JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF MECHANICAL ENGINEERING

DESIGN OF MECHANICAL SYSTEM ENGINEERING

DESIGN OPTIMIZATION AND PERFORMANCE EVALUATION OF MANUAL SCREW PRESS CRUDE HONEY EXTRACTOR

A Thesis Submitted to School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for Degree of Masters of Science in Design of Mechanical System

By: Galana Fufi Gula

December, 2023

Jimma, Ethiopia

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Main Advisor: Dr.-Ing. Getachew Shunki

Co-Advisor: Miss. Mekdes Tsegaye (MSc)

December, 2023

Jimma, Ethiopia

DECLARATION

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person for the award of any other degree or diploma of the university or other institute of higher learning which is entitled**" Design Optimization and Performance Evaluation of Manual Screw Press Crude Honey Extractor"** except where due acknowledgment has been made in the text. Any scholarly matter that is included in the thesis has been given recognition through citation.

Galana Fufi	________________	________________
Candidate	Signature	Date

This research has been submitted for examination with my approval as university supervisor.

Dr.-Ing. Getachew Shunki		Oct. 24, 2023
Main Advisor	Signature	Date
Miss. Mekdes Tsegaye (MSc)		25/10/2023
Co-Advisor	Signature	Date

APPROVAL SHEET

As a member of the Examination Board of the final Master of Science open defense, we certify that we have read and evaluated the thesis prepared by Mr.Galana Fufi Gula entitled ''D**esign Optimization and Performance Evaluation of Manual Screw Press Crude Honey Extractor''** We recommend that it could be accepted as a fulfilling the thesis requirement for the Degree of Master of Science in Mechanical Engineering (Design of Mechanical System).

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ABSTRACT

In Ethiopia, an estimated 5.89 million beehives out of which farmers keep about 5.66 million beekeepers use traditional hives. Honeycombs from these hives and colonies are normally harvested and extracted using traditional methods. This method leads to contamination of honey and incomplete extraction with impurities in the extract. Moreover time-consuming and tiresome, which implies that more valuable time is spent on extracting honey. Honey producers living in different rural areas have no idea of the quality of honey they produce. A screw press honeycomb extractor is a good alternative to the existing methods of honeycomb extraction for both traditional and modern hives. However, this method left some honey on the base of the pressing chamber limiting honey extraction efficiency. This may be due to honey smearing or hanging on the components making up the pressing chamber. This paper aims to design optimization and performance evaluation of manual screw press crude honey extractor to improve extraction efficiency. Therefore, this study is to address the problem of screw press honeycomb extraction focusing on the design of the pressing chamber, and the base of the pressing chamber for optimum shape and size. Freshly harvested 27 kg crude honey was obtained from honey producers residing in the East Wollega zone Gudeyabila district and divided into two portions. The first portion was given to a local honey processor who used the traditional method of honey extraction which involves the Debela shash and sieve method to extract the honey. The second portion of the freshly harvested honeycomb is used for the performance evaluation of the designed screw press. The average extraction capacity for the screw press honey extractor method was 38.24$Kghr^{-¿¿}$. This is significantly higher (p<0.05) than the extraction capacity calculated for the sieve and debela shash method which was 10.72 $Kghr^{-¿¿}$and 0.54 $Kghr^{-¿¿}$of honey respectively. The extraction efficiency which indicates equipment performance was 81.10 % for the designed Screw press honey extractor, 78.66 % for the sieve method, and 76.44 % for Debela shash method. The honey extracted using the designed screw press is more desirable compared with the honey extracted using the traditional method.

Keywords: *Beekeeping, Screw press, pressing chamber base optimization, comparative effect, Crude honey, and Honey extraction*

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ACRONYMS

HBRC	Holeta Bee Research Center
EIAR	Ethiopia Institute of Agricultural Research
EIAO	Environmental Impact Assessment Ordinance
CSA	Central Static Agency
ARSD	Apiculture Research and Development Strategy program
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
IVCA	Integrated Value Chain Analyses
MOARD	Ministry of Agriculture and Rural Development
AAU	Addis Ababa University
KTBH	Kenya Top Bar Hive
2D, 3D	two dimensional, three dimensional
3D-CAD	Three-dimensional computer-aided design
CAD	Computer-aided design
SPSS	Statistical Package for the Social Sciences
ANOVA	Analysis of Variance
DOF	Degree of freedom
FEA	Finite element analysis
AISI	American Iron and Steel Institute
BAERC	Bako Agricultural Research Center
OARI	Oromia Agricultural Research Institute

SYMBOLS

τ = Torsional shear stress,

T = Torque applied

d_c = Minor or core diameter

J= Polar moment of inertia

τ_s = Shear Stress

d = Major diameter

$\sigma_{b=¿¿}$Bending stress

σ_t = Permissible tensile stress

τ_{max}=¿Maximum principal shear stress

V = Volume

SA = Surface Area

σ_h = hoop stress

P = Internal pressure

σ_l = longitudinal stress

W = work done

m_f = Mass flow rate

CE = Extraction Capacity

η_E = Extraction Efficiency

CHAPTER 1

INTRODUCTION

In this chapter, a brief introduction to the design and performance evaluation of a manual screw press crude honey extractor is presented. The problem is stated, and the objectives, scope, and limitations of the research are explained.

1.1 BACKGROUND OF STUDY

A bee is a winged insect that gathers pollen and nectar from flowers and produces honey for food and wax for other purposes. They usually stay in large colonies and obtain their energy and proteins from flower nectars and pollen respectively[1]. Bees are characterized by their potential to collect honey in large quantities which can then be harvested for human consumption and generation of income from the sale of their products [2]. The beekeeping subsector is creating job opportunities in both rural and urban areas[3]. Many tropical countries have successfully processed and marketed crude honey using producers, cooperatives, and small-scale processors.

Honey is a sugary constituent produced naturally by bees from flower nectars. Bees gather and covert nectar by combing with particular substances of their own to produce honey. Honey is then deposited, dehydrated, stored, and left in the honeycombs to mature[4]. Its color varies from colorless to dark brown depending on the source. Honey is one of the oldest sweetening agents and is defined as the natural substance produced by *Apis mellifera* bees from the plant nectar, from secretions of living parts of the plants, or excretions of plant-sucking insects on the living part of plants[5]. It was the major product made by bees and consumed by humans apart from wax and propolis[6]. Honey has been appreciated as a food source because it is fit for human consumption[7]. It has been used as a sweetener in making cakes, bread, and drinks, among others. It is the main ingredient in alcoholic beverages like wine and beer, normally made with a mixture of honey, water, and the addition of yeast to allow for fermentation.

It contains antibacterial constituents essential in the treatment of several illnesses like gastric disturbances, wounds, sore throats, and burns[8]. It helps in increasing milk production in dairy cows and is also used in most industries for making hand lotion and facial cleansers. Therefore, the significance of the honey processing industry cannot be underestimated in a developing country like Ethiopia. Given the multi-dimensional array of benefits obtained from honey, investing in honey production is vital in improving the living standards of honey producers residing in rural areas.

Ethiopia is one of the countries with a large honey- producing potential in Africa. The country is home to a rich flora and has Africa’s greatest honeybee population due to its unique ecological and climatic circumstances [9]. The country's large and diversified botanical resources, together with favorable weather conditions, make it ideal for beekeeping. Around 10 million honeybee colonies exist in the country, with roughly 7 million kept in beehives by farmers and the rest living in the wild in the forests [10]. Because of its large number of colonies, it is Africa’s biggest honey and beeswax producer[11].

Ethiopia honey production accounts for approximately 2.5 % of world production and 21.7% of African honey production[12]. Ethiopia has the potential to produce a high amount of honey per year, but currently, production is limited to 48.71 million kilograms of which the greater portion is harvested from traditional hives. There are an estimated 5.89 million beehives out of which farmers keep about 5.66 million traditional, 71,900 intermediate, and 149,871 modern beehives[13]. The approximate potential is not met due to poor methods of harvesting, handling, extraction, storage as well and marketing of honey[14]. The inexistence of an extractor to improve the processing of quality honey harvested from indigenous hives and natural colonies has resulted in most honey producers using traditional methods to harvest and process honey. This method produces poor-quality honey due to the unhygienic way of handling honey. Honey producers squeeze honeycombs to extract honey using bare hands, hence leading to honey` contamination and impurities due to incomplete extraction. The method also involves the use of water baths to heat honeycombs, however, if this is not done wisely, would increase moisture content in honey leading to fermentation upon storage. Moreover, the beehive is usually burned down during harvesting hence destroying it completely. Several bees die and the remaining ones move to new sites to start over. This, in turn, reduces their population hence lowering honey production rates in the area. All these drawbacks as observed from poor harvesting, processing, and storage conditions of honey, have led to low-quality honey produced in the rural areas and sold in the local markets at very low prices.

Despite the higher potential to produce a high amount of honey per year in the country, there are still many challenges and constraints facing the beekeeping sector. Among these, challenges that are affecting the production and development of honey production and marketing are dependency on traditional and low technology input, poor pre and post-harvest management, inadequate extension service, and poor marketing infrastructure. Furthermore, the lack of smallholders' access to finance contributes to inhibiting the adoption of improved technology for honey production, Poor quality, limited supply in the face of higher local demand entailing higher domestic prices, coupled with the absence of organize market channels and lack of information have made Ethiopian honey uncompetitive in the international market[15].

Moreover, in many areas of the country, beekeepers suffer from the higher cost of honey-extracting equipment, which causes a shortage of good quality and quantity honey supply in the market from smallholders'. These conditions drive many smallholder beekeepers to sell their honey without processing at low prices at the farm gate. In most parts of the country, neither large-scale nor small-scale honey processors may lead to poor quality honey consequently with low prices for the producers. In addition, the lack of processing of honeybee products into different honeybee by-products is another bottleneck for the honeybee outputs price and proper use of the apiculture sector[16]. Scientific way of keeping honey bees, and access to improved way of processing equipment was not common in the specific area. Adopting improved technology and improved management practices would greatly improve the yield and quality of honey[17].

