both financial and environmental benefits (Pighinelli & Gambetta, 2012). According to Alam et al. (2020), for the continuous and sustainable production of oil from agricultural oil-bearing materials, it is essential to make the oil extraction process affordable and easily accessible for local farmers or oil producers. In developing countries with unreliable power supply, it is crucial for food production machines to be capable of working either manually or with electricity, or solely manually without relying on electricity.

Sabelli & Wilson (2004) mentioned that lever and screw presses are the most commonly used equipment for farmers to produce oil. In remote areas where industrial oil extraction machines are not available, production is often carried out entirely by hand due to limited access to electricity. Considering these factors, it becomes clear that the design and development of oil extraction technologies should prioritize affordability, ease of use, and the ability to operate with or without electricity in order to support local farmers and oil producers. Manual extractors are basic mechanical equipment that can be used by an individual or an animal. These devices operate without the use of fuel or electrical power owing to the mechanical compression

principle. The size of the press cage and the energy required by the operator to turn the press screw play significant roles in determining the processing capacity of the oil press. Additionally, the operator's ability to apply consistent and continuous pressure to the lever is a crucial factor in the speed at which the press operates. Increasing the length of the handle can enhance the pressure applied to the material, thereby improving the efficiency of the press. In terms of construction, lever and screw presses are typically made using inexpensive components that can often be produced locally. This makes them more accessible and affordable for farmers and oil producers. Raji et al. (2019) and Sheikh & Kazi (2016) have emphasized the utilization of cost-effective and locally available materials in the construction of oil presses. By considering these factors, such as the size of the press cage, energy requirements, lever pressure, and the use of inexpensive components, the design and implementation of oil extraction machines can be optimized to meet the needs of local farmers and oil producers.

According to Ibrahim & Onwualu (2005), the construction of oil presses mainly requires a specialized lathe for the production of the screw. It is recommended to use a nut made of softer metal in order to reduce wear and tear, as replacing or repairing the screw can be costly. However, apart from the screw, oil presses can be produced locally in rural areas.

In recent years, there have been numerous attempts to develop mechanical presses for extracting juice from fruits, tubers, and grains. Designers have focused on improving these machines, leading to various modifications and advancements (Raji et al., 2019). The primary goal of most of these designs is to optimize the cost of processing and equipment maintenance. Therefore, there is a strong emphasis on using local materials to make the equipment more affordable and accessible (Sheikh & Kazi, 2016). The convergence of these efforts has encouraged the development of oil presses that are suitable for local production and usage. By utilizing cost-effective materials and optimizing the design to reduce maintenance costs, these machines can be made more practical and sustainable for farmers and oil producers in rural areas.

Alam et al. (2020) developed a manually operated palm oil extraction machine in Bangladesh. The machine was constructed using mild steel, making it affordable for farmers with a cost of only BDT 10,000. Its working principle is simple and easy to handle, making it suitable for farmers who do not have access to electricity in their locality. One advantage of this machine is

its portability, as it weighs only 18.5 kg. This allows owners to easily transport it and set it up on their farm wherever needed. In terms of extraction efficiency, the machine achieved 19%, which is close to the average percentage reported in the literature. Increasing the applied force in the handle will also increase the compressive force during extraction (Alam et al., 2020). Overall, the palm oil extraction machine developed by Alam et al. (2020) offers a cost-effective and practical solution for farmers without access to electricity. Its simplicity, affordability, and portable design make it a suitable option for palm oil extraction in rural areas.

Figure 9. Manually Operated Palm Oil Extractor

Oluwole et al. (2007) developed and tested a spindle press that operates based on the power screw principle. The press consists of various components, including a tool frame, a power transmission unit, a lever arm, press plates, and a perforated cylindrical cage. The cage has 3 mm-diameter perforations distributed all over its surface. In their experiments, Oluwole et al. (2007) compared the results of the spindle press to those obtained using the conventional approach. The conventional method involved using a three kilogram (3 kg) feed of oil-bearing material in a nylon fabric bag as filter material.

The testing revealed that the spindle press achieved a maximum oil recovery rate of 78.1%. Additionally, the residue produced by the press was of the same grade as the residue obtained

using the conventional approach. This suggests that the spindle press was efficient in extracting oil from the oil-bearing material. Furthermore, the use of the nylon fabric bag as a filter prevented particles of groundnut paste from clogging the perforations on the cylindrical cage. This eliminated the need for rigorous cleaning of the machine after each use. Another advantage of the spindle press was the reduced extraction time. Compared to the conventional method, the oil extraction time was reduced by approximately 50%. This indicates that the spindle press was not only effective in terms of oil recovery but also improved the efficiency of the extraction process. In conclusion, the spindle press developed by Oluwole et al. (2007) demonstrated high oil recovery rates, produced residue of the same grade as the conventional method, reduced the extraction time, and eliminated the need for extensive cleaning. This highlights its potential as an improved method for palm oil extraction.

Figure 10. Power Screw Type Spindle Oil Press **(**Oluwole et al., 2007)

A study conducted by Oluwole et al. (2007) discovered that there is a need for a manually operated mechanical oil extraction mechanism in order to increase both the quantity and quality of oil output without compromising the nutritional content of the crude cake. This would be especially beneficial to the rural population as it would alleviate the challenges associated with traditional methods. Itanye (2001), who developed and evaluated a spindle oil press, also supports this idea. His tests revealed that approximately 48% of the oil could be extracted using this method, however, the quality of the resulting cake was inferior compared to the conventional approach. The main drawback of modern equipment is that it tends to extract

almost all the oil, thereby significantly reducing the nutritional value of the cake. Consequently, the economic value of the cake is diminished as it can only serve as animal feed (Oluwole et al., 2007).

Mekonnen Addisalem (2013) conducted a study that focused on evaluating the performance of oil presses based on their efficiency in oil expression and energy utilization. The efficiency of oil expression was measured by calculating the ratio of the quantity of extracted oil to the amount of oil present in the sample. The results indicated that various types of presses exhibited different levels of efficiency. Spindle presses were found to have an extraction efficiency ranging from 60 to 70%, hydraulic presses showed efficiencies between 80 to 87%, and Caltech screw presses demonstrated extraction efficiencies of 75 to 80% (Poku, 2002).

According to Mpagalile et al. (2007), several factors have been identified as crucial parameters in oil extraction processes. These include the moisture content of the feed materials, temperature, pressing time, and the particle size. These factors have a significant impact on the efficiency and effectiveness of oil extraction. Furthermore, Head & NRI (1995) noted that the inner diameter of the container or cage in a spindle press is an important determinant of the pressure generated during the extraction process. By reducing the diameter of the cage and pressure plate, higher pressures can be generated. This leads to increased oil output. However, a smaller cage diameter also results in a decrease in the amount of loading per batch. Tacoronte (2010) and Bhargavi et al. (2018) also found similar results, highlighting the importance of factors such as cage diameter in achieving higher oil output during oil extraction processes.

Head & NRI (1995) conducted a study to determine the maximum operating pressures associated with different types of oil presses. They found that the hand bridge press had a maximum operating pressure of 35 kg/cm², the small hydraulic press had a maximum operating pressure of 125 kg/cm², and the ram press had a maximum operating pressure of 190 kg/cm². These pressure levels are indicative of the efficiency of oil extraction achieved with each type of equipment. Interestingly, at low pressures, the addition of water during the extraction process has been found to enhance the effectiveness of oil extraction. This suggests that water can improve the efficiency of oil extraction, particularly when operating at lower pressures.

Furthermore, mechanical screw presses have been shown to recover approximately 86-92% of oil from oil-bearing products. This high recovery rate can be further improved through proper preparation of the oil-bearing goods. Measures such as cleaning, conditioning, decorticating, cracking, flaking, frying, extruding, and drying the materials to achieve the ideal moisture content can enhance oil recovery during the extraction process (Khadija, 2016).

In a study conducted by Tacoronte (2010), the relationship between extraction yield and operational pressure was investigated. For the smaller container, oil expression began at around 2kN, which is equivalent to 2.5 MPa of pressure. At approximately 12kN, or 15.1 MPa, the oil-containing products reached incompressibility. In the larger container, oil expression started at 15kN, or 6.6 MPa of pressure, and incompressibility was achieved at 100kN, or 44.1 MPa. The analysis revealed that the highest oil expression occurred within the pressure range of 3 to 7 MPa. The maximum yield obtained was around 27%.

These findings demonstrate that even at relatively low pressures, around 3 MPa, adjusting processing parameters during oil extraction can lead to acceptable extraction efficiency. Slower pressing speeds were found to promote greater oil expression by maintaining higher kernel pressure and allowing for better escape of crude oil from the cylinder. However, excessive speed resulted in increased pore pressure and diminished oil expression as the oil remained in the kernels for longer. Hence, it is important to apply pressure gradually and for a sustained period to efficiently extract oil.

Moreover, there is a risk of oil reabsorption by the cake if pressure is immediately released after compressing the oilseed material. Thus, the application of pressure should be done gradually to achieve optimal oil output. These findings are consistent with previous studies by Bako et al. (2017) and Head & NRI (1995), which highlight the importance of gradual pressure application and the influence of processing parameters on oil extraction efficiency.

According to a study conducted by Chowdhury & Mahmud (2020), the effectiveness of oil extraction improves with higher heating temperatures. It is common practice to subject materials containing oil to thermal treatment before or during pressing to enhance oil extraction. Heating or cooking the materials has several positive effects on oil yield. Firstly, the oil cells are broken down, allowing for easier oil extraction. Additionally, the protein in the material coagulates, the

moisture content is adjusted to an ideal level for pressing, and the viscosity of the oil is reduced, enabling better flow during extraction. Khadija (2016) supports this perspective by stating that the yield of oil-containing products in the "wet" method is significantly reduced when cold washing water is used. This suggests that temperature plays a crucial role in oil extraction efficiency, and heating the material prior to or during the extraction process can lead to higher oil yields.

Mpagalile et al. (2007) identified three major phases in the profile of oil extraction effectiveness. In the initial stage, which lasted around 2 minutes, very little oil expressiveness was observed as the oil-bearing material composite was compressed until the oil point was reached and oil started flowing out. Squeezing oil from the material took a longer time during this stage.

The second stage, occurring between two and eight minutes after pressing, showed a sudden increase in oil expression. This was due to the pressure exerted on the oil-bearing material matrix, causing the oil to be forced out. At this stage, almost all of the oil was extracted. This could be because there was still sufficient oil in the material and the channels for oil flow were still open since the matrix was not completely crushed.

In the final 8-12 minutes of pressing, a slight increase in oil extraction was observed. However, the material composition seemed to undergo compression, leading to the closure of oil escape pathways. Additionally, the lower natural oil content of the material required more pressure to extract further oil. This indicates that more compression was needed to achieve an oil point and explains the apparent saturation point in the dewatering of silage, as suggested by Sukumaran & Singh (1989) and Faborode & Favier (1996). Overall, the oil extraction process involves distinct phases and understanding the behavior of the material under compression is crucial for optimizing oil extraction effectiveness.

In their study, Raji et al. (2019) assessed the performance of an extractor by varying the load values applied, ranging from 1.5 kg to 5 kg. They aimed to determine the quantity of output obtained per kilogram of the material and evaluate the extractor's performance below and above the recommended load capacity. The researchers observed that, initially, as the input weight increased up to approximately 2.5 kg, the amount of material obtained from the sample also increased. However, as the input weight continued to increase, the amount of output per unit of

input weight decreased. This suggests that there is an optimal range for the input weight to achieve efficient processing.

According to the results, even though the extractor is designed to process 3 kg of feed, it is recommended that the maximum amount of nuts processed efficiently with this equipment should be within the range of 3 kg. This implies that operating the extractor with loads higher than 3 kg might result in decreased efficiency and lower output per unit of input. Based on their findings, the researchers concluded that the extractor is suitable for small-scale use. This implies that it may not be suitable for large-scale operations or processing high volumes of material efficiently.

The study conducted by Adeeko & Ajibola (1990) found that the oil yield did not significantly change as the pressing process progressed. However, they also observed that the oilseed cake hardened and the quantity of oil decreased over time. This means that as the pressing process continued, it became more difficult to extract oil from the cake. As a result, extracting more oil from the oilseed cake required a significant amount of additional energy. This finding aligns with the research conducted by Mpagalile et al. (2007), who also concluded that the oil expression process becomes self-defeating over time.

According to Poku (2002), varied designs of the cylinder's apertures allow one to analyze the manner in which the oil escapes as the oil-bearing components are being compressed. The more space there is, the farther the oil has to travel in order to escape, and the greater the chance that some of it will become stuck in the solid. Oil output would increase if new routes for oil to travel were created. Additionally, there is an appropriate ratio among the height and size for the squeezing mechanism's highest capacity, which will provide the best yield per press. The oil outputs increase with area size but decrease with pressure, therefore the frame needs to be more robust. Oil will become stuck in the core if the material thickness is too high.

In a study by Kole (2022), it was found that placing the honeycomb on top of the extractor resulted in an increased quantity of beeswax that could be extracted. Specifically, when 1 kg and 5 kg of honeycomb were used, 190g and 980g of beeswax were extracted, respectively. Additionally, when the honey extractor was filled with 3 kg of honeycomb and exposed to the sun for four days (seven hours per day), the study found that the optimum yield of 25.01% was

achieved. However, when 2 kg of honeycomb was introduced, the yield reduced to a minimum of 13.01%. These findings suggest that the method used for extracting beeswax from honeycomb can have a significant impact on the yield obtained. Placing the honeycomb atop the extractor and exposing it to the sun for a specific duration can enhance the extraction of beeswax.

Eshete et al., (2018) recently reported that the proportion of pure wax produced from 5 kg unrefined beeswax using the manual method of extraction ranged from 30 to 37% with an average of 33.5%, however this percentage varied from 12 to 32% with an average of 22% while employing the mechanical extraction technique. According to a study by Yeshitela Eshete (2018), the differences in wax output between manual and mechanical methods can be attributed to several factors. These include the presence of leftovers and foreign materials, the management of raw beeswax, the extraction process, and the effectiveness of the device used. The traditional unrefined wax extraction approach, while time-consuming and labor-intensive, was found to be superior in terms of the quantity of pure wax obtained. This means that the manual method resulted in a higher yield of pure wax compared to the mechanical method.