Honey extraction is the central process in beekeeping. It involves removing honey from combs to isolate it as pure liquid. There are three major different ways employed in extracting honey from the combs. These are squeezing, centrifuging, and pressing. The squeezing method is where the chopped /crushed combs are poured into a strainer clothing using hands to turn the end(s) of the strainer forcing the honey to drip into a container. This is tedious and results in low output. The centrifugal extractor varying in design and capacity from 2 to 72 frames is the modern and most appropriate technology because it guarantees a replacement of the honey combs, thereby increasing honey production efficiency by the bee colony as no energy is required for rebuilding the combs. The centrifuges are imported, not easily affordable, and very expensive to cost [18]. In honey pressing, the comb is first decamped, chopped into pieces, and pressure applied through various means to remove the honey. In this operation, the honey combs are mashed and then pressed to extract honey. Moreover, honey from this type of equipment has high levels of water-insoluble solids content, usually 0.5 g/100 g of honey and above, much higher than the recommended limit of 0.1 g/100 g for centrifuged honey[19].

The screw press has an extraction efficiency of 70.6%, against 56.33% for the traditional method (the weight and sieve method), better honey recovery, and saves time (average of 6.5min.as against 62.33min for the weight and sieve method) and slow honey recovery. After every batch of operation, the weight of the honey extracted and the residue that was left was collected and measured. A slight variation is noticed between the weights of samples before and after extraction. This may be due to honey smearing or hanging on the components making up the pressing chamber[20].

The study is concerned with increasing the performance of the press by changing the bottom part of the cylinder container and enhancing the size of the cylinder. The development of a presser is a long process that requires several design, fabrication, and evaluation. A systematic procedure is obtained where CAE and tests may be used together. Their use has enabled engineers to reduce product development costs and time while improving the safety, comfort, and durability of the press they produce. The optimized geometry is analyzed in the field.

1.2 Statement of the Problem

Honey producers living in different rural areas have no idea of the quality of honey they produce. The impurities like wax, insect parts, and debris extracted along with honey increase the amount of water-insoluble solids in the extract. Separation of these impurities requires extra cost. Therefore, there is little or no possibility of achieving competitive prices both locally and internationally due to the low quality of honey produced in the area[21].

Most honey producers in the area have traditional hives and natural colonies. Honeycombs from these hives and colonies are normally harvested and extracted using traditional methods. In Ethiopia, an estimated 5.89 million beehives out of which farmers keep about 5.66 million of the beekeepers use traditional hives that presumably lead to honey of low quality [22]. The process involves an unhygienic method of squeezing the honeycombs using bare hands. This leads to contamination of honey and incomplete extraction with impurities in the extract. Honey produced in this manner is not fit for human consumption due to health risks associated with the process and does not attract international market standards. This method is also time-consuming and tiresome, which implies that more valuable time is spent on honey extraction.

In most areas of the country, imported screw press honey extractors are used; such extractors are expensive and involve high-level technology which cannot be afforded by small-scale and low-income beekeepers in addition to lower extraction efficiency due to honey left on the screw press base, and smeared in the wax comb after extraction.

To reduce the problem of honeycomb processing, the extraction method is needed. Therefore, the objective of this study is to address the problem of screw press honeycomb extraction focusing on the design of the pressing chamber, and base of the pressing chamber for optimum size and shape. More over-stress analysis on the extraction was performed using finite element analysis software, Solid work in developing the conceptual framework to improve the efficiency of screw press crude honey extraction.

1.3 Objectives of the Study

1.3.1 General Objective

The main objective of this study is base line study, design optimization, and performance evaluation of manual screw press crude honey extractor to improve extraction efficiency

1.3.1 Specific objectives

The specific objectives of the study include:

- ❖ Base line study of a manual screw press crude honey extractor
- ❖ To design optimization of a manual screw press crude honey extractor
- ❖ To evaluate the performance of a manual screw press crude honey extractor

1.4. Significance of the study

Most honey producers process honey using traditional methods. This is due to inadequate finances to purchase modern honey extractors available in the market. Therefore the important of this project is to improve the efficiency of the screw press crude honey extractor which means to make easily discharge, save extraction time, and save the waste of material for production. And to establish base line study for the screw press and optimization pressing chamber base in the early phases of the product development process, the methodology included optimization-related subjects such as objective function, constraints, and also called physicochemical analysis constraints for a screw presser crude honey extractor. Furthermore, load distribution cases and boundary conditions that are relevant to the shape optimization process are treated. The enhanced stationary screw press problem would be resolved by the new pressing chamber base, and both the extraction capacity and extraction efficiency of the screw press were improved. In addition to this, the contribution of the study can serve as a baseline or reference for other researchers, either individuals or companies, who want to investigate screw presses.

1.5 Scope and limitation of the study

1.5.1 The scope of the research

The scope of this study is limited to focus on design optimization and performance evaluation of manual screw press crude honey extractor to improve extraction efficiency. The presser was designed and its performance evaluates to suit other small-scale producers who are low-income earners and cannot afford to purchase modern honey extractors. Optimizing the screw press with means of parametric parts by using software packages and other optimization and analysis methods were considered in this study.

1.5.2 Limitation of the research

The major limitation of the work of this study is the Physicochemical properties (Moisture content, Electrical conductivity, Ash content, Free acidity, HMF, Glucose, Fructose, Sucrose, and Diastase) of honey from three extraction methods was not verified due to a lack of sufficient laboratory and expensive material costs. The performance indicators will not be limited to the time elapsed to extract honey, the weight of honey extracted, extraction efficiency, extraction capacity, and weight of honey residue.

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CHAPTER 2

LITERATURE REVIEW

This chapter provides an overview of the literature from various researchers' previous works published in books and articles. The literature review aims to gain insights into previous works on implementing various types of honey extraction methods and optimizing the design of honeycomb extraction using screw presses. The main objective of this literature review is to gather knowledge in the academic and research fields related to the topic of study.

2.1 Beekeeping and honey production

Honey production is one of the direct contributions of beekeeping practices. In terms of economic contribution and export commodities, honey is one of the marketed livestock products of Ethiopia. As a result, there was an increased demand for honey production between 2000 and 2008 the total honey production in Ethiopia increased almost by 69% from 29,000 to 42,000 tons [24].

The capacity of honey production varies generally from one country to another. For instance, the highest production yields produced by China were 170,000 tones, while Argentina produced 45,500 tones. In Africa, Ethiopia is the leading honey producer, followed by Tanzania[25]. Generally, the leading importers of honey in the world are mainly United States, Germany, Japan, the United Kingdom, and France. In 2017, honey production in the world was at 1.9 million tones with China having the highest percentage of 29 % of this total. Other major honey-producing countries were Turkey, the United States, Iran and Ukraine. Appendix (III) shows the production of natural honey as of 2017 from these countries [26]. In most African countries, honey mostly consumed is from traditional hives and processed using hand-squeezing methods.

2.2 Types of Beehives

Currently, there are three types of beehives in Ethiopia, namely, traditional (forest and backyard), intermediate (transitional), and modern (frame) hives. The critical classification of each beehive is based on employed technologies and the probable productivity of each system [27].

2.2.1 Traditional Forest and Backyard hive

Traditional beekeeping is the major and oldest type of beekeeping practiced in Ethiopia. It is practiced by traditionally constructed hives which are mostly cylindrical in shape (about 1-1.5 meters in length and 30-50-centimeter width) and single chamber fixed comb [28]. This type of hive can be made from wood, mud/ clay. It has no internal structures; frames were provided for the bees; the bees created their honeycomb within the hives. The comb is often cross-attached and cannot be moved without destroying it (G, 2017). The comb is often cross-attached and cannot be moved without destroying it. From this hive, on average 7kg/hive/season crude honey is produced.

Figure 2 - 1 Traditional Forest and Backyard hive

(Source: Sebsib Ababor and Yibrah Tekle*, 2018)

2.2.2 Intermediate (transitional) hive

A transitional hive is a frameless beehive in which the comb hangs from removable bars. The bars form a continuous roof over the comb, whereas the frames in most current hives allow space for bees to move up or down between boxes. This hive is similar in design to the Kenyan top bar and made from locally available materials. From this hive, on average 15kg/hive/season crude honey is produced. It is the hive between the traditional and frame hive or modern hive[29]. The transitional system started in Ethiopia in the year 1976 and the types of beehives used are Kenya top-bar beehives, Tanzania top-bar beehives, Mud-block beehives, and Ethio-ribrab hives. However, Ethio-ribrab is commonly used in many parts of the country [30].

Figure 2 - 2 Transitional hive

(Source: Demisew W 2016)

2.2.3 Modern/Frame hive

Frame/Box hives is type of vertically modular bee hive that accepts frames. The hive frame is a key part of the frame/box hive since it can be removed to inspect the bees for disease or to extract the excess honey. From this type of hive, pure honey can be harvested and the average honey production is 25 kg/hive/season.

The frame hive beekeeping methods aim to obtain the maximum honey crop, without harming bees. It uses different types of frame beehives such as Zandar, Langstroth, Dadant, Modified Zander, and Foam beehives exist in Ethiopia [31]. These beehives differ in number of frames and size of the hive. The most commonly used frame beehive type in Ethiopia is the Zander type.

Figure 2 - 3 Modern/Frame hive

(Source: Tessega, 2009)

2.3 Honey processing methods

The existing centrifugal extractors in the market are either radial or tangential depending on how the honeycomb frames are arranged inside the extractor [32]. These extractors give clean honey with fewer impurities such as pollen grains, wax, debris, and insect parts. In radial extractors, there is no need to rearrange the frames once they have been loaded because honey is extracted simultaneously from both sides of the frame. Whereas, in tangential extractors, honey is empty from one side of the frames while spinning, then turned around so that the other side of the frame is also empty. There is no difference in the direction of rotation for both radial and tangential honey extractors. Tangential, radial, automatic programmable, and electrical-driven types of honey extractors have been developed in advanced countries such as the United States, Germany, etc., [6]. However, these extractors are of high cost to be purchased by indigenous honey producers [1].

2.3.1 Tangential and radial honey extractor

The centrifugal extractors in the market are either radial or tangential depending on how the honeycomb frames are arranged inside the extractor. The tangential extractors type (the combs sit tangent to the direction of the spinner's rotation) that is used for extracting honey. Honey is emptied from one side of the frame when spinning, then turned around so that the other side of the frame is also emptied [33]. In radial extractors, there is no need to rearrange the frames once they have been loaded because honey is extracted simultaneously from both sides of the frame. There is no difference in the direction of rotation for both radial and tangential honey extractors. Tangential, radial, automatic programmable, and electrical-driven types of honey extractors have been developed in advanced countries such as the United States, Germany, etc.,

Figure 2 - 4 Tangential Honey Extractors

(Source: AL-Rajhi. M. A. and A. M. A. EL-Sheikh,2014)

2.3.2 Honey extracting machine

The honey extractor was designed to extract honey from honeycombs when pressed against a fixed wall. In the operation of the machine, the electric motor is switched to its anti-clockwise motion to drive the pressure plate to an already marked-out point to allow for the loading of the hopper/extractor chamber [34]. However, these extractors are of high cost to be purchased and this extractor was not fabricated using locally available materials. The extraction machine is shown in figure 2.5.

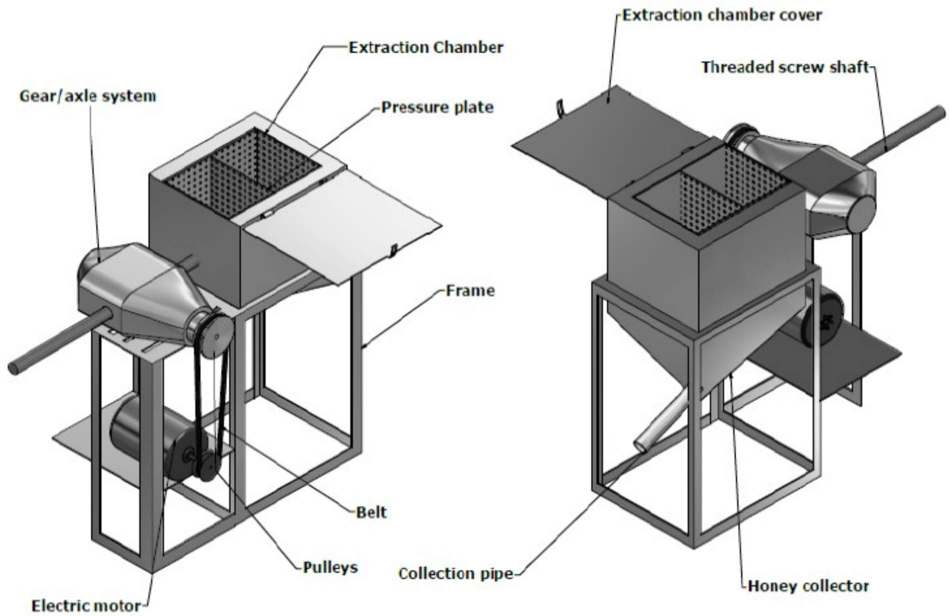


Figure 2 - 5 Honey-extracting machine

(Source: Archibong F. N, Ugwuishiwu,B. O. , Okechukwu M. E. and Ajah S. A. 2021)

2.3.3 Pedal-operated honey extractor

Design a pedal-driven honey extractor for extracting honey from frame hives as shown in Figure 5, which was an improvement of the formerly designed hand-driven extractor [1]. The extractor was designed to accommodate a pedal mechanism. The efficiency of the designed extractor was found to be 85 % more efficient than the previous design which had an efficiency of 83.29 %. The operator cannot get tired easily because it can be cycled repeatedly as many times as possible to increase honey production. This would ensure improved standards of living for the honey producers from the sale of their products.

The designed extractor was found to be effective and could extract honey hygienically from the honeycombs. The machine could be operated by anyone and requires less energy to drive the pedals.

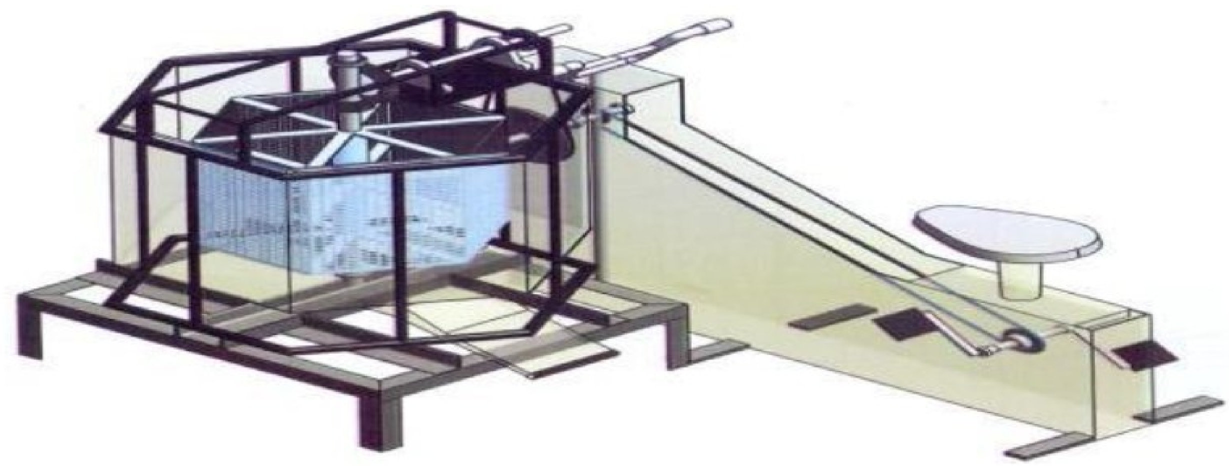


Figure 2 - 6 Pedal-operated honey extractor

(Source: Akinnuli B, Awopetu O, Ikubanni P and Agboola O 2016)

2.3.4 Electrically-operated honey extractor

Designed and constructed an electrically operated honey extractor for frame hives as shown in Figure 6 using easily available and accessible materials to cut the cost of producing the machine [35]. The designed extractor was deemed portable and could be operated by anyone without any special training or technical expertise. The extractor was designed to be used at any time of the day regardless of the temperature or climatic conditions. The efficiency of the machine was 68.16%.

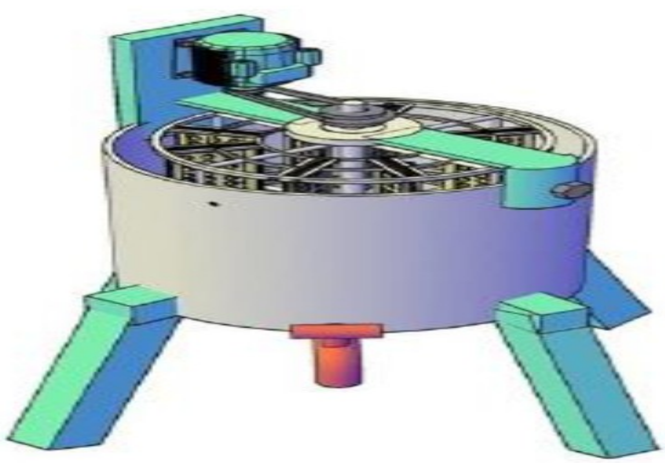


Figure 2 - 7 Electrically-operated honey extractor

(Source: Joel O, Patrick I and Oyejide J 2018)

2.3.5 Vibratory honey extractor

Designed and fabricated a vibratory honey extractor for extracting honey from Kenya Top Bar hive (KTBH) as shown in figure 2.8 to solve the problem of crushing the honeycombs along with the extract [36]. The machine was made of stainless steel, mild steel, and plastic materials. The machine operated at a speed of 483 rpm and a frequency of 50 Hz. It was able to extract honey in the preferred quality and quantity within 40 minutes of operation at an efficiency of 98.9%. It was found to produce good quality honey that has high market value thereby improving the livelihood of stakeholders in honey business industries.

Figure 2 - 8 Aerial view of the vibratory honey extractor

(Source: Ola, et al., 2016)

2.3.6 Manually-operated honey extractor

Developed an affordable and portable manually-operated honey extractor for extracting honey from frame hives [6] as shown. The extractor was fabricated using locally available materials to reduce the cost of purchasing the machine for the honey producers. It was stated that the extractor produces honey for economic and medicinal purposes. It was also stated that the accessibility of the fabricated extractor would ensure increased production rates of honey into the market, reduce drudgery among the honey producers during processing, create employment opportunities for the jobless, and increase the economy of a country through the exportation of honey and its products. The physical properties of honey such as viscosity, density, hygroscopicity, surface tension, and thermal properties were taken into consideration before designing and fabricating the extractor. The extractor was made simple and manually operated so that it could be installed at home or farm where the breeding of honey bees is possible. The machine could be used in both rural and urban areas where there is no electricity. The fabricated extractor was 82 % efficient.

Figure 2 - 9 Manually-operated honey extractor

(Source: Sircar and Yadav, 2018)

2.3.7 Mechanical screw press honey extractor

Designed and fabricated a mechanical screw press honey extractor for extracting honey from both frame and log hives [20]. The extractor was considered a good option for the existing methods of honey extraction. The extractor was found to be timely in its production and minimized the workload involved during honey extraction. The extractor was also found to reduce the risk of contamination due to contact with bare hands, overheating, over-exposure to the environment, and filtering medium as compared to the traditional method.

It was considered to be cheap and hence could be purchased by low-income honey producers, long-lasting, and requires no special proficiencies in its operation. The designed extractor had an efficiency of 70.6 %, as compared to that of the weight and sieve method with an efficiency of 56.33 %. The extractor components were sourced from locally available materials. However, these imported screw press honey extractors honey remains that had been extracted smeared in the wax comb and screw press base.
Figure 10 shows the isometric projection of the screw press. Parts A, B, C, D, E, and F represent the turning bar, threaded pressing shaft, flat iron bar, pressing chamber, discharge outlet, and supporting frame respectively.