On the other hand, the mechanical wax extraction process was found to be more efficient in terms of time and labor requirements. This suggests that the mechanical method can save time and reduce the amount of labor needed compared to the manual method. Overall, the choice between the manual and mechanical methods for wax extraction depends on the specific needs and priorities of the beekeeper. The manual method may be preferred when maximizing the quantity of pure wax is a priority, while the mechanical method may be more suitable in situations where time and labor efficiency are of greater importance (Yeshitela Eshete, 2018).

According to Aremu and Clement (2016), mechanically produced oils often have an opaque appearance due to the presence of small solid particles that are created during the pressure application process. These particles solidify and remain suspended in the extracted oil, resulting in a hazy or slurry-like appearance. To obtain clear liquids that can be packaged and used for residential and industrial purposes, the mechanically produced oils need to undergo a filtration process. Filtration helps remove the suspended solid particles, resulting in a clear and transparent oil. The filtration process is an essential step in refining mechanically produced oils.

It helps improve the appearance of the oil, making it suitable for various applications. By eliminating the solid particles, the oil becomes visually appealing and can be easily packaged and used in different industries, including the food, cosmetic, and pharmaceutical sectors.

Aremu and Clement (2016) developed a portable multi-purpose extractor for extracting juice from various tropical fruits like pineapple, orange, and watermelon. The device was tested and evaluated using established evaluation methods. The tests involved three trial runs, each with both peeled and unpeeled fruits, using different sieve opening diameters (0.5mm, 1mm, 1.5mm, and 2mm).

The results showed that with a 2mm sieve opening diameter, the highest juice output and extraction efficiency were achieved. This means that the portable extractor was most effective in extracting juice when using a 2mm sieve. The sieve diameter had a significant impact on the machine's juice yield, extraction efficiency, and extraction loss. These variables were affected by the size of the sieve openings, with a larger diameter resulting in higher juice yield and extraction efficiency.

This study highlights the importance of selecting the appropriate sieve opening diameter when using the portable multi-purpose extractor. By choosing the right sieve size, the machine can optimize juice extraction and minimize extraction loss. The findings of this evaluation can inform the design and use of similar portable extractors for fruit juice production.

In a study conducted by Oluwole et al. (2007), a portable multifunctional extractor was developed. The researchers found that using nylon fabric as a filter helped prevent groundnut paste particulates from blocking the openings on the cylinder-shaped cage of the extractor. During the first trial, the oil recovery rate was relatively low, at 57.8%. This could be attributed to the filter absorbing and retaining some of the expressed oil, reducing the overall oil recovery. However, as the trials progressed, the oil recovery rate steadily increased. In the subsequent trials, the oil recovery reached a maximum of 78.1% and 66%, respectively.

This increase in oil recovery rate could be explained by the saturation of the filter. When the filter becomes saturated, it is no longer able to absorb and hold any more of the expressed oil. As a result, more oil is able to pass through the filter and be collected, leading to higher oil

recovery rates. These findings suggest that the performance of the portable multifunctional extractor can be optimized by considering the saturation level of the filter. By using a filter that can effectively prevent particulates from obstructing the extraction process without absorbing a significant amount of oil, the overall oil recovery rate can be improved. The study provides valuable insights for the design and use of similar portable extractors for oil extraction purposes.

CHAPTER THREE

3. MATERIAL AND METHODS

3.1. Study Site Description

The beeswax presser was modified and produced at the Holeta Bee Research Center. The performance evaluation was conducted in the research center. The center lies 3 km east of Holeta town and 37 km west of Addis Ababa, the nation's capital. It is located at an altitude of 2400 meters above sea level, at 9°00'N and 38°30'E in the longitude and latitude, respectively. The area receives 1144 mm of rain on average per year. The average high and low temperatures at the location are 22°C and 6°C, respectively. The area's predominant soil types are nitosols and vertisols. The average annual rainfall is 763 mm, 70% of which occurs from June to September, the main planting season. Sandy loam is among the most common type soil found in the region. The majority of highland crop varieties flourish in the region due to its favorable agro-climate.

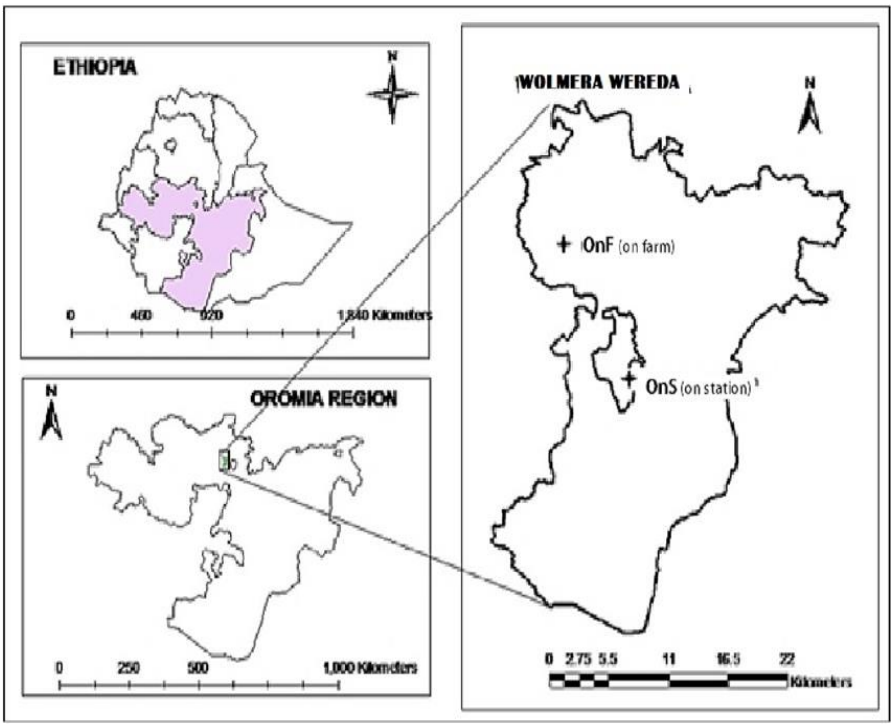


Figure 11. Study Area Map

3.2. Materials

Table 3. List of Materials Used

No	Part Name	Dimensions	Material used
1	Top Press plate(piston)	20mm	Aluminum plate
2	Perforated Cylinder	150 x180 x360	Aluminum sheet
3	Oil collector or outer cylinder	Gauge 18 (1000mmx2000mm)	Aluminum sheet
4	Spindle or threaded screw	Ø20mm, 400mm	Aluminum rod
5	Bottom Press	40mm	Aluminum plate
6	Top frame	8mm	Mild Steel plate
7	Vertical frame	Ø200mm, 400mm	Aluminum rod
8	Stand	8mm	Mild steel rod
9	Collar	M12	Mild Steel
10	Nut	M8	Mild Steel
11	Nylon Cloth	$3m^2$	Nylon Cloth
12	Oil Outlet	¾ Ø pipe	Aluminum pipe
13	Thermometer	1 Pcs	Thermometer
14	Electrode	12 Gauge	12 Gauge
15	Lever Arm	Ø5x300mm	Galvanize pipe

3.3. Modification of the Manually Operated Screw Press Beeswax Extractor

The modification of the manually operated screw press beeswax extractor involved the following steps:

1. Selection of workshop: The Holeta Bee Research Center workshop was chosen as the location for the modification and construction of the extractor. This workshop likely had the necessary tools and equipment for the modification process.
2. Evaluation of performance: The laboratory facilities at the research center were utilized to assess the performance of the existing extractor and identify areas for improvement or modification.

3. AutoCAD drawings: Using AutoCAD 2018, detailed drawings were created for the modified extractor. These included part drawings, assembly drawings, and manufacturing drawings, which provided the necessary specifications for building the modified prototype.
4. Construction of the prototype: Based on the modification design and drawings, the researchers or technicians at the research center proceeded to build the modified beeswax presser prototype. This likely involved fabricating and assembling the necessary parts and components.
5. Adherence to modification: The construction of the prototype was done in accordance with the modification plans and specifications outlined in the AutoCAD drawings. This ensured that the modifications were properly implemented and integrated into the extractor design.

Overall, the modification process of the manually operated screw press beeswax extractor involved using the research center's workshop, evaluating the performance of the existing extractor, creating detailed design drawings on AutoCAD, and constructing the modified prototype based on these drawings. This process likely aimed to enhance the efficiency, effectiveness, or functionality of the extractor in extracting beeswax.

3.3.1. Design considerations

During the modification of the manual screw press beeswax extractor, several design considerations were taken into account. These considerations aimed to ensure that the modified presser would meet the required operating pressure, temperature restrictions, and other desirable characteristics. The following design considerations were considered:

I. Rigidity: The modified presser needed to have sufficient rigidity to withstand the maximum operating pressure of 35g/cm3. This entailed selecting appropriate materials and ensuring the structural integrity of the presser.
II. Corrosion resistance: As the presser would be in contact with beeswax and potentially other substances, it was important to choose materials that were corrosion-resistant. This would ensure the longevity and durability of the modified presser.

III. Cost-effective: The modification process aimed to create a cost-effective solution. This involved selecting materials and components that were affordable without compromising on functionality or durability.

IV. Non-reactivity with beeswax: To preserve the quality and purity of the extracted beeswax, it was crucial to use materials that were non-reactive with beeswax. This would prevent contamination or alteration of the beeswax during the extraction process.

By considering these design considerations, the modified presser was likely designed to be rigid enough to withstand the required operating pressure, corrosion-resistant to ensure longevity, cost-effective to reduce manufacturing expenses, and made from materials that were non-reactive with beeswax to preserve its quality.

3.3.2. Working principle of the screw presser

The working principle of a screw presser involves the following steps:

1. Introduction of material: The material to be processed, such as crude beeswax, was placed in a nylon fabric bag and introduced into the perforated cage of the presser.
2. Compression: By turning a lever, the top pressing plate moves downwards, exerting pressure on the material in the bag against the bottom press plate. This compression squeezes the material and forces the oil to run out through the perforations in the cage.
3. Oil collection: The oil that is squeezed out flows through the perforations in the cage and accumulates in the oil receiver, where it can be collected separately from the solid residue.
4. Piston cleaning: Once the compression process is complete, the pressure in the piston is released by turning the threaded rod counterclockwise. This allows the unwanted material to be removed from the cylinder by raising it to the top of the cylinder, preparing it for another compression process if needed.

Overall, the working principle of a screw presser involves the application of compressive force to extract oil or liquids from a material by squeezing it against a press plate, allowing the oil to separate and collect while the solid residue remains behind.

Figure 12. Beeswax Screw Presser Prototype

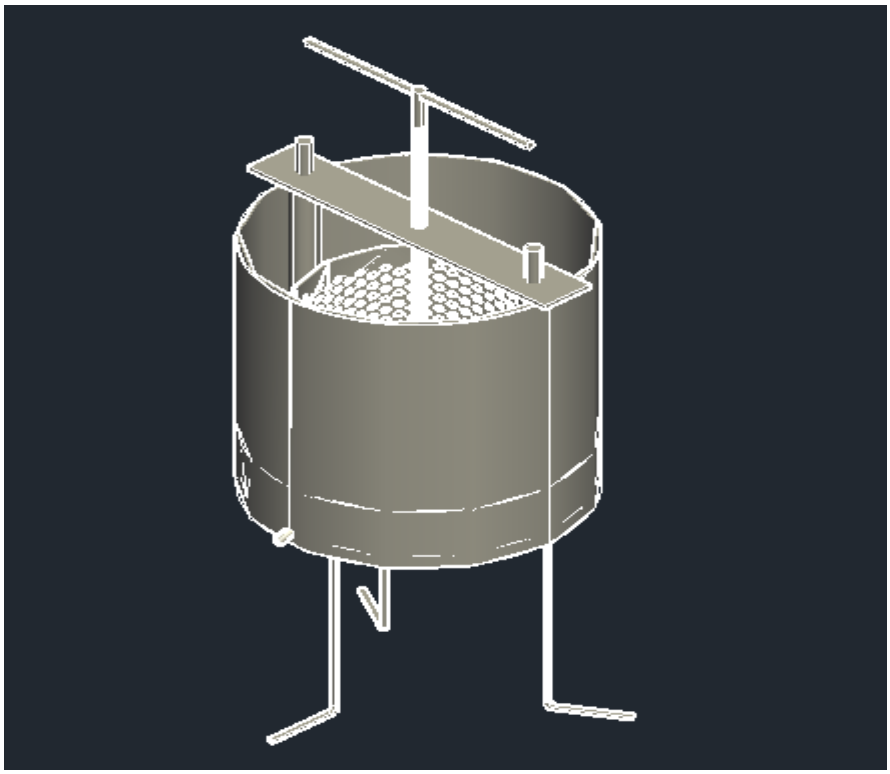


Figure 13. Isometric View of the Screw Presser

3.3.3. Design specification

The modification of this screw press beeswax extractor were based on design specifications whose choices are based on;

- Ease of construction (using standard parts to create things with basic geometry and few parts)
- Improved extraction capacity and efficiency accompanied by lower extraction loss.
- It should be produced using inexpensive materials that are readily available locally.
- The price of the presser must be affordable for small and medium farmers.
- For ease of transportation, the presser's weight and volume should be as low as possible.
- A strong frame to ensure structural stability and strong support for the machine, and ability to easily dismantle the machine for cleaning purposes

The capacity or volume of the beeswax extractor was determined by employing the size of screw honey presser. Equation (3.1) was utilized for this purpose.