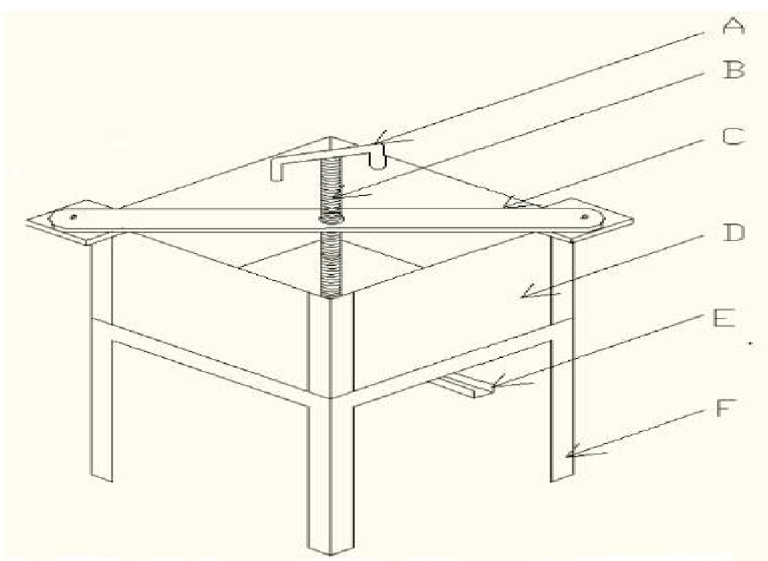


Figure 2 - 10 Mechanical screw press honey extractor

(Source: Maradun and Sanusi, 2013)

2.4 summary of the literature survey and research gap

Several researchers have proposed different methods for honey processing methods. The following points can be summarized from the pieces of literature review. Designed and fabricated honey extractors for extracting honey from modern beehives, i.e., Zander hives [1], [6], [34], [35]. These beehives have frames that can be loaded onto the extractors. However, these extractors are only used for modern (frame) hives and also high cost to be purchased [20]. Designed and fabricated a mechanical screw press honey extractor for extracting honey from both modern and traditional hives. The extractor was considered a good option for the existing methods of honey extraction. In most areas of the country, imported screw press honey extractors are used; such extractors are expensive and involve high-level technology which cannot be afforded by small-scale and low-income beekeepers in addition to lower extraction efficiency due to honey left smeared in the wax comb after extraction. To assist the small-scale beekeepers in rural communities, the imported screw press honey extractor was needed to design optimized, evaluated, and integrated into the beekeeping subsector.

In the reviewed literature it is observed that the design optimization of the screw press crude honey extractor has not taken into consideration of the parameter part, shape, and size optimization of the screw press honeycomb extractor. Also, there is no information about the base of the pressing chamber shape optimization, stresses, and strains that are concentrated at the base of the pressing chamber. Therefore, there is a need to design optimization and validate a screw press crude honey extractor to improve extraction efficiency. The optimized screw press minimizes honey left on the pressing chamber base and reduces human power operation and extraction time due to the cone shape in the design optimization of the pressing chamber base.

CHAPTER 3

MATERIALS AND METHODS

3.1 DESCRIPTION OF STUDY AREA

The study was carried out at the Holeta Bee Research Center. Holeta Bee research center is a pioneer research center that is mandated to conduct research in apiculture in the region as well as the country, which is found in the West Shoa zone of the Oromia region, around Addis Ababa, 39 km west of Addis Ababa**.** It has a latitude and longitude of 9°3′N 38°30′E and an altitude of 2391 meters above sea level. The selection of a research study field is influenced by the researcher's goals and interests as well as the topic's applicability to the honey production area. The prototype was manufactured in the Bako Agricultural Engineering Research Center (BAERC) workshop, and the Screw press performance evaluation was carried out in the East Wollega zone.

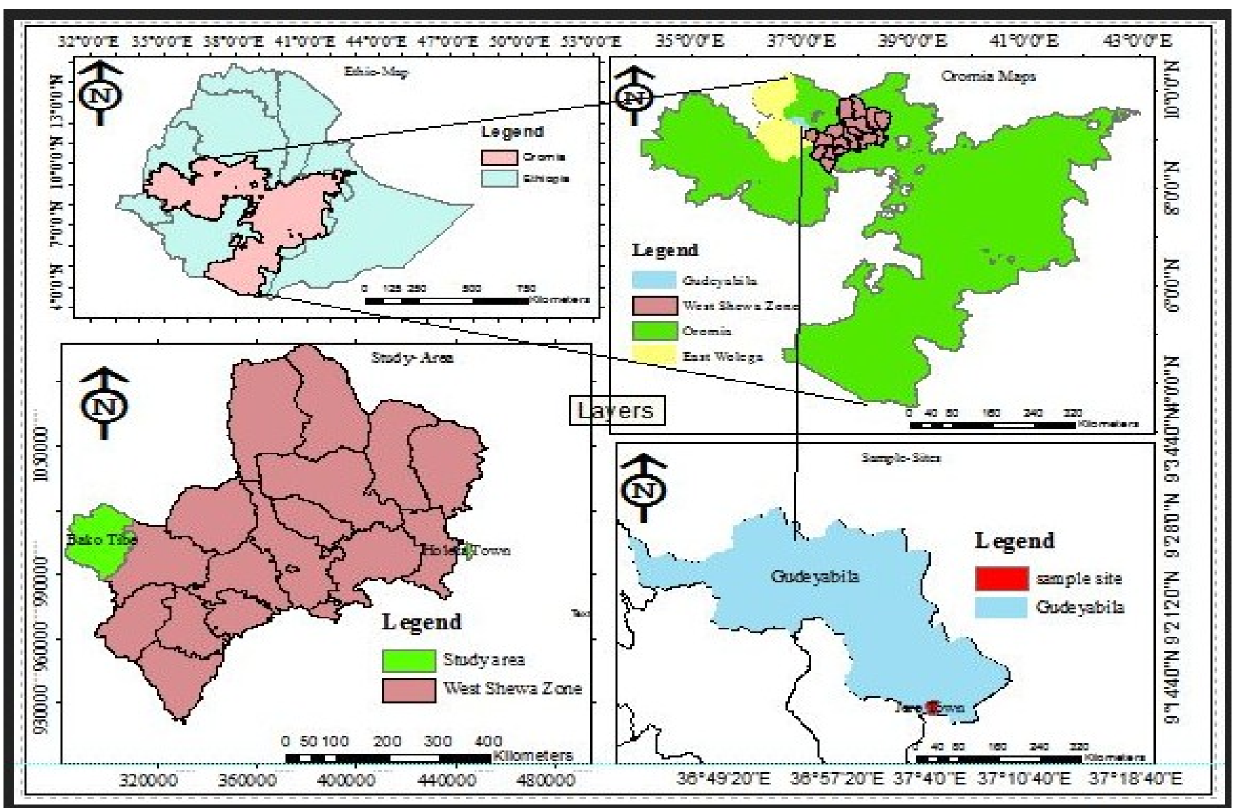


Figure 3 - 1 Holeta in Oromia region and the selected sites

3.2 Research Design

This study was carried out in two phases: the first phase was design optimization and fabrication of a model manual screw press crude honey extractor and the second phase is performance evaluation of the designed manual screw press crude honey extractor. The characterization of honey extraction was compared with the traditional processing method.

3.3 Materials selection for construction

When selecting engineering materials, especially for food processing equipment and in particular honey processors, the overriding consideration for material selection is its ability to resist corrosion. Since honey is an acidic food with a pH of about 3.9 [37] the material used for the construction of the main parts of the honey extraction is stainless steel. This material is corrosion-resistant with sufficient strength and is easy to work on during fabrication. Though a little bit expensive, stainless steel satisfies both processing and mechanical requirements, allowing for maintenance, and replacement, as well as offering safety with no product contamination. The criteria for selecting the materials were based on their durability, strength, and suitability of the material for honey extraction. This ensures an increase in the shelf-life of equipment as well as reducing the cost of maintenance.

List of materials used in the experiment:

- ✓ Stainless steel sheets
- ✓ Stainless steel rods
- ✓ Angle cast iron
- ✓ flat iron bar
- ✓ Bolts and nuts
- ✓ Welding electrodes
- ✓ Honeycomb
- ✓ plastic containers

3.4 Conceptual Framework

The Conceptual Framework that was implemented in this thesis work is explained in detail in Figure 3.2