Outer cylinder diameter = 0.25m diameter and 0.30m height

Perforated cylinder diameter = 0.24m diameter and 0.2m height

Volume of the outer cylinder;(Oyawale et al., 2007)

$$V = \pi r^2 h \quad \text{(Oyawale et al., 2007)} \tag{3.1}$$

Where: r= radius of the cylinder (mm)

h= height of the cylinder (mm)

$V = \pi r^2 h = \pi (0.125)^2 \times 0.3 = 0.028 m^3$ for Outer cylinder

$V = \pi r^2 h = \pi (0.12)^2 \times 0.2 = 0.026 m^3$ for perforated cylinder

$$\rho = \frac{m}{V} \qquad (Oyawale\ et\ al., 2007) \tag{3.2}$$

Density of Aluminum which is used for used for the cylinder = $2700 kg/m^3$

By rearranging Equation (3.1) the mass of the outer cylinder

$$m = \rho V \tag{3.3}$$

Where: V= Volume of the perforated cylinder (m^3)

ρ = Density of the Aluminum = $2700 kg/m^3$

= 2700 x 0.028 = 224.22kg

Weight of outer cylinder;

$$W = mg \quad (3.4)$$

Where: m= mass of aluminum (kg)

g= gravitational acceleration (m/s^2) = 9.81

= 224.22 x 9.81 = 2199.59N

$$V = \pi r^2 h \quad (3.5)$$

By using Equation (3.4) the Volume of the perforated cylinder;

$V = \pi r^2 h$ (4) = π $(0.135)^2$ x 0.32= $0.018m^3$

By using Equation (3.2) the mass of the perforated cylinder

$m = \rho V$ = 7930 x 0.018, m = 142.74kg

Weight of the perforated container

W = mg = 142.74 x 9.81 = 1400.27N

The volume of water supplied $V = \pi r^2 h$; where r = 0.15m, h = 0.3m

V = π $(0.15)^2$ x 0.04= V = $0.0028m^3$

By using Equation (3.3) mass of the water supplied m =ρv

Density of the water = $1000kg/m^3$

M = 1000 x 0.0028 = 2.827kg

Weight of the water; the amount of water supplied to the extraction chamber is 1/3 of the volume of the extraction chamber; W = mg = 2.827 x 9.81 = 27.737N

3.4. Modification of the Components of the Screw Presser

3.4.1. Modification of the perforated and cylinder of the presser

This is a thin walled perforated cylinder made of Aluminum sheet. The maximum operating pressure, P, required to the beeswax was $35g/cm^3$ (Head et al., 1995)

$$P = \frac{W}{A} \ ((\text{Oluwole et al.}, 2007)) \quad (3.6)$$

Where: P = pressure required to extract beeswax from crude beeswax ($14N/cm^2$)

W= load required to generate the pressure, (N)

A= cross-sectional area of the perforated cage, (mm^2)

$$A = \frac{\pi D_0^2}{4}$$

$$A = \pi r^2 \quad (3.7)$$

Where: A = Area of the cylindrical (mm^2) (Oluwole et al., 2007)

$_r$ = internal Radius of the cylinder (mm)

$A = \pi r^2 = \pi(100)^2 = 31{,}400mm^2$

For a perforated cylindrical cage of 200 mm internal diameter, by Substituting Equation (3.8) on equation (3.7) the load, W, required to generate this pressure is given as:

$$W = \frac{(P\pi xD^2)}{4} \quad (3.8)$$

$$W = \frac{(14 \times \pi \times 200^2)}{4} = 26{,}507N$$

According to Levinson (1970) the hoop stress in a thin walled cylinder is given as:

$$\sigma_a = \frac{Prn}{t^2} \text{(Levinson (1970))} \quad (3.9)$$

Where: δ_a= hoop stress= $0.27\delta_o$= (N/mm^2)

δ_a = yield stress of Aluminum $340N/mm^3$) =340/2= $170N/mm^3$

t = thickness of the perforated cylindrical cage (mm)

n = factor of safety= 3

R = radius of the perforated cylindrical cag (200mm)

P= the pressure to be withstood by the perforated cylinder (the internal pressure of cylinder ($35MN/m^2$)

$$t = \sqrt{\frac{Prn}{\sigma_h}} \text{ (Levinson (1970)} \quad (3.10)$$

For a perforated cylindrical cage of radius 200mm and allowable hoop stress of 340 N/mm^2 and taking factor of safety of 3 (Hall *et al. 1982*), the thickness of the perorated cylinder was calculated by equation (3.11),

$$t = \sqrt{\frac{Prn}{\sigma_h}}$$

$$t = \sqrt{\frac{35 \times 100 \times 3}{170}}$$

t = 1.41 mm

3.4.2. Modification of press plate or piston

$$t = \sqrt{32F\sigma bPL}\ (Sabelli\ \&Wilson, 2004) \quad (3.11)$$

Where; t = Thickness of plate
p = Force exerted on plate
σ = Compressive strength of mild steel = 320N/m2
L = Length of plate
b = width of plate

The optimum compressive force of sunflower seed, a popular agricultural seed is estimated 110kN. Hence for effective oil extraction, the force exerted on the plate should be equal to the compressive force of the feedstock material. For this design, an assumption is made taking general compressive force of agricultural seeds to be 110kN. Therefore F_p = 110kN. Thus, from Equation (3.11), t = 0.0227m.

The thickness of the press plate was determined from the longitudinal stress developed inside the perforated cylinder as a result of the action of the hydraulic jack. Circumferential or hoop stress was utilized to determine the thickness of the perforated cylinder (Aviara & Lawal, 2013).

3.4.3. Modification of the vertical supporting columns of the presser

Since there are two columns, the force acting on each column becomes; F =165473.8N/2
Therefore, force on each column = 82734N
Let the column be taken to have a cylindrical surface, and the area of the cylindrical bar was represented as "A". From Equation (3.15),

$$\sigma = \frac{F}{A}\ (Sabelli\ \&Wilson, 2004) \quad (3.12)$$

Where: σ = Tensile strength of mild steel bar = 400MPa (Sabelli & Wilson, 2004)

F = Force exerted on plate

By Substituting Equation (3.15) on equation (3.25) the diameter of the vertical column was calculated

$$\sigma = \frac{F}{\frac{\pi D_0^2}{4}}$$

$$D_o = \sqrt[2]{\frac{4 \times F}{\sigma \times \pi}}$$

$$D_o = \sqrt[2]{\frac{4 \times 82734}{400 \times \pi}}$$

D_o= 19.3mm

3.4.4. Modification of the top and bottom frame of the presser

Mild steel flat plate was used to build the equipment's structure. The piston is kept there. The frame's middle, which holds the collar that the screw was pushed through, was fitted with a nut. The total force applied by the press, which equals 165473.8N, is the force felt at the base of the column. The base's measurements are listed as 0.5 meters in length and 0.4 meters in width. As a result, the area grows to 0.2 m2. Therefore, Equation (3.13) can be used to determine the bottom plate's thickness.

$$t = \sqrt{32\sigma F_P bL} \quad (Sabelli\ \&Wilson, 2004) \qquad (3.13)$$

Where;σ = Tensile strength of mild steel bar = 400MPa

F_P = Force exerted on plate (N) (Sabelli & Wilson, 2004)

W_w=Weight of the water =27.737N

$$t = \sqrt{32 \times 400 \times 165473.8 \times 0.4 \times 0.5}$$

Therefore t= 3mm

The top frame's thickness is 0.03 m because every force applied to the bottom frame will have an equal and opposite reaction on the top frame.

3.4.5. Modification of the Bottom or Main Frame

Flat bar and mild steel sheet were used to build the supporting structure (Figure 13). The supporting frame is 344 mm wide and 127 mm in height. The supporting frame's stands each include a 6 mm-diameter hole, allowing the machine to be attached to any surface by securing the stands with a bolt..

Weight of the apparatus plus the load that must be removed from the unrefined beeswax equals the load on the supporting frame.

$$Deadloads = W_c + W_P + W_W \ (Sabelli \ \&Wilson, 2004) \quad (3.14)$$

Where: W_c =Weight of the outer cylinder= 2199.59N

W_p =Weight of the perforated container= 1400.27N

W_w =Weight of the water =27.737N

$Deadloads = 2199.59 + 1400.27 \ + 27.727 = 3627.59$N

Load required to express oil from the crude beeswax = Pressure required to express oil × Area of the cylinder =1.04Nmm-2×πr^2 =1.04×3.1416×1522N = 75486.86 N

Therefore, load on the supporting frame, W = (181.485+75486.86)

N= 75668.35 N

Now,

$$\frac{P}{A} = \frac{S}{N} \ (Alam \ et \ al., 2020) \quad (3.15)$$

Where: P= load on each stand, = (75668.35/ 3) N = 18917.08 N

S = Yield strength of mild steel (250 MPa) = 250 N mm-2

N = Factor of safety N = 3

A = Cross sectional area of circular cylinder, mm^2 =

r = Radios of circular plate bar, mm

The breadth of each square stand, b = 150 mm

Where, P is the extracted crude beeswax pressure (1866.232N/m^2), F is the force needed (675 N) and A is the inner perforated cylinder's cross sectional area in the extracting chamber. (0.362m^2).

Assuming weight is equally distributed on the stands. Therefore

$$Weighton\ a\ stand = \frac{Deadload}{3}\ (\text{Oyawale et al.}, 2007) \quad (3.16)$$

$$Weighton\ a\ stand = \frac{3627.59}{3}$$

Downward force on stand = 906.89N

Area of channel of angle iron can be found by using Equation 3.17

$$A_{ch} = \frac{f}{\sigma} \times factor\ of\ Safety \quad (Surendra\ \&\ Singh, 1982) \quad (3.17)$$

Where: σ = shear stress of flat iron material = 68MN/m^2 (hardened steel)f_s

fs= Factor of safety(3)

f= Downward force on the stand (N)

$$A_{ch} = \frac{906.89}{68} \times 3$$

∴ A_{ch} = 1.33 x 10-6m^2

∴ Dimension chosen are 21 x 21mm of mild steel plate

3.5. Manufacturing of Main Parts

The In the manufacturing process of the modified presser for beeswax extraction, several main parts were produced. This production process could be carried out in a medium-sized workshop with appropriate machining and fabrication capabilities. Various tasks such as facing, turning, boring, milling, welding, cutting, tapping, and filing were involved in the manufacturing process. Workshop facilities such as a lathe, milling machine, welding equipment, hand grinder, drill, M10 tap, and file were the main tools used during the construction of the equipment. These tools enabled the necessary machining, shaping, and joining of the components.

The quality of construction was a crucial factor in the operation of the equipment. Therefore, careful consideration was given to selecting appropriate production procedures and determining the proper operating sequences to ensure the desired level of quality. This would have included performing necessary operations in a precise and accurate manner to ensure the functionality and reliability of the final product. Overall, the manufacturing of the main parts of the modified presser involved various machining and fabrication processes carried out in a workshop with

the necessary facilities. The focus was on achieving the desired level of quality through careful selection of production procedures and adherence to proper operating sequences.

3.5.1. Manufacturing of bottom press plate of the presser

One of the main parts that would have been manufactured for the modified presser is the bottom press plate. The bottom press plate is a crucial component responsible for applying pressure to the beeswax during extraction. To manufacture the bottom press plate, several steps would be involved. Firstly, a suitable material for the plate, aluminum, would be selected based on its strength and durability. It was built to serve as both a bottom pressing plate and an oil the receiver. The bottom pressing vessel or plate had an 80 mm depth, a cylindrical 290 mm diameter, and 4 mm thick aluminum vessel. Next, the selected material would be cut to the desired shape and size using cutting tools such as a bandsaw or plasma cutter. The edges would then be deburred and smoothed to ensure a clean and precise finish. Afterward, the rough shape of the plate would be machined using a lathe, milling machine, or other suitable machining equipment. The machining process would involve turning and facing operations to create the required dimensions and a flat surface on the plate.

Depending on the design of the presser, additional tasks such as boring or drilling may be required to create holes or openings in the bottom press plate for the passage of wax or other components. Once the machining operations are completed, the bottom press plate may undergo further processes such as welding, if necessary, to attach any additional components or reinforcements. Finally, the plate would undergo a grinding and finishing process to ensure a smooth and even surface. This may involve hand grinding or the use of grinding machines to achieve the desired finish. The manufacturing process for the bottom press plate would need to adhere to the specified quality standards, ensuring precise dimensions, smooth surfaces, and sufficient strength to withstand the pressure applied during wax extraction.

Figure 14. Bottom Pressing Plate

3.5.2. Manufacturing of pressing chamber of the presser

The equipment's cylindrical barrel, which holds the perforated cylinder, and the threaded screw with pressing plate or piston make up the extraction chamber. It can only be fed vertically according to its design. Its materials for construction Aluminum sheet measuring 1 mm thick, which is easily found in the market, was used. It was a cylindrical vessel with a diameter of 240 mm and a depth of 300 mm, with a thickness of 1 mm. The loose ends of the aluminum sheet were then joined by welding after it had been folded into a cylindrical shape. It sits against or is welded to the exterior press vessel bottom edge.

Figure 15. Pressing Chamber

3.5.3. Manufacturing of perforated inner cylinder

In addition to serving as an extraction chamber, the perforated cylinder also aids in gently bringing the unprocessed beeswax into the pressing compartment. It can only be fed vertically

according to its design. The cylindrical perforated barrel that contains the piston is part of the presser's perforated cylinder. To endure the pressure the presser applied to the raw beeswax and to encourage the oil-bearing material to discharge its oil content to the very last drop, the cylinder was made from a 2 mm thick aluminum sheet. To prevent the beeswax from becoming contaminated, aluminum sheet was employed.

After being cut to the necessary sizes, the aluminum sheet was folded into a cylinder shape, and the free ends were then joined by welding. It was constructed from a 200 by 220 mm, 2 mm thick, and completely perforated aluminum sheet. Its wall was perforated with 3 mm-diameter apertures spaced 10 mm apart. It is encased in the outer cylindrical vessel after being given the pressed crude beeswax. It was made to be removable when necessary and to be equally capable of being replaced on its seat.

Figure 16. Perforated Cylinder

3.5.4. Manufacturing of pressing plate (piston)

The pressing plate, also known as the piston, is a crucial component of a screw press beeswax extractor. It is responsible for exerting pressure on the honeycombs to extract wax and honey. The pressing plate was made of Aluminum steel, as it comes in direct contact with wax. This ensures hygiene and prevents any contamination during extraction. The pressing plate was a cylindrical shape that fits inside the extractor cylinder. This is a circular aluminum plate 20mm thick and 175 mm in diameter. A circular plate was cut into the required dimension and drilled at the center, where the treaded screw fastened. It provides the necessary pressure required for the expression of the oil from the crude beeswax. The clearance between the inner cylinder and

the press plate is 100mm to ensure smooth movement of the pressing plate. Pressing plates have a drain holes to facilitate the draining of beeswax during the extraction process. It was connected to the plunger or threaded screw mechanism of the extractor. As the screw was turned, it pushes the pressing plate downwards, exerting pressure on the honeycombs. The pressure applied by the pressing plate was critical in extracting beeswax.

Figure 17. Pressing Plate (Piston)

3.5.5. Manufacturing of lower frame (stand)

The supporting frame is made of a 50-mm-angle iron bar of 690 mm in length. The work piece was cut, bent to the required dimensions, and fastened below the lower or bottom press. A flat, mild steel plate was to serve as support for the base for the oil receiver cylinders (bottom press) as well as the entire structure. It gives a certain height to the machine so that the extracted beeswax can be properly removed from the bottom.