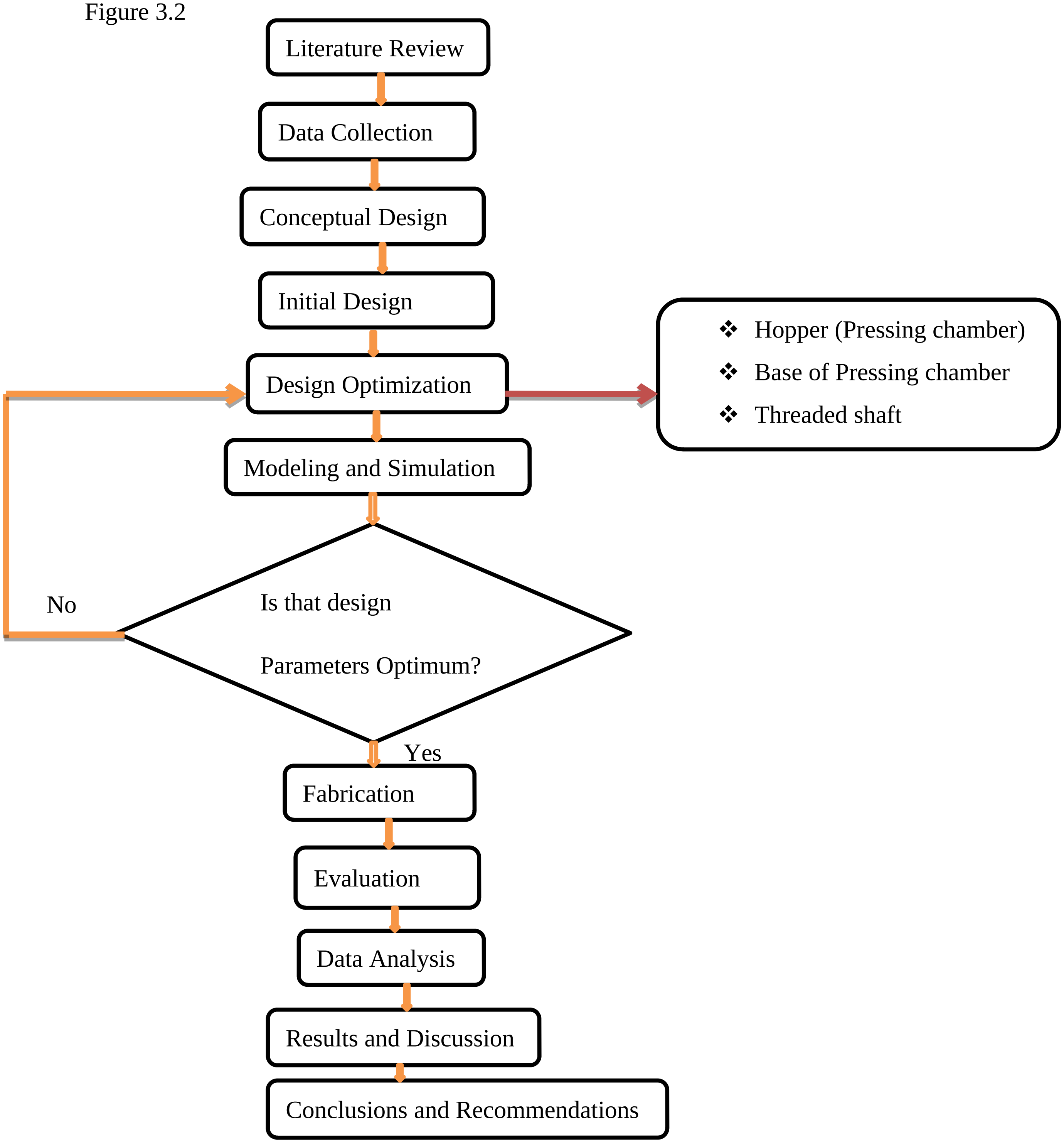


Figure 3- 2 Conceptual Framework

3.5 Analysis and optimization Methods of a manual screw press crude honey extractor

Design optimization is an important engineering design activity. The process of determining the best design is called optimization. In general, design optimization determines values for design variables such that an objective function is optimized while performance and other constraints are satisfied. The use of design optimization in engineering design continues to increase, driven by more powerful software packages and the formulation of new design optimization problems motivated by the decision-based design (DBD) framework. The design optimization model is a subjective process that requires engineering judgment and technical skills. In a given design situation, there are likely to be many variables, parameters, constraints, and criteria related to different performance attributes. Thus, there are a variety of relevant optimization models from which to choose[38].

The design and analysis of the screw press are done by considering it as a pressing chamber base. Screw presses with cone shape are commonly used. From the literature presented in this paper circular shape mechanical screw press is done. This study deals with the study of a screw press consists the cone shape as well as the modification of the pressing chamber in which the extraction efficiency and extraction capacity optimization is done by changing the pressing chamber base. For this method of optimization, shape optimization is used as a tool. Based on the honey flow rate pressing chamber base is changed.

Table 3- 1 Analyzed variables and analyzed functions for screw press optimization case

Analyzed variables	Analyzed functions
✓ Pressing chamber base	✓ Maximizing extraction efficiency ✓ Maximizing extraction capacity
✓ Pressing chamber (Hopper)	✓ Hoop stress ✓ Longitudinal Stress ✓ Equivalent (Von-Mises) stress ✓ Total deformation

3.5.1 Structural design and optimization

Many structural design problems aim to find the best design among many possible candidates. For this reason, the design engineer has to specify the best possible design as well as the best possible candidates[39]. Structural design tools include topology, topography, and free-size optimization. Sizing, shape, and free shape optimization are available for structural optimization. Structural optimization techniques consist of various aspects. For example, structural optimization may depend on the application fields it was used for. Then it is divided into size, shape, and topology optimization.

3.5.2 Mathematical formulation of the optimization problem

The optimization task for the problem is to determine the optimal geometric parametric of the base of the pressing chamber which led to the maximization of extraction efficiency and extraction capacity of the screw press, and minimizing time-consuming and human power operation.

The optimization problem is defined in the following way; Maximization of the objective function

f¿¿)

Subject to the constraint function

$g_i(x) \leq 0$, i=1…, m

Where it fulfilled, $x_j \geq 0$

And

$1 \leq x_j \leq u_i$, i=1… n

Where $f_{(x)}$= the objective function

$g_i(x) \leq 0$, i¿ 1...., m¿the constraint function

l_i, u_i ¿Lower and upper limits of design variables,

$i, _j$= Number of constraints and number of design variables,

$X ¿ \{X_{1...,} X_n\}^T$Projected vector of n variables; project variables are the value that should be determined during the optimization process (each project variable is defined by its lower and upper limit)

3.5.3 Objective function and constraints

1. Objective function

The objective function is represented by the maximization of a base of pressing chamber to optimum extraction efficiency and extraction capacity of the screw press and minimizing time-consuming and human power operation.

2. Constraints functions

Optimization processes are based on permissible stresses, according to the Winkler-Bach theory. The total deformation in the pressure plate is proportional to the distance from the base of the pressing chamber (axis). The base of the pressing chamber is characteristic points with allowed stresses, according to the constraint function of the mathematical form.

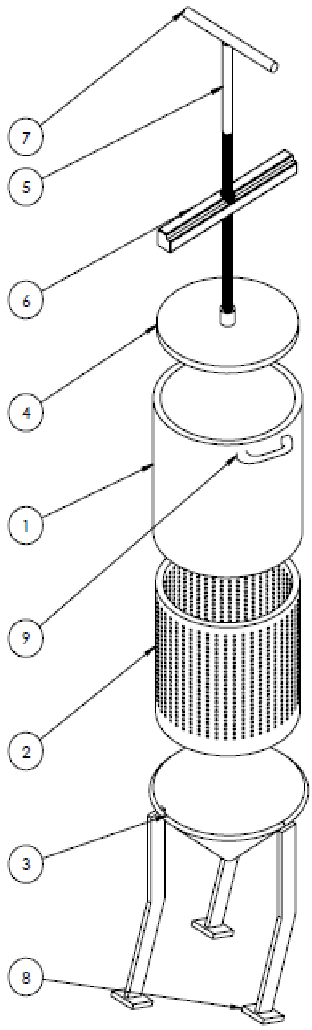
3.5.4 Structural size and shape optimization

To better understand the optimization of structures and the focus of this work, two definitions must be stated. The first definition is that of the structure, including all implications and capabilities in the static analysis of such systems. The second definition applies to that of structural optimization, more specifically the optimization of size and shape. These two primary definitions hold for the entirety of this research and are derived from[40]. The goal of a shape optimization analysis is to find the best use of material for a body.

3.6 Design optimized models for the screw press honey extractor

3.6.1 Parts of the screw press honey extractor

Figure 3.3 shows an exploded view design optimization and performance evaluation of a manual screw press honeycomb extractor to improve extraction efficiency. Table 3.1 also shows a summarized description of the various components of the design-optimized screw press honey extractor.



ITEM NO.	PART NUMBER	QTY.
1	OUTER CYLINDER	1
2	INNER CYLINDER	1
3	BASE OF PRESSING CHAMBER	1
4	PRESSURE PLATE	1
5	THREADED SHAFT	1
6	ANGLE CAST IRON	1
7	TURNING BAR	1
8	FRAME	3
9	HANDLE	2

Figure 3 - 3 Exploded view of the screw press honey extractor

Table 3 - 2 Parts of the Screw press extractor

No	Part name	Description
1	Outer Cylinder	Made of stainless steel plate used to hold the inner cylinder and to support the frame and angle iron bar
2	Inner Cylinder	Made of stainless steel plate used to hold crude honey and sieving crude honey
3	The base of the pressing chamber	Made of stainless steel plate used for the easy flow of the extracted crude honey
4	Pressure Plate	Made of stainless steel circular disk used for compressing crude honey
5	Threaded Shaft	Made of stainless steel rod used to transmit power or motion from one place to another.
6	Angle iron bar	Imprisoned on the top of the outer cylinder, and used to support the threaded shaft is detachable from the pressing chamber.
7	Turning bar	Made of stainless steel rod used to rotate threaded shaft
8	Frame	Made of a flat iron bar and its function is to carry the components of the screw press crude honey extractor.
9	Handle	Used for moving and handling screw press

3.6.2 Design features

During the design following points are considered:

- The design should be simple and the construction should be at minimum cost.
- Power requirements to operate the equipment should be minimal. This is to be achieved by providing means for efficient power utilization.
- The parts should be easily replaceable in case of any damage.

3.6.3 Design analyses

In the design analysis part, the following components of the screw press crude honey extractor were designed for optimum and safe operation.

The screw press crude honey extractor is made up of the following components:

- Threaded shaft

- ❖ Hopper (pressing chamber)
- ❖ The base of the pressing chamber

Design of screw thread

A screw thread is defined as a ridge of uniform section in the form of a helix on either the external or internal surface of a cylinder. Internal threads refer to those on nuts and tapped holes, while external threads are those on bolts, studs, or screws [41].

A. Screw threads terminology

Major diameter: The major diameter is the diameter of an imaginary cylinder that bounds the crest of an external thread (d) or the root of an internal thread (D) (Also called nominal diameter)
Minor diameter: The minor diameter is the diameter of an imaginary cylinder that bounds the roots of an external thread (dc) or the crest of an internal thread (Dc)
Pitch diameter: The pitch diameter is the diameter of an imaginary cylinder, the surface of which would pass through the threads at such points as to make the width of the threads equal to the width of spaces cut by the surface of the cylinder

Pitch, p: It is the distance between two similar points on adjacent threads measured parallel to the axis of the thread
Lead: It is the distance that the nut moves parallel to the axis of the screw when the nut is given one turn
Thread angle: It is the angle between the sides of the thread measured in an axial plane
Tensile stress area: The tensile strength of the threaded rods is equal to the tensile strength of the unthreaded rod whose diameter is equal to the mean of the pitch and the minor diameter. The cross-sectional area of this unthreaded rod is called as tensile stress area.