Figure 18. Lower Frame

3.5.6. Manufacturing of plunger or threaded screw

The screw press beeswax extractor handle allows beekeepers to control the pressure exerted on the honeycomb, ensuring the optimal extraction of both honey and beeswax. The handle's length provides leverage, reducing the physical effort required while maximizing the efficiency of the extraction process. Since beeswax is a valuable product within the beekeeping industry, the screw press beeswax extractor handle is a valuable tool that aids in the collection of this natural substance. Once the extraction is complete, beekeepers can further process the collected beeswax to produce candles, cosmetics, or other beeswax-based products. The screw press beeswax extractor handle is an indispensable tool for beekeepers seeking to extract beeswax efficiently. Its thoughtful design, durability, and ease of use make it an essential component of any beekeeper's toolkit, ensuring a smooth and productive extraction process. The work piece was cut from aluminum rod to the required dimension, and the treaded tooth was created by the laser machine according to the designed dimension. The treaded screw has a diameter of 15 mm and a height of 390 mm. It was welded to the left arm at the top.

Figure 19. Threaded Screw

3.5.7. Manufacturing of top frame

The work piece was cut from aluminum rode cut in to the required dimension and the treaded tooth was created by the leas machine according to the designed dimension. The treaded screw has a diameter of 15 mm and a height of 390 mm.

Figure 20. Top Frame

3.5.8. Manufacturing of vertical columns or frame

The vertical columns or frame of a screw press beeswax extractor provide the structural support and stability to the entire presser. They play a critical role in maintaining the integrity and stability of the extraction process. The vertical columns were made from mild steel to ensure durability and stability. They are designed to withstand the pressure and force applied during

the extraction process without bending or warping. Overall, the vertical columns or frame of a screw press beeswax extractor contribute to the stability, safety, and effectiveness of the extraction process. They provide a solid structure that ensures the extraction is performed efficiently and without any compromise to the quality of the extracted honey and wax.

The bottom frame, measuring 270 mm long, and the top frame, that measures 360 mm long, were both cut to size. The upper frame's midpoint had been drilled with an opening of 50 mm in diameter, and a nut with a square thread was fastened to the shaft. The bottom frame, which acts as the basis for the oil receiver, was also bolted to the two vertical frames 400 mm below the top frame. The top frame was attached to the two vertical frames at the top end. The middle of the collar, which has dimensions of 52 mm on the outside, 44 mm inside, and 50 mm on top, was welded to the lever arm. The lever was then bolted with two lock bolts after being positioned on the spindle through the collar.

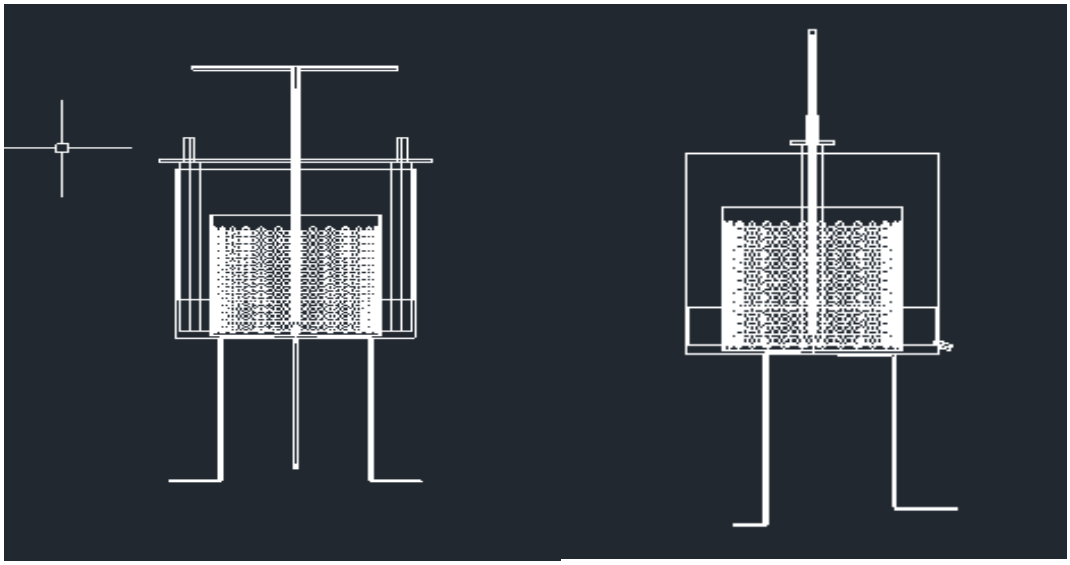
Figure 21. Vertical Columns

3.6. Assembly of the Screw Presser Components

Because it is simple to concentrate heat, the electric arc welding technology was employed for joining all the different components of this equipment. Cracking and buckling can be reduced by heat spread. The extent of penetrating is additionally improved by the heat concentration, and the welding process is accelerated. First constructed was the base, a three-channel mild steel supporting stand. The base measures 840 mm in length, 180 mm in width, and 6 mm in

thickness. The column was welded to the top of the pressing plate and is constructed from two sections of vertical flat mild steel plate.

Each plate measures 102 mm in width, 8 mm in thickness, and 1650 mm in length (vertical height). To create the machine's column, they were all welded to the base. Right after this, two sections of flat mild steel plate with dimensions measuring 840 mm in length, 225 mm in width, and 16 mm in thickness were fastened together to the top portion of the frame. The main frame support was joined by welding to the base of the main body once all of the key frame components were in place, ensuring the stability of the machine while it was in use.



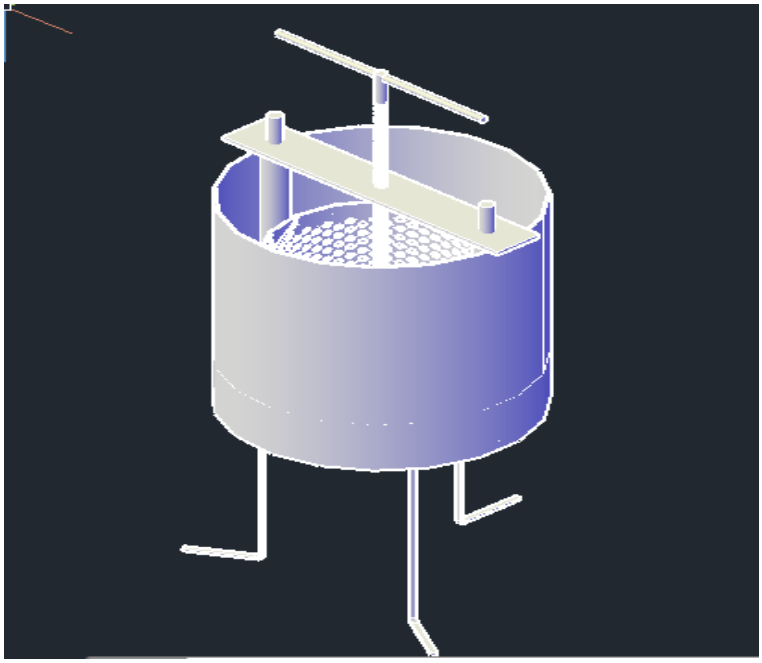


Figure 22. Front, Side, Isometric Views and Beeswax Presser Assemble

3.7. Performance Evaluation of a Screw Presser

After modification, the Manually Operated Beeswax Extractor's performance was assessed in order to establish the best beeswax extraction settings for the device. Considered extraction parameters include:

I. Operating factor was the sample size, which was 3.0 kg of raw beeswax.
II. Performance Parameters: These were extraction time, E_T (hours), extraction capacity, E_C and extraction efficiency, E_E (%).

3.7.1. Materials

The materials/equipment to be used in conducting the experiment are;

i. A weighing scale
ii. Thermometer
iii. Crude beeswax
iv. Improved beeswax pressing extractor
v. Thermometer

3.7.2. Test procedure

The performance evaluation necessitated purchasing of the representative samples of unprocessed beeswax from various producers and beekeepers or from Tej houses. In preparation for the test, 54 kg of raw beeswax were bought from the neighborhood market. The crude beeswax has to be cleaned as part of the preparation. The unprocessed beeswax from various sources was put in separate clean water baths for 24 hours in order to soak out any leftover honey, sheath, and water-soluble dirt. The entire procedure was performed two times before the resulting mixture were filtered. After drying and getting ready the sample to be processed or extraction. Before extraction process commenced, homogenization and labeling were among the procedures that were performed.

During homogenizing process all of the samples collected from various producers and beekeepers or from Tej houses was be bulked into 18 samples with an average weight of 3kg each. After The samples was categorized into manual squeezing and screw press extraction methods after homogenization and coding in order to examine the efficiency of two methods of extraction. 3kg sample was used for each of the experiment and replicated nine times. Three kilogram (3 kg) of the crude beeswax was taken in the cloth bag and tie using the string. During the performance evaluation the working temperature of the beeswax was controlled by a thermometer. The efficiency of the two beeswax extraction methods was evaluated by rendering 9 crude beeswax samples using the traditional squeezing methods and the screw presser. The data was analyzed and expressed using Microsoft excel and descriptive statistics. At the end of the extraction process, total weight of a sample before and after the extraction were collected and recorded.

These tests were repeated nine times and the extracted capacity and the extraction efficiency was determined by this formula,

$$Extraction\ Capacity(Kg/hr) = \frac{W_I}{T_t} \qquad (3.18)$$

Where: W_I= the total weight of input crude beeswax (Kg)

T_t = The Total time taken (hr.)

$$Extraction\ Efficency(\%) = \frac{W_e}{W_T} \times 100 \quad (3.19)$$

Where: W_e= the total weight of extracted beeswax (Kg)

W_t = The Total weight of sample before extraction (Kg)s

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

4.1. Results

The press was produced for beeswax extraction on an intimate scale. This production includes tasks that may be completed in any medium-sized workshop with adequate machining and fabrication capacity, including face, turning, boring, milling, welding, cutting, tapping, and fills. The whole operation of the equipment is significantly influenced by the quality of its construction. That attribute was taken into account when choosing the production procedures and operating sequences for the creation of the equipment.

Figure 23: The Modified Beeswax Extractor

When compared to the current one, the presser was manufactured of aluminum steel, which is more inexpensive for farmers. The machine's operating system was highly straightforward and user-friendly. The presser was appropriate for farmers in areas without access to electricity. The machine's owner can simply take it and set it up wherever their farm is, though, as it only weighs 18.5 kg. The compressive force will grow as the applied force in the handle increases. The processing capacity of the press is influenced by the size of the press cage and the amount of force used by the operator to move the press screw. However, the user's ability to press on the lever steadily and continuously poses a challenge.

The resources that are readily available locally can be used to construct this piece of machinery. Both a man and a woman could easily use the apparatus, which was simple to use and could be safely used while seated. The equipment's overall height of 0.75 m and its minimal energy requirements enable this. By reducing beeswax extraction loss and using the beeswax that was left in the beekeeper's home without extraction, the tool may improve beeswax extraction and processing. The equipment's input volume determines the quantity of energy needed at the handle. However, the handle's length can be increased to increase the pressure placed on the substance. The container's inner diameter controls how much pressure is produced inside the spindle (bridge) press. Greater pressures were produced by reducing the diameter of the cage and the pressure plate. Smaller cage diameter reduces the amount of loading per batch. Smaller diameter led to higher oil output. The results of the performance evaluation carried out on the modified manually operated screw press beeswax extractor are shown in figures 23 to 30 and in appendix 3.

4.1.1. The modified screw pressers performance

In this study, a manually operated screw press beeswax extractor was modified, constructed, and tested to assess its performance. The goal was to determine how effective the extractor was at producing pure wax. The results showed that when 3 kg of crude beeswax was processed, the percentage of pure wax obtained ranged from 19.1% to 32.5%. The maximum value of pure wax produced was 25.8%.

On the other hand, when the manual extraction method was used, the percentage of pure wax produced ranged from 29.7% to 59.3%, with an average of 44.5%. These findings indicate noticeable differences in the yield obtained between the manual extraction method and the mechanical extraction method. The mechanical extraction method resulted in higher percentages of pure wax compared to the manual method.

The Figures 23 to 25 represent the performance characteristics of the modified screw presser. These modifications have been made to improve the efficiency and effectiveness of the crude beeswax refining process.

Figure 23 to 25 showcases the performance of the modified screw presser in terms of extraction efficiency. It indicates how effectively the presser is able to extract beeswax from the raw materials. This can be measured in terms of the yield of beeswax obtained from a given amount of raw material.

Figure 28 depicts the performance of the modified screw presser in terms of processing time. It shows how quickly the presser is able to extract beeswax from the raw materials. This is an important factor to consider, as reducing the processing time can greatly increase the overall efficiency of the refining process.

Figure 29 represents the performance of the modified screw presser in terms of labor requirements. It shows the amount of manual labor needed to operate the presser and extract beeswax. By reducing the labor requirements, the presser becomes more cost-effective and time-efficient.