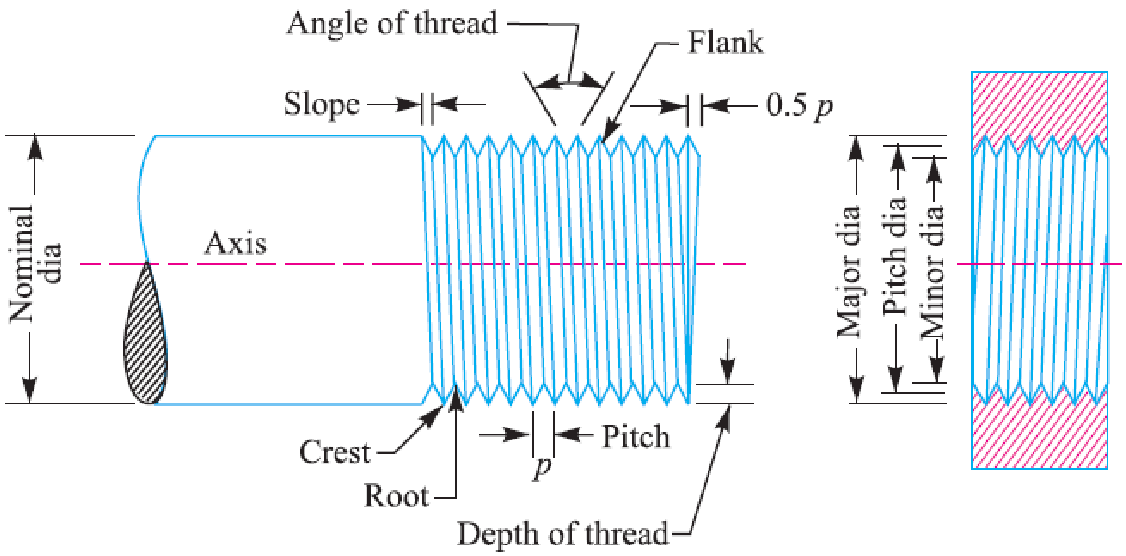


Figure 3 - 4 Screw Threads

(Source: Machine design text book, 2000)

B. Standard Dimensions of Screw Threads

The design dimensions of I.S.O. screw threads for screws, bolts, and nuts of coarse and fine series are shown in Appendix A

Appendix A.Design dimensions of screw threads, bolts, and nuts according to IS: 4218 (Part III) 1976 (Reaffirmed 1996) (Refer Appendix A)

3.6.4 Design of threaded shaft

A shaft is a rotating member, used to transmit power or motion from one place to another. Power is delivered to the shaft by some tangential force and the resulting torque (or twisting moment) set up within the shaft permits the power to be transferred to various machines linked up to the shaft.

A threaded shaft is made up of a stainless steel rod used to transmit power or motion from one place to another. A threaded screw shaft of 22 mm diameter and 600 mm length is screwed to the center of the plate which ran through a translational motion of the thread shaft. The shaft is subject to a turning bar and pressure plate.

Figure 3 - 5 Threaded shaft

3.6.4.1 Stresses due to Screwing up Forces

I. Tensile stress:- The initial tension in a bolt, based on experiments, may be found by the relation

P_i = 1420 *d* N ………………………… (1)

Where P_i = Initial tension in a bolt, and

d = Nominal diameter of the bolt, in mm.

From the standard dimension of screw thread, the minor (or) nominal diameter of the bolt is: - d=20.160mm

P_i =1420*20.160 = 2.86 *10^4 N mm

II. Torsional shear stress: - The torsional shear stress caused by the frictional resistance of the threads during its tightening may be obtained by using the torsion equation.

<u>Assumption:-</u>

d = 22 mm

d_c = 20.160 mm

Required:-

Torque applied on threaded shaft

Torsional shear stress,

Solution:-

We know that

$\frac{T}{J} = \frac{\tau}{r}$ …………………………….. (2)

$$\therefore \tau = \frac{T}{J} * r = \frac{T}{\frac{\pi}{32}(d_c)^4} * \frac{d_c}{2} = \frac{16T}{\pi (d¿¿c)^3 ¿}$$

Where τ = Torsional shear stress,

T = Torque applied, and

d_c = Minor or core diameter of the thread.

J= Polar moment of inertia of the shaft about the axis of rotation

From the equation (2) we have

$\frac{T}{J} = \frac{\tau}{r}$,

We know that,

$T = F * \frac{d}{2}$

$T = 637.56 * \frac{22}{2}$

$T = 7.01 * 10^3$ N mm

$J = \frac{\pi}{32}(d_c)^4 = \frac{\pi}{32}(20.160)^4 = 16216.68 mm^4$

The torsional shear stress is calculated by

$\tau = \frac{T * r}{J}$,

$\tau = \frac{7013.16 * 11}{16216.68}$

τ = 4.75 N/mm^2

III. Shear stress across the threads:- The average thread shearing stress for the screw (τ_s) is obtained by using the relation :

$$\tau_s = \frac{P}{\pi d_{c*b*n}} \text{ ……………………………………….. (3)}$$

Where b= depth of the thread section at the root.

$$\tau_s = \frac{28672.2}{\pi * 20.160 * 0.920 * 150} = 3.28 \text{ N / mm}$$

The average thread shearing stress for the nut is

$$\tau_n = \frac{28672.2}{\pi * 22 * 0.920 * 150} = 3 \text{ N / mm}$$

Where d = Major diameter

IV. Compression or crushing stress on threads. The compression or crushing stress between the threads (σ_c) may be obtained by using the relation :

$$\sigma_c = \frac{P}{\pi ¿¿} \text{ .... (4)}$$

Where d = Major diameter,

d_c = Minor diameter, and

n = Number of threads in engagement.

$$\sigma_c = \frac{28672.2}{\pi ¿¿} = 0.78 \frac{N}{mm^2}$$

V. Bending stress if the surfaces under the head or nut are not perfectly parallel to the bolt axis. When the outside surfaces of the parts to be connected are not parallel to each other, then the bolt will be subjected to bending action. The bending stress (σ_b) induced in the shank of the bolt is given by:-

$$\sigma_b = \frac{x.E}{2l} \text{ .... (5)}$$

Where x = Difference in height between the extreme corners of the nut or head,

l = Length of the shank of the bolt, and

E = Young's modulus for the material of the stainless steel rod.

$$\sigma_b = \frac{100 * 190000}{2 * 600} = 15833.33 \text{ N / } mm^2$$

3.6.4.2 Stresses due to External Forces

1. Tensile stress:- The bolts, studs, and screws usually carry a load in the direction of the bolt axis which induces tensile stress in the bolt

Let d_c = Root or core diameter of the thread, and

σ_t = Permissible tensile stress for the bolt material.

The external load applied is given by:-

$$P = \frac{\pi}{4}(d_c ¿¿^2 \sigma_t \quad \text{(or)} \quad d_c = \sqrt{\frac{4P}{\pi \sigma_t}}$$

$$\sigma_t = \frac{P}{\frac{\pi}{4} ¿¿} \text{ ----------------------------- (6)}$$

$$\therefore \sigma_t = \frac{28672.2}{319.2} = 89.82 \text{ N} / mm^2$$

2. Shear stress: - when the bolts are subjected to direct shearing loads, they should be located in such a way that the shearing load comes upon the body (*i.e.* shank) of the bolt and not upon the threaded portion. In some cases, the bolts may be relieved of shear load by using shear pins.

∴ The shearing load carried by the bolts,

$$P_s = \frac{\pi}{4} * d^2 * \tau * \text{n} \quad \text{(or) d} = \frac{4P}{\pi \tau_n} \text{ .... (7)}$$

Where d = Major diameter of the bolt, and

n = Number of bolts.

$$P_s = \frac{\pi}{4} * (22\, mm ¿¿^2 * 4.75 \text{ N}/mm^2 * 1$$

$$P_s = 1.8 * 10^3 \text{ N}$$

3. Combined tension and shear stress: - When the bolt is subjected to both tension and shear loads, as in the case of coupling bolts or bearings, then the diameter of the shank of the bolt is obtained from the shear load and that of the threaded part from the tensile load. A diameter slightly larger than that required for either shear or tension may be assumed and stresses due to combined load should be checked for the following principal stresses.[41]

   Maximum principal shear stress,

$$\tau_{max} = \frac{1}{2}\sqrt{(\sigma_t)^2 + 4\tau^2} \text{.. (8)}$$

$$\tau_{max} = \frac{1}{2}\sqrt{(89.82)^2 + 4\text{¿¿}}$$

$$\tau_{max} = 45.16\ N/mm^2$$

and maximum principal tensile stress,

$$\sigma_{t(max)=\text{¿¿}} \frac{\sigma_t}{2} + \frac{1}{2}\sqrt{(\sigma_t)^2 + 4\tau^2} \text{ .... (9)}$$

$$\sigma_{t(max)=\text{¿¿}} \frac{89.82}{2} + \frac{1}{2}\sqrt{(89.82)^2 + 4(4.75)^2}$$

$$\sigma_{tmax} = 90.07\ N/mm^2$$

3.6.5 Design of Pressing Chamber (hopper)

The hopper/pressing chamber was a cylindrical box made up of a perforate 1.5 mm thick stainless steel plate having dimensions of 290 mm height, 911 mm length, and 290 mm breadth. The perforations on the plates are 5 mm in diameter.

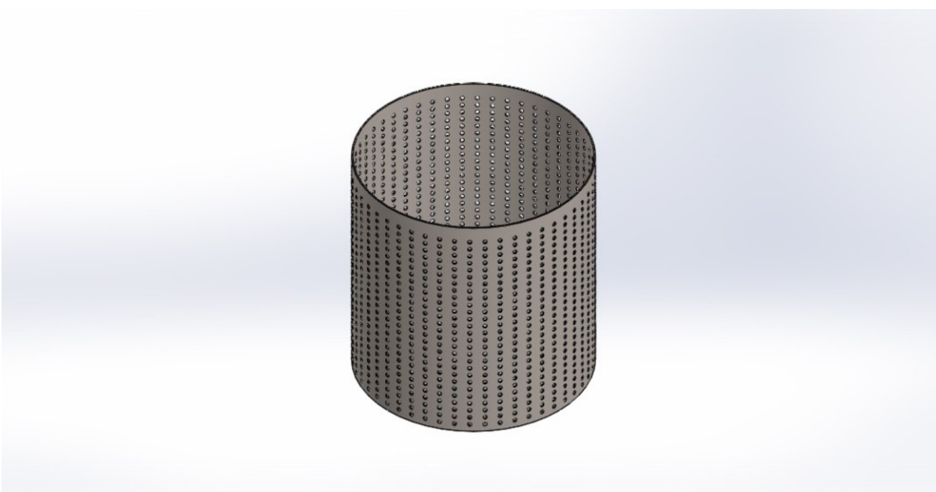


Figure 3 - 6 Pressing chamber

3.6.5.1 Analysis of Volume and Surface area of pressing chamber

A pressing chamber is a three-dimensional shape with two circular bases connected by a lateral surface known as the curved surface. The distance between the two parallel circular bases of the cylinder is referred to as the height (h) of the cylinder and the line connecting the centers of the two circular bases is the axis of the cylinder. The radius (r) of a cylinder is the distance from the center to the outer boundary of a cylinder.