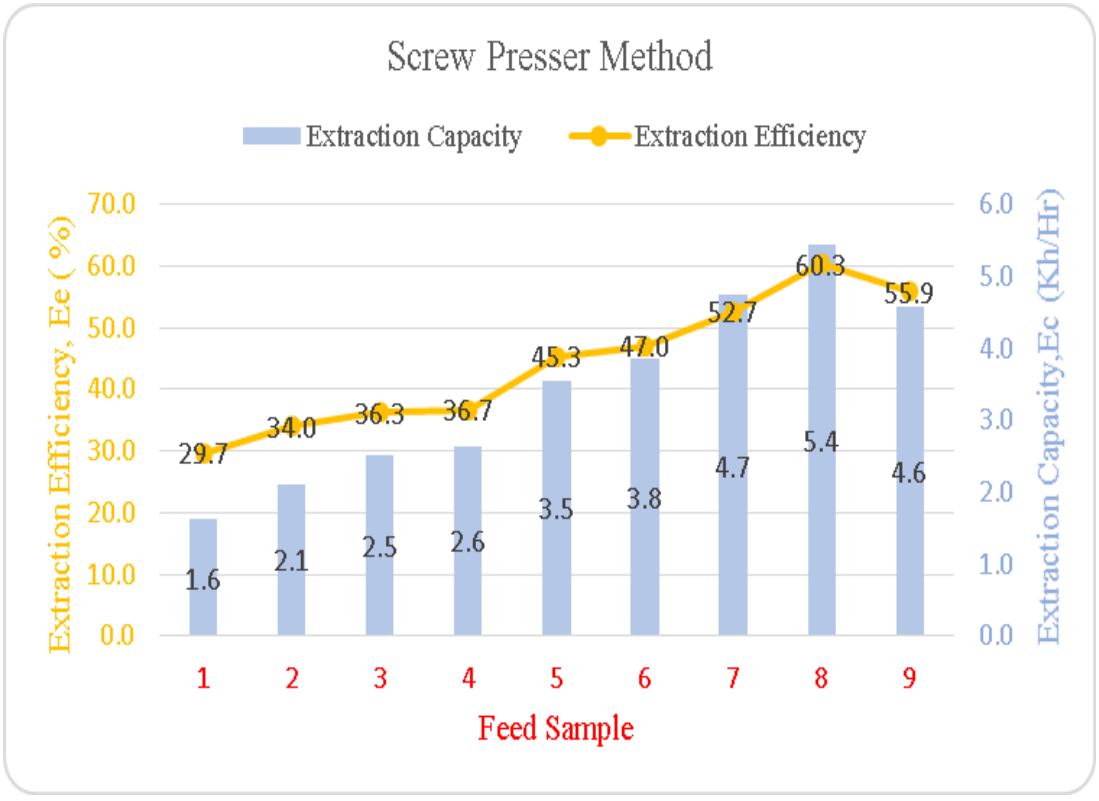


Figure 24: Extraction Capacity Vs Extraction Efficiency of the Screw Press

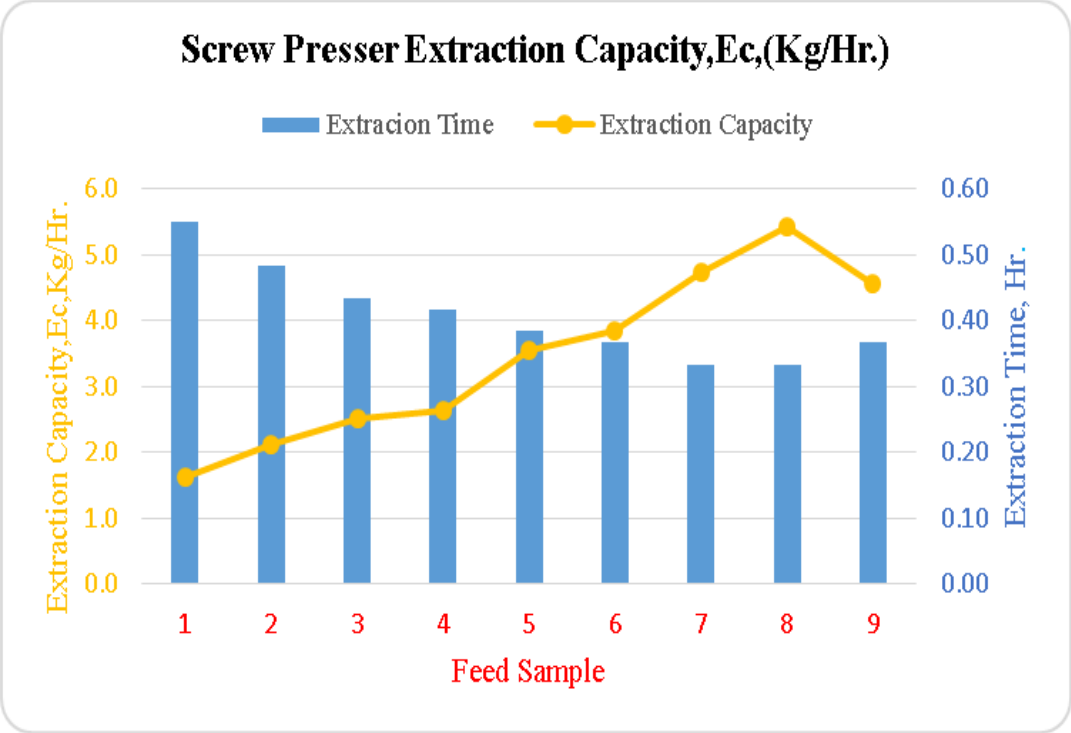


Figure 25. Extraction Capacity of Screw Press Methods

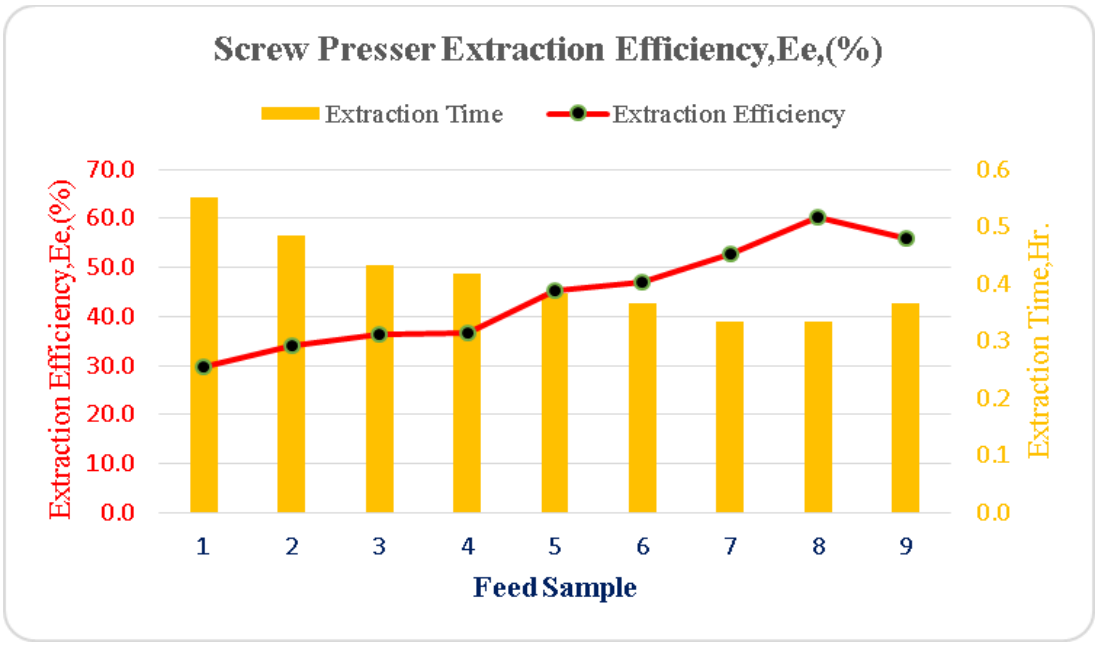


Figure 26. Extraction Efficiency of Screw Press Methods

The modifications of the performance parameters for the conventional squeezing method as indicated by their individual titles are shown in Figures 26 to 28.

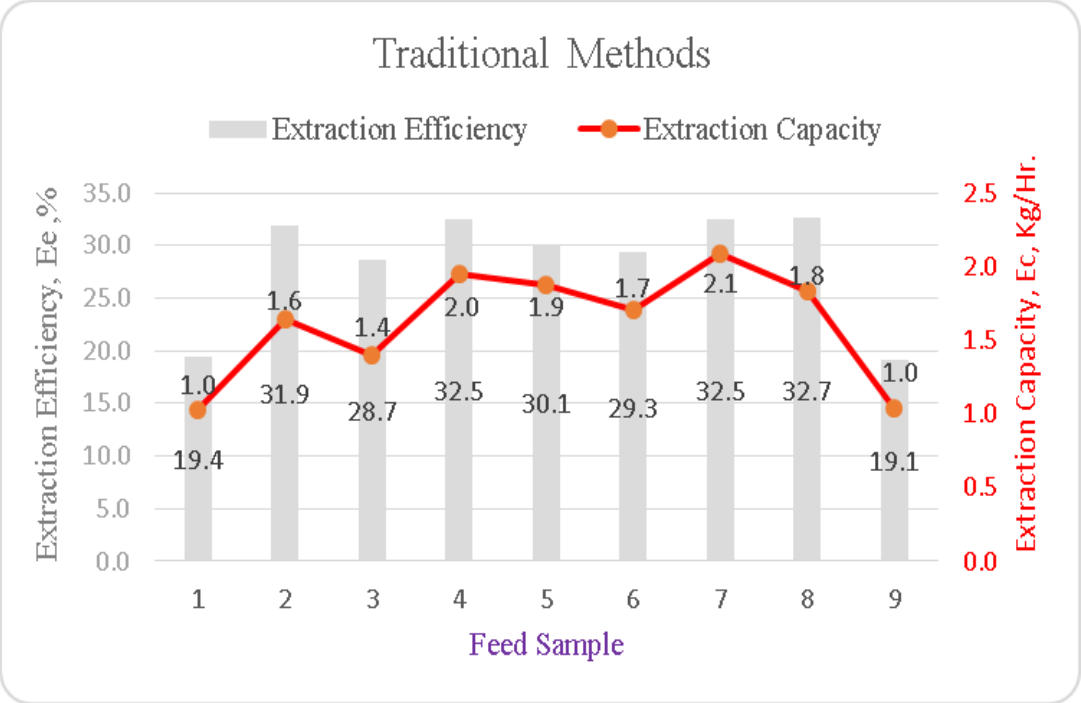


Figure 27: Extraction Capacity Vs Extraction Efficiency of the Traditional Method

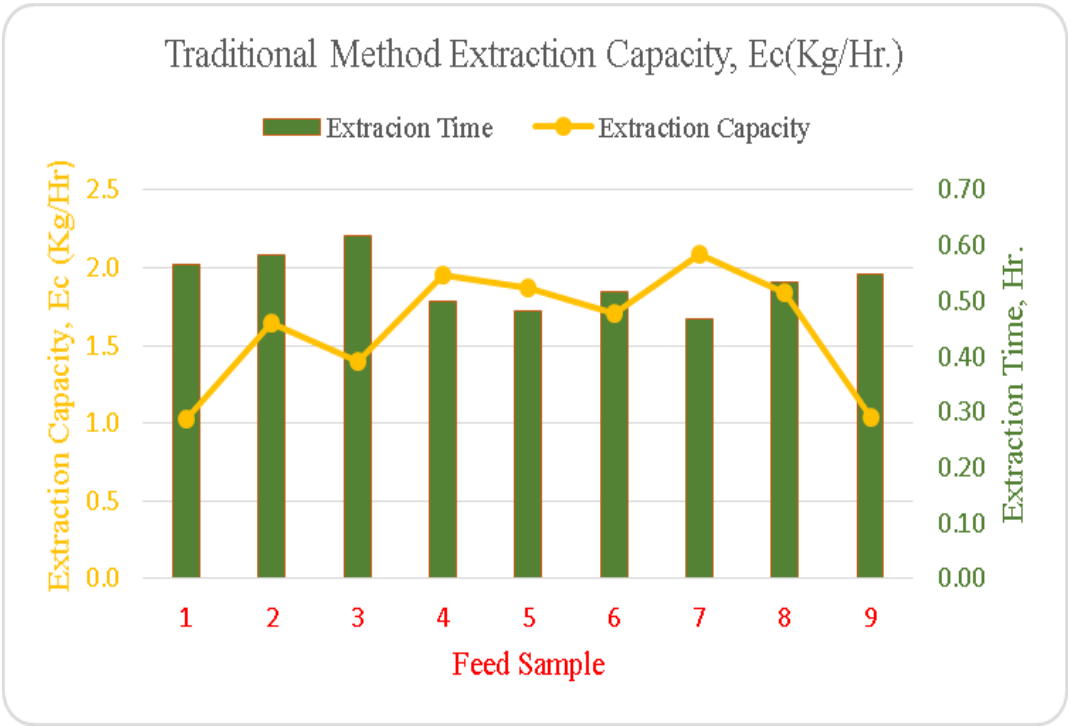


Figure 28. Extraction Capacity of Traditional Methods

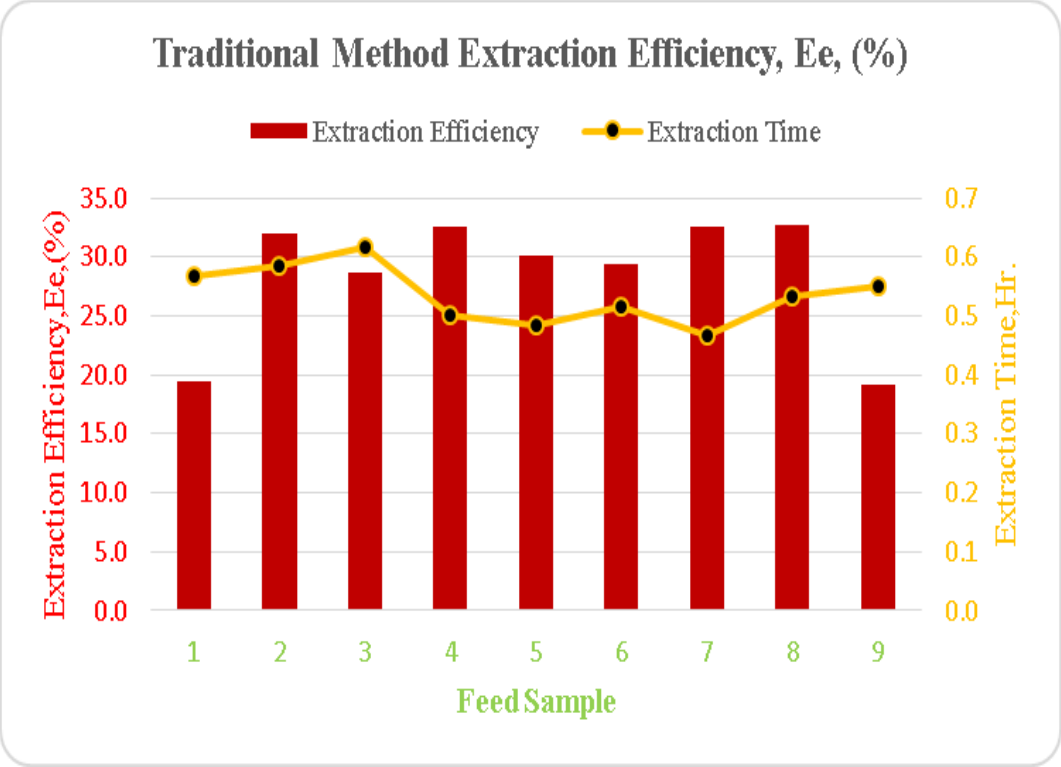


Figure 29. Extraction Efficiency of Traditional Methods

The modifications of the performance parameters for the conventional squeezing method as indicated by their individual titles are shown in Figures 29 to 30.

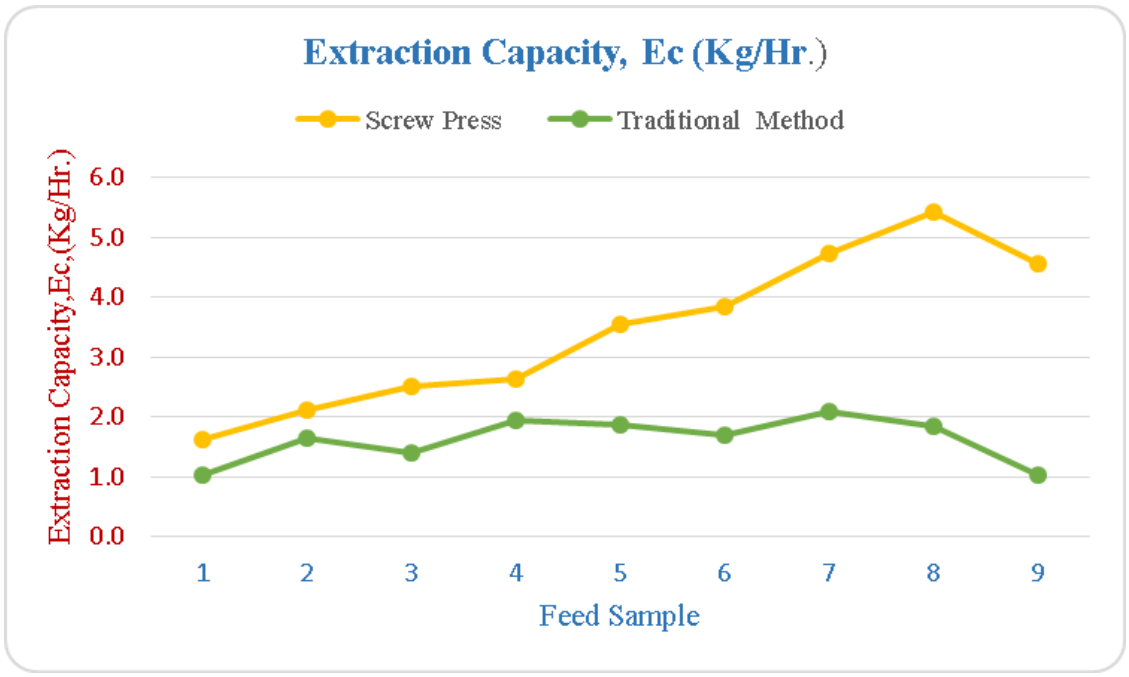


Figure 30: Extraction Capacity of the Screw Press Vs Traditional Method

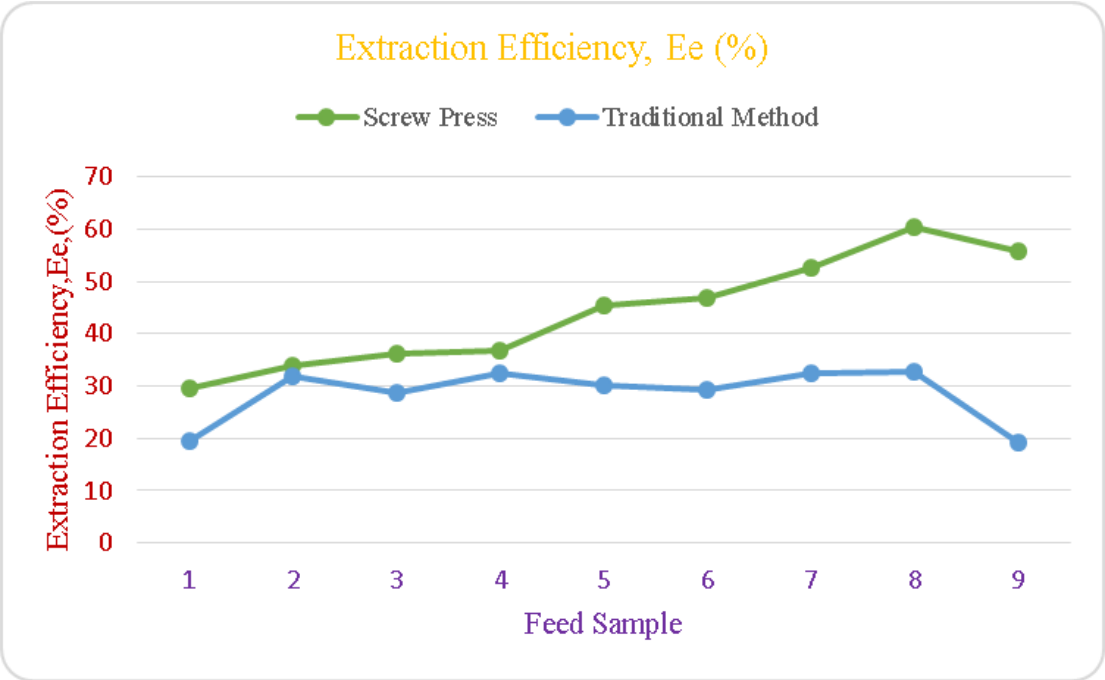


Figure 31. Extraction Efficiency of Screw Press Vs traditional Method

4.2. Discussion

The tables in the appendices and the graphs drawn in figures 23 to 30 are better explained in the three major parameters below.

4.2.1. Extraction efficiency

The results from the tests conducted on the manual and conventional beeswax extractor revealed interesting findings. When using the traditional extraction procedure, the percentage of pure wax obtained from 3 kg of crude beeswax ranged between 19.1 to 32.7%, with an average of 28.9% (Figure 23). This indicates that the conventional method may not be as efficient in extracting pure wax from the raw material.

On the other hand, the mechanical screw press extraction method, known as the screw presser, yielded significantly higher results. The amount of pure wax recovered from 3 kg of crude beeswax varied from 29.7 to 60.3%, with a mean of 44.4% (Figure 24). This demonstrates that the use of the mechanical device greatly increased the effectiveness of the extraction process.

Mekonnen Addisalem (2013) discusses the efficiency of different types of presses in extracting oil. According to Poku (2002), spindle presses have an efficiency ranging from 60 to 70%, hydraulic presses have an efficiency of 80 to 87%, and Caltech screw presses have an efficiency of 75 to 80%.

Multiple factors contributed to the variation in results obtained using the screw presser. Firstly, the efficiency of the extraction device played a crucial role. A well-designed and properly calibrated screw presser would likely provide better extraction outcomes. Secondly, the quality of the crude beeswax used also affected the percentage of pure wax obtained. Higher quality raw beeswax often resulted in a higher yield of pure wax. Lastly, the amount of crude beeswax used per extraction influenced the results. Different quantities of beeswax may require adjustments in the extraction process, impacting the final yield of pure wax.

These findings suggest that the mechanical screw press extraction method is a more favorable option for obtaining higher amounts of pure wax from crude beeswax. Further improvements in the design and calibration of the screw presser could potentially enhance the overall extraction efficiency. Additionally, ensuring the use of high-quality raw beeswax and properly adjusting the process based on the quantity used can further optimize the extraction results.

The extraction efficiency of a beeswax screw presser plays a crucial role in determining the overall productivity and quality of the extracted wax. The results of the experiment indicate a significant improvement in the extraction efficiency of the screw press beeswax extractor. This accomplishment is attributed to several key factors:

1. Enhanced Design and Mechanism:

The modified screw presser exhibits a more efficient design and mechanism, effectively optimizing the extraction process. The incorporation of large size handle and external extraction chamber ensures smoother operations, reducing wastage and maximizing the utilization of beeswax feedstock.

2. Increased Pressing Capacity:

The improved screw press beeswax extractor boasts an increased pressing capacity, allowing for higher volumes of wax to be extracted within a given timeframe. This scalability enhances

productivity while minimizing downtime associated with frequent equipment refilling or maintenance.

3. Improved Material Processing:

The modifications made to the extractor enable better handling and processing of beeswax. This attributed by enhanced beeswax quality which is brown color beeswax was extracted.

4. Enhanced Yield and Quality:

The extraction efficiency directly correlates with the yield and quality of extracted wax. The study indicates a notable increase in both yield and quality, demonstrating the efficacy of the improved screw press beeswax extractor. The efficient removal of impurities and the preservation of wax composition during pressing contribute to a higher grade of beeswax with optimal properties for various applications.

The improved extraction efficiency of the screw press beeswax extractor opens up numerous possibilities and implications for the industry:

1) Increased Productivity and Cost-effectiveness:

The enhanced extraction efficiency translates into higher productivity, allowing manufacturers to meet growing demand while reducing operational costs. This advancement can alleviate supply constraints and contribute to the economic growth of beekeepers.

2) Consistent Wax Quality:

The improved extraction process ensures a more consistent quality of extracted wax. This enables manufacturers to produce beeswax-based products with consistent characteristics and performance, gaining consumer trust and loyalty.

3) Sustainable Resource Utilization:

The increased extraction efficiency minimizes wastage and optimizes the use of beeswax feedstock.

4) Technological Advancements:

The success of the modified screw press beeswax extractor illustrates the potential for further technological advancements in the beeswax industry. Continued research and development could lead to even greater extraction efficiencies and the exploration of new applications for beeswax.

4.2.2. Extraction capacity

The traditional beeswax extraction method had an extraction capacity ranging from 0.009 kg per hour to 0.025 kg per hour, with an average of 0.0177 kg per hour (Figure 25). In comparison, the manually operated beeswax screw presser had an extraction capacity ranging from 0.018 kg per hour to 0.064 kg per hour, with an average of 0.04 kg per hour.

Figure (26) revealed that in the first trial, only 29.7% of the beeswax was recovered. This could be attributed to the filter absorbing and retaining some of the expressed oil. However, the oil recovery improved in subsequent trials, reaching a maximum value of 54.1% by mass in the third trial (34%). The process of filling the press, applying pressure, and removing the cake took approximately 35 minutes, whereas the traditional method took around 50.6 minutes for the same amount of paste. The increased oil recovery could be due to the filter becoming saturated and unable to absorb more oil.

Similar findings were obtained by Wiemer and Korthals (1989) using a spindle oil press, with oil recovery ranging from 73.3% to 77.8%. The use of nylon as a filter prevented groundnut paste particles from blocking the perforations in the cylindrical cage, eliminating the need for labor-intensive cleaning of the machine after use.

The extraction capacity of a screw press beeswax extractor plays a crucial role in determining the overall productivity and efficiency of the wax extraction process. The results of the experiment indicate a significant improvement in the extraction capacity of the screw press beeswax extractor. This accomplishment is attributed to several key factors:

1. Increased Pressing Capacity:

The experiment demonstrates that the modified screw press beeswax extractor has a higher pressing capacity compared to traditional extractors. This increase allows for a larger volume of wax to be pressed at a time, resulting in higher productivity and efficiency.

2. Processing Speed:

The study demonstrates that the screw press beeswax extractor operates at a faster processing speed compared to conventional extractors. This increased speed allows for a more rapid extraction process and reduces the overall time required for wax extraction.

3. Continuous Operation:

The improved screw press beeswax extractor is designed to operate continuously, without the need for frequent interruptions or pauses. This continuous operation capability significantly enhances the extraction capacity by eliminating downtime associated with equipment rest or maintenance. The improved extraction capacity of the screw press beeswax extractor offers several advantages for the beeswax production and marketing.

I. Increased Production Output:

The higher pressing capacity allows beekeepers to extract a larger volume of beeswax within a given timeframe. This increase in production output can meet growing market demand and potentially lead to higher profitability.

II. Time and Cost Savings:

The faster processing speed of the screw press beeswax extractor reduces the overall time required for wax extraction. This time-saving feature allows manufacturers to streamline their production processes and potentially save on labor costs.

III. Improved Efficiency:

The continuous operation capability of the improved screw press extractor eliminates downtime, increasing overall efficiency.

IV. Scalability:

The enhanced extraction capacity of the screw press beeswax extractor enables manufacturers to scale up their operations. The ability to process larger volumes of wax can expand production capabilities to meet the demands of a growing market. The increased pressing capacity, faster processing speed, continuous operation capability, and scalability contribute to higher production output, time and cost savings, improved efficiency, and the potential for business growth in the beeswax industry. These findings emphasize the importance of investing in advanced equipment technologies to enhance productivity and remain competitive in the market.

4.2.3. Extraction time

The extraction time of a screw press beeswax extractor is a critical factor in the efficiency and productivity of the wax extraction process. The results of the experiment indicate that the extraction time of the screw press beeswax extractor has been significantly reduced compared to traditional extractors. Several factors contribute to this achievement. The study demonstrates

that the modified screw press beeswax extractor incorporates design enhancements that optimize the extraction process. These improvements minimize friction and resistance during pressing, resulting in a faster extraction time. Moreover the experiment reveals that the screw press beeswax extractor exerts higher pressure on the wax during extraction, facilitating the efficient separation of wax from other impurities. Increased pressure enables a quicker release of wax from the comb, further reducing extraction time. The study highlights that the heating mechanism in the screw press beeswax extractor has been fine-tuned. This adjustment ensures that the wax is heated to the optimal temperature for extraction, accelerating the process and minimizing the required time.

CONCLUSION AND RECOMMENDATION

Conclusion

A manually operated screw press beeswax extractor was modified, built, and put to the test to determine how well it worked. This study found that the percentage of pure wax produced from 3 kg of crude beeswax ranged from 19.1 to 32.5% with a maximum value of 25.8%, and that the percentage of pure wax produced using the manual extraction method ranged from 29.7 to 59.3% with a mean of 44.5% when using the mechanical extraction method. Between manual and mechanical wax extraction methods, there were noticeable differences in the yield obtained.