The formula for the volume (V) and surface area (SA) of a pressing chamber are shown. To calculate the volume and surface area of any pressing chamber, we need the radius and the height of the chamber.

The volume of a chamber is the area of its circular base multiplied by the height.

V = $\pi r^2 h$ --- (10)

The area of the curved surface of the chamber which is contained between the two parallel circular bases

A = $2\pi rh$ -- (11)

SA = $2\pi r(r+h)$

- For the inner cylinder chamber, we have:-

Input data:-

r = 145 mm

h = 290 mm

Required:-

V and SA

Solution:-

$\therefore$ V = $\pi * ¿$* 290

V = 1.9 * 10^7 mm^3

A = $2\pi * 145 * 290$

A = 2.64*10^5 mm^2

SA = $2\pi r$ (r+h)

SA = 2¿ π *145 * (145+290)

SA = 3.96 *10^5 mm^2

- For the outer cylinder chamber, we have:-

Input data:-

r = 150 mm

h = 300 mm

$\therefore$ V = $\pi *$¿* 300

V = $2.12*10^7 mm^3$

A = $2\pi*150*300$

A = 2.82*10^5 mm^2

SA = 2¿ π *150 * (150+300)

SA = 4.42 *10^5 mm^2

3.6.5.2 Inner pressing chamber stress analysis

A pressing chamber stress is a stress distribution with rotational symmetry; that is, which remains unchanged if the stressed object is rotated about some fixed axis. The thin-walled chamber stress patterns include circumferential stress (or) hoop stress and axial (or) longitudinal stress. The hoop stress is the force due to internal fluid pressure circumferentially (perpendicular to the axis and the diameter of the object) in both directions on every particle in the chamber wall. Stress acting along the length of a thin cylinder chamber will be termed longitudinal stress.

The hoop stress can be calculated by:-

$$\sigma_h = \frac{Pd}{2t} \text{ -- (12)}$$

Where:

P Internal pressure

d Internal diameter of the thin cylinder chamber wall

t Thickness of the cylinder chamber wall

<u>Given data:-</u>

d = 290 mm

t = 1.5 mm

<u>Required:-</u>

$\sigma_h = ?$

<u>Solution:-</u>

$\sigma_h = \frac{Pd}{2t}$

P = $\frac{F}{A}$, F= mg = 65 * 9.81

F= 637.65 N

P = $\frac{637.65}{66,051.9}$ = 0.009653MP_a

$\therefore \sigma_h = \frac{0.009653*290}{2*1.5}$

$\sigma_h =$ ¿0.933 MP_a

The longitudinal stress can be calculated by:

$\sigma_l = \frac{Pd}{4t} = \frac{0.009653*290}{4*1.5}$

σ_l = 0.466 MP_a

3.6.6 Design pressing chamber base

The base of the pressing chamber is made of stainless steel material with a 305 mm diameter. The base of the pressing chamber is found below the extraction chamber. It's the conical object, attached to the outside cylinder. The conical shape is slanted at an angle of 90° to the vertical for the easy flow of the extracted honey by gravity and then takes the honey from the inner cylinder to the honey storage container.

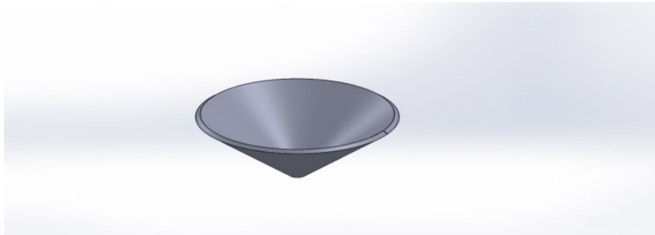


Figure 3 - 7 Pressing chamber base

3.6.6.1 Analysis of Volume and Surface area of pressing chamber base

The pressing chamber base is a conical shape has r is the radius of the base, h is the height and l is the slant height[42]. Therefore volume and surface area of the cone are calculated by:-

<u>Given data:-</u>

h = 150 mm

r = 152.5 mm

l = 213.9 mm

<u>Required:-</u>

V and SA

<u>Solution:-</u>

The volume of a cone = $\frac{1}{3}$ * area of the base × height

V = $\frac{1}{3}\pi r^2$ h = $\frac{1}{3}$ * π * (152.5¿¿^{2} * 150

V = 3.65 * 10^6 mm^3

Area of the pressing chamber base =$2\pi r^2$

A = π * (152.5 mm¿¿^{2}

A = 7.3 * 10^4 mm^2

The surface area of the pressing chamber base is calculated by:-

SA = $\pi rl = \pi * 152.5\,mm * 213.9\,mm$

SA = 1.02 * 10^5 mm^2

3.7 Description and working principle of screw press honeycomb extractor

The honey presser was designed to extract honey from crude honey when pressed against a fixed wall. The extractor chambers fill with crude honey. The whole operation was housed in a stainless-steel cylindrical drum. The drive system mechanism consists of a threaded shaft and pressure plate that transmits motion from the turning bar to the threaded shaft that drives the pressing chamber base.

The screw press operates by the principle of circumferential motion of the threaded shaft by compressing crude honey. The threaded shaft was spun to rotation by utilizing the energy produced by human operating the screw press. The rotational effect produced a centrifugal force that triggered a flow of honey out of the comb cells onto the extractor wall. As the centrifugal force increases, the rate of honey outflow increases until the combs are empty. The pressing chamber base eased the flow of extracted honey into the collector ready for packaging.

3.8 Torque transmitted by the threaded shaft

A threaded shaft was used to transmit power and motion from the turning bar to the pressure plate. The weight difference between beekeepers operating the screw press was estimated to be between 50 kg and 80 kg since not all beekeepers who operate the press have the same weight. Therefore, an average weight of 65 kg per human was considered. A threaded shaft is designed vertically straight at 90°. Knowing that torque is given by the following equations

$T = F * d/2 = F * r$ -- (13)

Where d is the diameter of a threaded shaft

$d = 22$ mm

$F = ma = mg$

Where m is the average weight of a human to operate the screw press

$F = 65 * 9.81 = 637.65$ N

$\therefore T = 637.65 * 0.011$

$T = 7.014$ N m

3.9 Mass flow rate of honey from the screw press

The mean relative density value of honey and the mass of honeycombs were significant in determining the mass flow rate of honey from the screw press.

The mass flow rate was determined by calculating the volume of the honeycomb pressing chamber. It took a period of 4 minutes equivalent to 240 seconds of spinning the turning bar to empty the honeycombs without breaking them. On the day of testing the press performance, 3 test runs were done within 4 minutes each.

Therefore, the mass flow rate of honey from the extractor was calculated using equation 14.

$m_f = \rho * V$ -- (14)

Where,

m_f is the mass flow rate of honey in K_g/s.

ρ is the density of honey in K_g/m^3.

V is the volumetric flow rate of honey from the honeycomb pressing chamber in $\frac{m^3}{s}$ and was calculated as shown in equation 15.

$V = \frac{mass\ of\ honeycombs}{density\ of\ honey}$ -- (15)

The mean relative density of honey was $1.415 g/ml$ or $1415 K_g/m^3$. The average mass of honeycombs for one trial was obtained as 3000 g or 3 kg. Therefore, the volumetric flow rate of honey within 4 minutes equivalent to 240 s was derived as shown

$$V = \frac{3}{1415} = 2.12*10^{-3}\ m^3$$

The volumetric flow rate of honey in one second,

$$V = \frac{2.12*10^{-3}}{240} = 8.83*10^{-6} m^3/s$$

Therefore, the mass flow rate of honey,

$m_f = 1415*8.83*10^{-6} = 1.24*10^{-2}\ K_g/s$

In one day, 3 test runs were achieved within 4 minutes each. Therefore, the number of seconds to empty the pressing chamber,

=3*4*60 =720 seconds

The mass flow rate of honey per day,

$m_f = ¿1.24*10^{-2} * 720 = 8.99\ K_g/day$

3.10 Honeycomb samples and measurements

Freshly harvested 27 kg honeycomb were obtained from honey producers residing in East Wollega zone Gudeyabila district and divided into two portions. The first portion was given to a local honey processor who used the traditional method of honey extraction which involves the Debela shash method and sieve method to extract the honey. The second portion of the freshly harvested honeycomb is used for the performance evaluation of the designed screw press.

Three methods of honey extraction were used i.e. the Debela shash method, the sieve method, and the screw press method. In each method, three trials using 3.0kg of honeycombs were used, taking into cognizance the time taken for each trial. All samples were harvested from colonies in traditional and transitional hives and measured by an electronic weighing balance machine. The quantity of honey extracted from each sample and the residues after the extraction were collected and recorded. The following were the measurements taken before and after the extraction, the total weight of a sample before and after the extraction, the weight of honey extracted, the weight of residues obtained, and the time taken for each extraction.

Figure 3 - 8 Twenty-seven (27 kg) samples of the crude honey collected from Gudeyabila district

3.11 Data analysis and presentation

One-way Analysis of Variance (ANOVA) was used to analyze the data obtained from measuring honey samples. ANOVA was done to detect if there were any significant differences between the treatments of the honey extraction method at the 5% level from statistical tables. In this case, each of the honey extraction methods was the only factor under investigation. Data was presented in the form of tables. Table 3.2 shows a summary of one-way analysis of variance computational formulas.

Table 3 - 3 Summary of one-way analysis of variance computational formulas

Source of variation	**A sum of squares (SS)**	**Degrees of freedom (DF)**	**Mean squares (MS)**	**Variance ratios**
Between treatments	$SS_B =$ $\sum \frac{(T_j)^2}{n_j}$	C - 1	¿ $MS_B = \frac{SS_B}{C-1}$	$F_{observed} =$ ¿ $\frac{MS_B}{MS_W}$
Within treatments	$SS_W =$ $\sum X_{ij}^2 -$ ¿ $\sum \frac{(T_j)^2}{n_j}$	N - C	¿ $MS_{W=}$ ¿¿ $\frac{SS_W}{N-C}$	
About grand mean	$SS_T =$ $\sum X_{ij}^2 -$ ¿ CF ¿	N - 1	¿ $MS_{T=}$ ¿¿ $\frac{SS_T}{N-1}$	

Source: (Kothary, 2004)

From table 3.2 $(T_j)^2$ is the square of each sample total and n_j is the number of items in the concerning sample,

$\sum X_{ij}^2$ is the sum of squares of all item values,

CF is the correction factor,

N is the total number of treatments and c is the number of treatment means.