The extraction capacity of the extractor ranged from 0.018 kg/h to 0.064 kg/h, with a mean of 0.040 kg/h for the mechanical one, and from 0.009 kg/h to 0.017 kg/h, with a mean of 0.025 kg/h for the traditional one. Regarding the extractor's extraction efficiency, the filtering cloth's impact is a crucial factor. The extraction efficiency is significantly influenced by the extraction time. The amount of residue, other foreign materials, handling of raw beeswax and of extraction, as well as the effectiveness of the device, were the causes of the large variance in wax yield between the manual and mechanical methods. Beeswax extraction in remote areas will no longer be as laborious thanks to the machine, which will also speed up the procedure.

Recommendations

- Even if the presser already has all the aforementioned benefits, it might still be improved to increase its capacity by raising the presser's capacity, which would decrease the need for frequent refills and boost the equipment's extraction efficiency.
- If a thermometer is included in the design, the quality of the beeswax that is extracted will improve.
- If the extractor was assessed using several beeswax sources. Analysis of the extracted beeswax's quality was not done. It is advised that a job quality analysis be done in the future.
- Since the combs are not heated throughout the pressing process, it is best to extract in warm weather or a place that can be heated by a stove to prevent the wax from becoming too cold.

- If the ideal feed material size is determined, the extractor's efficiency will increase. The lower size of the extractor and the aforementioned need to be identified in the future.

REFERENCES

Addisu Bihonegn. (2017). *Assessment of Beeswax Production, Quality and Market Chains in Selected Districts of South Wollo Zone, Amhara Region, Ethiopia*. *March*, 1–145.

Adeeko, K.A., Ajibola, O.O., 1990. Processing factors affecting yield and quality of mechanically expressed groundnuts. J. Agric. Eng. Res. 45, 33–43.

Agonafir, J. (2005). *Strategic Intervention Plan on Honey & Beeswax Value Chains*. *August*, 38.

Alam, M., Nandi, R., & Kabir, E. (2020). Development of a manually operated palm oil extraction machine. *Agricultural Engineering International: CIGR Journal*, *22*(1), 213–218. http://www.cigrjournal.org

Aremu, A., & Clement, O. (2016). Development and Evaluation of a Multipurpose Juice Extractor. *New York Science Journal*, *9*(6), 7–14. https://doi.org/10.7537/marsnys09061602

Atsbaha, G.-S., & Tessema, B. (2012). Global Growing Casebook. *Global Growing Casebook*, *Medic 1999*, 1–64. https://land.igad.int/index.php/documents-1/countries/ethiopia/rural-development-1/275-a-review-of-ethiopian-agriculture-roles-policy-and-small-scale-farming-systems/file

Ayalew Kassaye. (2008). Honey and Beeswax Value Chain of BOAM Programme, establishment of Apiculture Data Base in Ethiopia, SNV Netherlands Development Organization, Addis Ababa, Ethiopia.

Ayele Gezahegn, Nebil Kellow and Samru Mehary. 2006. Strategic Options for Quality improvement of Ethiopian Beeswax exports. Prepared for: The Stakeholders of the Honey and Beeswax value chain Co-ordination Group First. *First Consult PLC*.

Bako, T., Awulu, J. O., & Garba, A. J. (2017). Conceptual Design of a Fish Oil Extracting Machine. *American Journal of Modern Energy*, *3*(6), 136–145. https://doi.org/10.11648/j.ajme.20170306.14

Bhargavi, G., Rao, P. N., & Renganathan, S. (2018). Review on the Extraction Methods of Crude oil from all Generation Biofuels in last few Decades. *IOP Conference Series: Materials Science and Engineering*, *330*(012024). https://doi.org/10.1088/1757-899X/330/1/012024

Bogdanov, S. (2004). Beeswax: Quality issues today. *Bee World*, *85*(3), 46–50. https://doi.org/10.1080/0005772X.2004.11099623

Bogdanov, S. (2016). Beeswax: Production, Properties, Composition, Control. In *Bee Product*

Science. Bee Product Science. https://www.researchgate.net/publication/304012435

Bradbear, N. (2009). *Bees and their role in forest livelihoods: a guide to the services provided by bees and the sustainable harvesting, processing and marketing of their products. In Non-Wood Forest Products*. Food and Agriculture Organization of the United Nations(FAO). https://books.google.co.uk/books/about/Bees_and_their_role_in_forest_livelihood.html?id=0Bb1AAAAMAAJ&redir_esc=y

Chowdhury, N. M., & Mahmud, F. (2020). Development and performance evaluation of an optimized screw type domestic oil expeller. *Proceedings of the International Conference on Industrial Engineering and Operations Management*, *August*. http://www.ieomsociety.org/detroit2020/papers/417.pdf

Cowan, T. W. (2015). Wax Craft: All about Beeswax Its History, Production, Adulteration, and Commercial Value. In *Nature* (Vol. 78, Issue 2034). Sagwan Press. https://doi.org/10.1038/078630b0

CSA. (2016/17), Central Statistical Agency: Agricultural Sample Survey 2016/17. Report on livestock and livestock characteristics. Addis Ababa, FDRE, Ethiopia.

CSA. (2021). Federal Democratic Republic of Ethiopia Central Statistical Agency Agricultural Sample Survey 2020/21. In *Report on Livestock and Livestock Characteristics (Private Peasant Holdings). Statistical Buletin 578 (Vol. II).: Vol. II* (Issue February). http://www.statsethiopia.gov.et/wp-content/uploads/2021/05/2013.LIVESTOCK-REPORT.FINAL_.pdf

Degu, T. K., & Megerssa, G. R. (2020). *Role of Beekeeping in the Community Forest Conservation : Evidence from Ethiopia*. https://doi.org/10.1080/0005772X.2020.1825308

Eshete, Y., Zelalem, D., Tadesse, H., Lemma, T., Eshetie, T., & Negera, T. (2018). Determination of the proportion of pure beeswax recovered from crude beeswax resources at local honey wine making houses in Ethiopia. *Journal of Nutritional Health & Food Engineering*, *8*(3), 269–273. https://doi.org/10.15406/jnhfe.2018.08.00281

Faborode, M.O., Favier, J.F., 1996. Identification and significance of the oil-point. J. Agric. Eng. Res. 45, 335–345.

Gimlet. (2014). *Rendering Beeswax*. Beespoke.Info. http://greenroadfarm.com/beekeeping/?page_id=566

Gratzer, K., Wakjira, K., Fiedler, S., & Brodschneider, R. (2021). *Challenges and perspectives for beekeeping in Ethiopia . A review*. *July*. https://doi.org/10.1007/s13593-021-00702-2

Hall, A.S., A.R. Holowenko and H.G. Laughtin (1982). *Theory and practice of machine*

design. Schaum's outline series McGrew-hill Book Company. New York.

HBRC. (2020). *International Partnership on Innovation SAMS - Smart Apiculture Management Services: Report on Needs Assessment and Evaluation*. *2020*, 1–29.

Head, S. W., & NRI. (1995). *Small scale vegetable oil extraction*. Natural Resources Institute. https://www.nzdl.org/cgi-bin/library?e=d-00000-00---off-0hdl--00-0----0-10-0---0---0direct-10---4-------0-0l--11-en-50---20-about---00-0-1-00-0-0-11----0-0-&a=d&c=hdl&cl=CL1.16&d=HASH0ec2d91c38153027e7c19f.11#HASH0ec2d91c38153027e7c19f.11

Head, S. W., Swetman, A. A., Hammonds, T. W., Gordon, A., Southwell, K. H., & Harris, R. V. (1995). *Small scale vegetable oil extraction*. Natural Resources Institute.

Ibrahim, A., & Onwualu, A. P. (2005). Technologies for Extraction of Oil From Oil-Bearing Agricultural Products: a Review. *Journal of Agricultural Engineering and Technology*, *13*, 58–89. https://nairametrics.com/wp-content/uploads/2013/02/technology-of-extracting-oil-from-the-oil-bearing.pdf

IMF. (2016). The Federal Democratic Republic of Ethiopia: 2016 Article IV Consultation-Press Release; Staff Report; and Statement by the Executive Director for The Federal Democratic Republic of Ethiopia. In *IMF Staff Country Reports* (Vol. 16, Issue 322). https://doi.org/10.5089/9781475543643.002

Itanye, O.P. (2001). Construction of groundnut oil extraction machine. Unpublished ND project. Ramat Polytechnic, Maiduguri, Nigeria.

Khadija G.A.T, T. N. B. N. (2016). *Design and Development of Jatropha Oil Expelling Machine* (Issue November). University of Khartoum.

Khan, K., Ali, M., Obaydullah, A. K. M., & Wadud, M. (2019). Candle Production Using Solar Thermal Systems. *1st International Conference on 'Energy Systems, Drives and Automations', ESDA2018*, 59–66. https://www.researchgate.net/publication/330102943

Kiggundu, N., & Jjagwe, J. (2021). Performance evaluation of a motorised palm oil extractor with quality assessment of the palm oil extracted in comparison with a manual vertical press. *Journal of Oil Palm Research*, *33*(1), 64–73. https://doi.org/10.21894/jopr.2020.0096

Kole, A. T. (2022). *Adaptation and Performance Evaluation of Small-Scale Solar Beeswax Extractor*. *11*(06), 149–153.

Levinson, J.I. (1970). *Mechanics of materials.* Prentice-Hall, inc. Englewood Cliffs, N.J.

Louhichi, K., Temursho, U., & Gomez, S. (2019). *Upscaling the productivity performance of*

the Agricultural Commercialization Cluster Initiative in Ethiopia. https://doi.org/10.2760/57450

Mekonnen, A. (2013). *Design and Optimization of Electric Motor Driven Mechanical Oil Press*. Addis Ababa University.

Meseret, G., & Deressa, K. (2019). Evaluation of the Quality of Beeswax from Different Sources and Rendering Methods. *International Journal of Research Studies in Biosciences*, *7*(6), 20–25. https://doi.org/10.20431/2349-0365.0706005

Moderator. (2016, February 24). All About Beeswax – Latest and Most Economical Methods of Rendering Old Combs, Refining, and Marketing of Beeswax. *Beesource*. http://www.beesource.com/resources/elements-of-beekeeping/all-about-beeswax/

Mohammed, S. S., & Hassen, A. (2021). The Current Constraints and Opportunity of Beekeeping in Ethiopia: A Review. *Advance in Biological Research*, *2*(1), 8–15. https://doi.org/10.26855/abr.2021.12.001

MoA. (2019).Transforming Ethiopian Agriculture: Power Point Presentation, Briefing for Agricultural Scholar Consultative Forum, April 2019, and Addis Ababa.

Moses, D M (2014). Performance evaluation of continuous screw press for extraction of soybean oil. Amer. J. Science and Technology, 1(5): 238-242

Mpagalile, J. J., Hanna, M. A., & Weber, R. (2007). Seed oil extraction using a solar powered screw press. *Industrial Crops and Products*, *25*(1), 101–107. https://doi.org/10.1016/j.indcrop.2006.08.001

Mutsaers, M., Blitterswijk, H. van, Leven, L. van 't, Jaap, K., & Waerdt, J. van de. (2005). *Bee products : properties, processing and marketing. Agrodok-series No. 42* (M. Mutsaers (Ed.); First edit). Agromisa Foundation.

Nuru, A., & Eddosa, N. (1995). *Ethiopian Society of Animal Production Profitability of processing crude honey*. https://www.researchgate.net/publication/313842145

Oluwole, F. A., Abdulrahim, A. T., & Aviara, N. A. (2007). DEVELOPMENT AND PERFORMANCE EVALUATION OF A SPINDLE PRESS FOR OIL EXTRACTION. *Arid Zone Journal of Engineering*, *5*, 66–75. www.azojete.com.ng

Oyawale, F., Oyawale, F. A., & Olaoye, A. E. (2007). Design and Construction of an Autoclave Sustainable design and manufacturing View project Pollution View project Design and Construction of an Autoclave. In *The Pacific Journal of Science and Technology-224* (Vol. 8, Issue 2). http://www.akamaiuniversity.us/PJST.htm

Olaniyan, A M; Yusuf, K A; Wahab, A L and Afolayan, K O (2012). Design, development

and testing of a screw press expeller for palm kernel and soybean oil extraction. Post-harvest, Food and Process Engineering. Int. Conference of Agricultural Engineering-CI?R-AgEng 2012. Valencia, Spain. p. 1748.

QSAE, Q. and S. A. of E. (2005). *Beeswax - Specification*. *1202*.

Pighinelli, L. A. M. T., & Gambetta, R. (2012). Oil presses. In U. G. Akpan (Ed.), *Oilseeds*. https://doi.org/10.5772/30699

Poku, K. (2002). Small-Scale Palm Oil Processing in Africa. In *Food and Agriculture Organisation of the UN, Rome* (Vol. 84). http://www.fao.org/DOCREP/005/y4355e/y4355e00.HTM

Preciseethiopia.com. (2013). *HONEY SECTOR INVESTMENT OPPORTUNITY BRIEF: Honey and Beeswax Refinery Plant in High Potential Regions*.

Raji, N. A., Adedeji, K. A., Olaleye, J. O., & Adele, F. A. (2019). Design and fabrication of tiger nut juice extractor. *Journal of Applied Sciences and Environmental Management(JASCM)*, *23*(3), 563–568. https://doi.org/10.4314/jasem.v23i3.29

Sabelli, A. M., & Wilson, D. G. (2004). *Design of a Press for Oil Extraction from Moringa Seeds for Haiti*. MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

SANFORD, M. T., & DIETZ, A. (1976). THE FINE STRUCTURE OF THE WAX GLAND OF THE HONEY BEE (APIS MELLIFERA L.). *Apidologie*, *7*(3), 197–207. https://doi.org/10.1051/apido:19760301

Shapiro, B. I., Gebru, G., Desta, S., Negassa, A., Nigussie, K., Aboset, G., & Mechale, H. (2017). *Ethiopia livestock sector analysis. ILRI Project Report.* International Livestock Research Institute (ILRI).

Shegaw, T., & Edimew, T. (2021). Assessment on Production, Processing and Marketing Status of Beeswax in Kafa Zone, Southern Nations Nationalities and Peoples Region (SNNPR), Ethiopia. *American Journal of Agriculture and Forestry*, *9*(4), 172. https://doi.org/10.11648/j.ajaf.20210904.12

Shikur, Z. H. (2020). Agricultural policies, agricultural production and rural households' welfare in Ethiopia. *Journal of Economic Structures*, *9*(1). https://doi.org/10.1186/s40008-020-00228-y

Singh, S. 1982. *Strength of Materials. 2nd edition.*. Vilkas Publishing House Ltd.: New Delhi, India.

Siraj M.S, P. (2016). Technologies for Oil Extraction: A Review. *International Journal of*

Environment Agriculture and Biotechnology, *1*(2), 106–110. https://ijeab.com/detail/technologies-for-oil-extraction-a-review/

Suparyanto, & Rosad. (2020). *Bee Wax: Collection and Processing*. Central Bee Research Institute. https://kvic.gov.in/kvicres/newhm/cbrti/hive produce/0- Bee wax.pdf

Sukumaran, G.R., Singh, B.P.N., 1989. Compression of bed of rape- seed: oil-point. J. Agric. Eng. Res. 42, 77–84

Tacoronte, L. C. (2010). *Putting the Press to the Test: Effects of Temperature on Shea Nut Oil Output*. MASSACHUSETTS OF INSTITUTE OF TECHNOLOGY.

Tewodros Kassa. (2020, September 3). Ethiopia Could Harvest 500,000 Tons of Honey. The Ethiopian Herald.

WAMUCII, S. (2022). *Ethiopian Beeswax Prices*. https://www.selinawamucii.com/insights/prices/philippines/yeast/

Weidmann, G., & Kilcher, L. (Eds.). (2011). *African Organic Agriculture Training Manual* (Version 1). Research Institute of Organic Agriculture,FiBL.

Yadeta, G. L. (2014). Beeswax production and marketing in Ethiopia: Challenges in value chain. *Forestry and Fisheries*, *3*(6), 447–451. https://doi.org/10.11648/j.aff.20140306.12

Yeshitela Eshete. (2018). *Beehive Product Processing and Quality Assurance Guideline*.

Yeshitila, E., & Tekeba, E. (2018). A review on crude beeswax mismanagement and lose: opportunities for collection, processing and marketing in Ethiopia. *Journal of Nutritional Health & Food Engineering*, *8*(6). https://doi.org/10.15406/jnhfe.2018.08.00300

APPENDIXES

Appendix I. Picture Sample Preparation for Performance Evaluation

Appendix II. Picture Traditional Methods of Extraction

Appendix III. Picture Traditional Beekeeping

Appendix IV. Picture Modern Beekeeping

Appendix V. Table Performance Evaluation Data of Screw Presser

Sample code	Initial Wt(kg)	Final Wt(kg)	Time(Hr)	Extraction Capacity(SP)	Extraction Efficiency(%)(SP)	Time In Hr
1	3	0.91	31	1.76	30.333	0.517
2	3	0.89	28	1.91	29.667	0.467
3	3	1.02	28	2.19	34.000	0.467
4	3	1.09	26	2.52	36.333	0.433
5	3	1.1	25	2.64	36.667	0.417
6	3	1.36	23	3.55	45.333	0.383
7	3	1.41	22	3.85	47.000	0.367
8	3	1.78	20	5.34	59.333	0.333
9	3	1.81	20	5.43	60.333	0.333
10	3	1.676	22	4.57	55.867	0.367
Max				5.43	60.3	
Min				1.76	29.667	
Ave				3.24	43.739	

Appendix VI. Table Performance Evaluation Data of Traditional Method

Sample code	Initial Wt(kg)	Final Wt(kg)	Time(min)	Extraction Capacity(Kg/hr)(TM)	Extraction Efficiency(%)(TM)	Time In Hr
1	3	0.854	39	1.31	28.5	0.65
2	3	0.583	34	1.03	19.4	0.57
3	3	0.958	35	1.64	31.9	0.58
4	3	0.860	37	1.40	28.7	0.62
5	3	0.976	30	1.95	32.5	0.50
6	3	0.904	29	1.87	30.1	0.48
7	3	0.880	31	1.70	29.3	0.52
8	3	0.976	28	2.09	32.5	0.47
9	3	0.980	32	1.84	32.7	0.53
10	3	0.573	33	1.04	19.1	0.55
Max				2.09	32.7	
Min				1.03	19.1	
Ave				1.58	28.0	

Appendix VII. Force that an Average Human Can Apply

Exertable horizonal force	Applied with	Condition (μ: coefficient of friction)
110 N (24.7 lbf) push of pull	both hands or one shoulder or the back	with low traction $0.2 < \mu$ 0.3
200 N (45.0 lbf) push or pull	both hands or one shoulder or the back	with medium traction $\mu = 0.6$
240 N (54.0 lbf) push	one hand	if braced against a vertical wall 510-1520 mm (20.08-59.84 in) from and parallel to the push panel
310 N (70.0 lbf) push or pull	both hands or one shoulder or the back	with high traction $\mu > 0.9$
490 N (110.2 lbf) push or pull	both hands or one shoulder or the back	if braced against a vertical wall 510-1780 mm (20.08-70.08 in) from and parallel to the panel or if anchoring the feet on a perfectly non-slip ground (like a footrest)
730 N (164.1 lbf) push	the back	if braced against a vertical wall 580-1090 mm (22.83-42.91 in) from and parallel to the push panel or if the anchoring the feet on a perfectly non-slip ground (like a footrest)

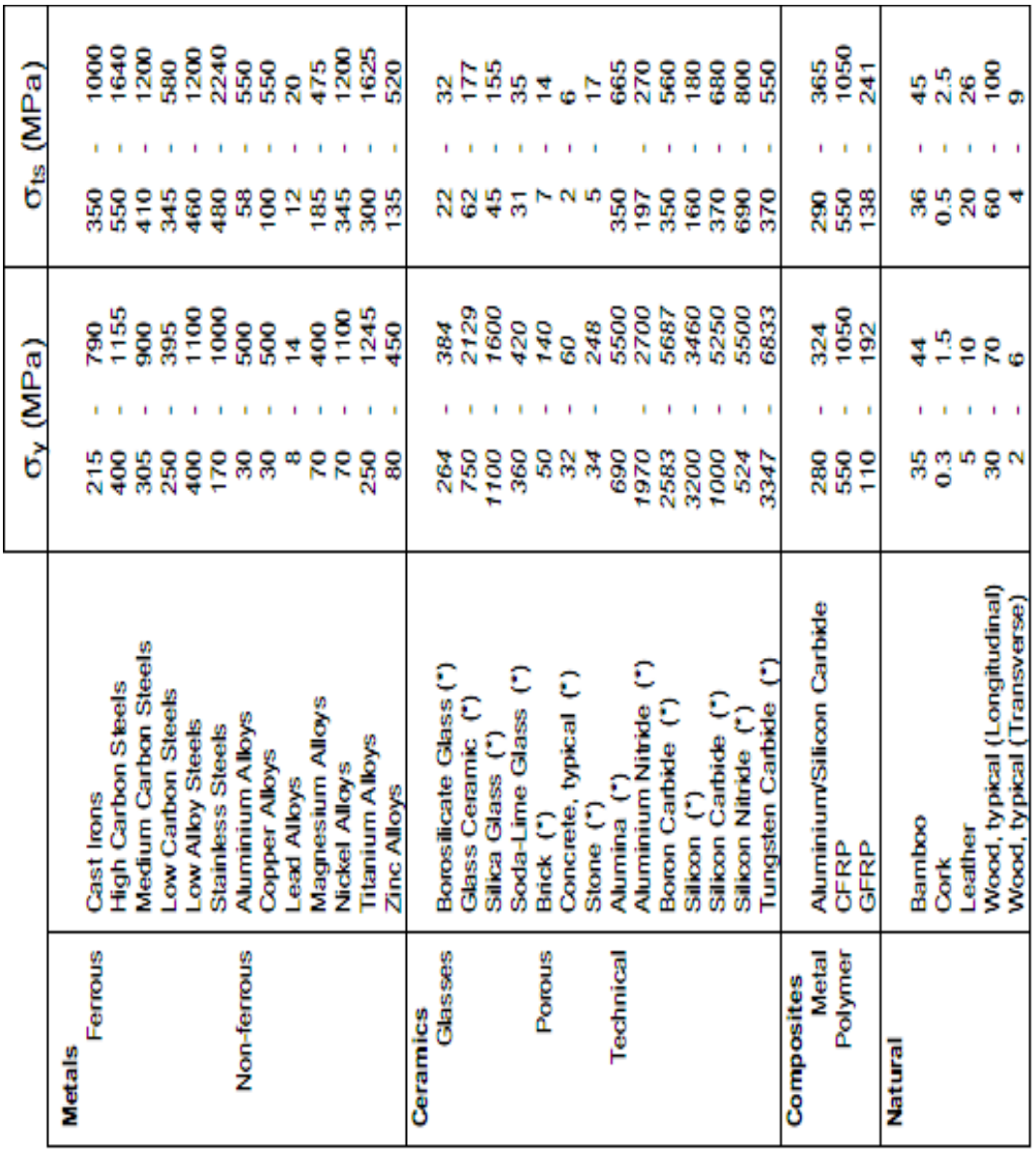
Appendix VIII. Density of Different Materials

		ρ (Mg/m^3)
Metals		
Ferrous	Cast Irons	7.05 - 7.25
	High Carbon Steels	7.8 - 7.9
	Medium Carbon Steels	7.8 - 7.9
	Low Carbon Steels	7.8 - 7.9
	Low Alloy Steels	7.8 - 7.9
	Stainless Steels	7.6 - 8.1
Non-ferrous	Aluminium Alloys	2.5 - 2.9
	Copper Alloys	8.93 - 8.94
	Lead Alloys	10 - 11.4
	Magnesium Alloys	1.74 - 1.95
	Nickel Alloys	8.83 - 8.95
	Titanium Alloys	4.4 - 4.8
	Zinc Alloys	4.95 - 7
Ceramics		
Glasses	Borosilicate Glass	2.2 - 2.3
	Glass Ceramic	2.2 - 2.8
	Silica Glass	2.17 - 2.22
	Soda-Lime Glass	2.44 - 2.49
Porous	Brick	1.9 - 2.1
	Concrete, typical	2.2 - 2.6
	Stone	2.5 - 3
Technical	Alumina	3.5 - 3.98
	Aluminium Nitride	3.26 - 3.33
	Boron Carbide	2.35 - 2.55
	Silicon	2.3 - 2.35
	Silicon Carbide	3 - 3.21
	Silicon Nitride	3 - 3.29
	Tungsten Carbide	15.3 - 15.9
Composites		
Metal	Aluminium/Silicon Carbide	2.66 - 2.9
Polymer	CFRP	1.5 - 1.6
	GFRP	1.75 - 1.97
Natural		
	Bamboo	0.6 - 0.8
	Cork	0.12 - 0.24
	Leather	0.81 - 1.05
	Wood, typical (Longitudinal)	0.6 - 0.8
	Wood, typical (Transverse)	0.6 - 0.8

Appendix IX. Young's Modules of Different Materials

		E (GPa)
Metals		
Ferrous	Cast Irons	165 - 180
	High Carbon Steels	200 - 215
	Medium Carbon Steels	200 - 216
	Low Carbon Steels	200 - 215
	Low Alloy Steels	201 - 217
	Stainless Steels	189 - 210
Non-ferrous	Aluminium Alloys	68 - 82
	Copper Alloys	112 - 148
	Lead Alloys	12.5 - 15
	Magnesium Alloys	42 - 47
	Nickel Alloys	190 - 220
	Titanium Alloys	90 - 120
	Zinc Alloys	68 - 95
Ceramics		
Glasses	Borosilicate Glass	61 - 64
	Glass Ceramic	64 - 110
	Silica Glass	68 - 74
	Soda-Lime Glass	68 - 72
Porous	Brick	10 - 50
	Concrete, typical	25 - 38
	Stone	6.9 - 21
Technical	Alumina	215 - 413
	Aluminium Nitride	302 - 348
	Boron Carbide	400 - 472
	Silicon	140 - 155
	Silicon Carbide	300 - 460
	Silicon Nitride	280 - 310
	Tungsten Carbide	600 - 720
Composites		
Metal	Aluminium/Silicon Carbide	81 - 100
Polymer	CFRP	69 - 150
	GFRP	15 - 28
Natural		
	Bamboo	15 - 20
	Cork	0.013 - 0.05
	Leather	0.1 - 0.5
	Wood, typical (Longitudinal)	6 - 20
	Wood, typical (Transverse)	0.5 - 3

Appendix X. Yield stress of Different Materials



		σ_y (MPa)	σ_{ts} (MPa)
Metals			
Ferrous	Cast Irons	215 - 790	350 - 1000
	High Carbon Steels	400 - 1155	550 - 1640
	Medium Carbon Steels	305 - 900	410 - 1200
	Low Carbon Steels	250 - 395	345 - 580
	Low Alloy Steels	400 - 1100	460 - 1200
	Stainless Steels	170 - 1000	480 - 2240
Non-ferrous	Aluminium Alloys	30 - 500	58 - 550
	Copper Alloys	30 - 500	100 - 550
	Lead Alloys	8 - 14	12 - 20
	Magnesium Alloys	70 - 400	185 - 475
	Nickel Alloys	70 - 1100	345 - 1200
	Titanium Alloys	250 - 1245	300 - 1625
	Zinc Alloys	80 - 450	135 - 520
Ceramics			
Glasses	Borosilicate Glass (*)	264 - 384	22 - 32
	Glass Ceramic (*)	750 - 2129	62 - 177
	Silica Glass (*)	1100 - 1600	45 - 155
	Soda-Lime Glass (*)	360 - 420	31 - 35
Porous	Brick (*)	50 - 140	7 - 14
	Concrete, typical (*)	32 - 60	2 - 6
	Stone (*)	34 - 248	5 - 17
Technical	Alumina (*)	690 - 5500	350 - 665
	Aluminium Nitride (*)	1970 - 2700	197 - 270
	Boron Carbide (*)	2583 - 5687	350 - 560
	Silicon (*)	3200 - 3460	160 - 180
	Silicon Carbide (*)	1000 - 5250	370 - 680
	Silicon Nitride (*)	524 - 5500	690 - 800
	Tungsten Carbide (*)	3347 - 6833	370 - 550
Composites			
Metal	Aluminium/Silicon Carbide	280 - 324	290 - 365
Polymer	CFRP	550 - 1050	550 - 1050
	GFRP	110 - 192	138 - 241
Natural			
	Bamboo	35 - 44	36 - 45
	Cork	0.3 - 1.5	0.5 - 2.5
	Leather	5 - 10	20 - 26
	Wood, typical (Longitudinal)	30 - 70	60 - 100
	Wood, typical (Transverse)	2 - 6	4 - 9

(Data courtesy of Granta Design Ltd)