CHAPTER 4

RESULTS AND DISCUSSION

This portion is discussed the whole results of the Screw press compared with the traditional extraction method (i.e. sieve and Debela shash). To achieve the objective of this paper design optimization and performance evaluation analysis are done on the production of a Screw press. Then should discuss these results and compare the results to others.

4.1 Design optimization and validation of a Screw press honey extractor

4.1.1 Designed Screw Press

The detailed design drawings of the designed screw press honey extractor are shown in Appendix I. Solid works software was used in designing the drawings. Figure 4.1 shows the design of the screw press honey extractor.

Figure 4 - 1 Developed Screw press honey extractor

4.1.2 Structural analysis of the pressing chamber

The results of static structural analysis are obtained from the FEA software ANSYS 16.0. The results involve pressure, maximum von-Misses stress, hoop stress, longitudinal stress, and total deformation of the pressing chamber. In figure 4.2 the number of nodes and elements are 425,278 and 203,463 respectively.

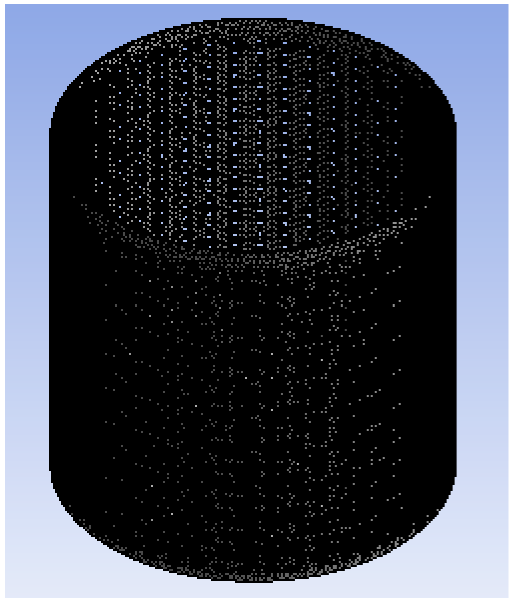


Figure 4 - 2 Mesh design of Pressing chamber

Figure 4.3 shows the equivalent (von-Mises) stress distribution contour the maximum Von Mises stress is 3.89 MPa and the minimum Von-Mises stress is 0 MPa. From this simulation

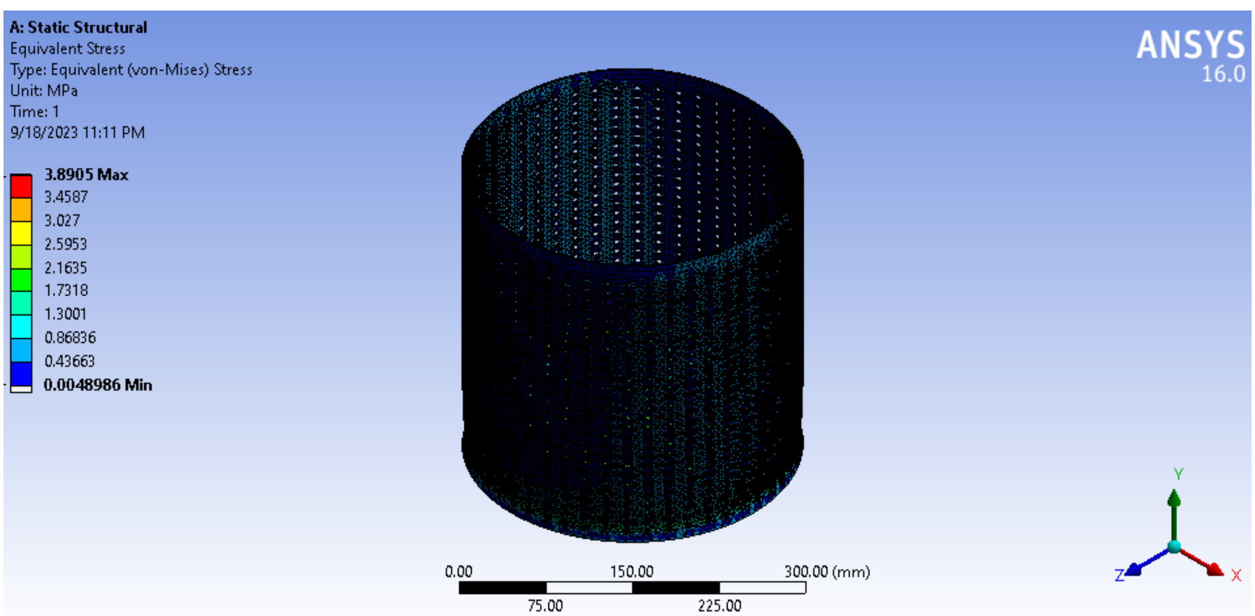


Figure 4 - 3 Equivalent (Von-Mises) stress of Pressing chamber

Figure 4.4 shows the hoop stress distribution contour the maximum stress is 0.96 MPa and the minimum stress is - 4.36 MPa. From this simulation

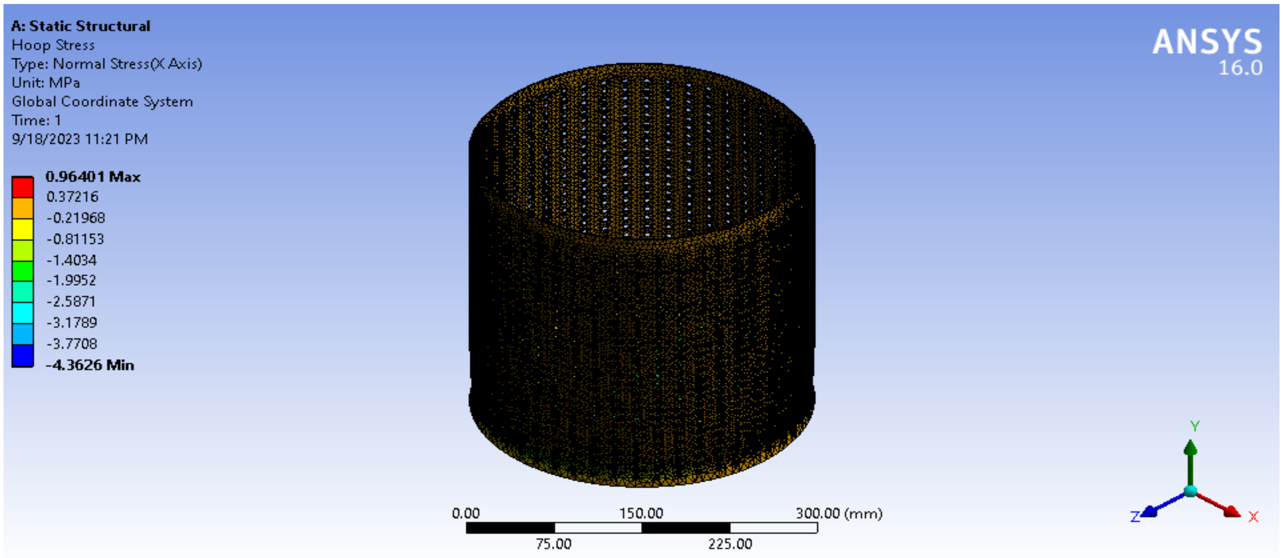


Figure 4 - 4 Hoop Stress of Pressing Chamber

Figure 4.5 shows the longitudinal stress distribution contour the maximum stress is 3.38 MPa and the minimum stress is – 2.75 MPa. From this simulation

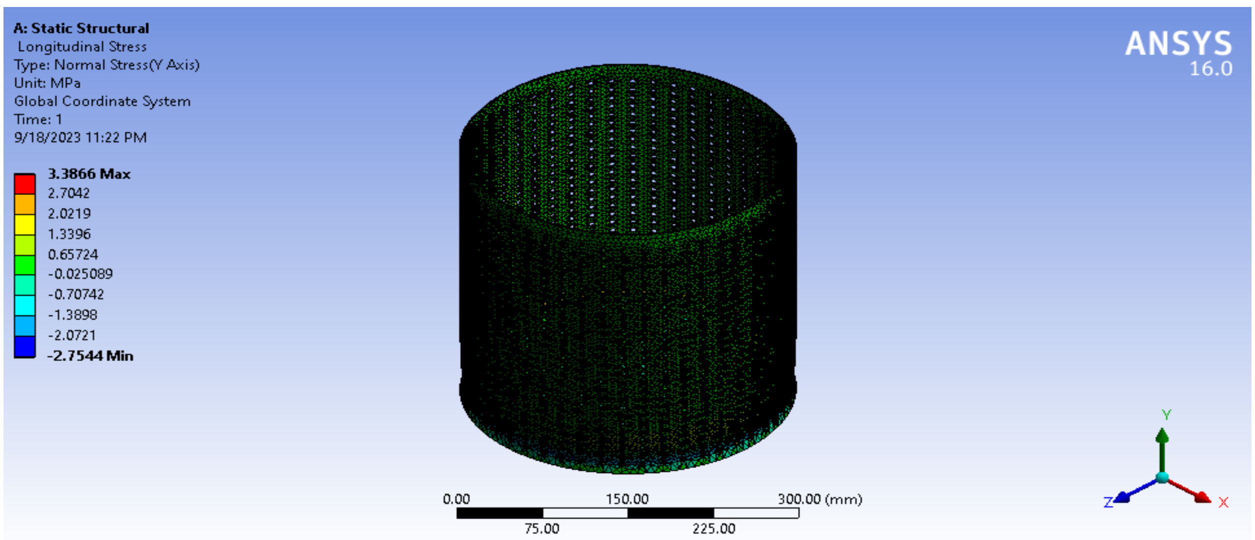


Figure 4 - 5 Longitudinal Stress of Pressing Chamber

Figure 4.6 shows the total deformation contour along the pressing chamber due to the applied loads considered in this study. The total loads applied give the result of the maximum total deformation of 0.01 mm, which is found at the bottom of the pressing chamber. As the length of the pressing chamber increases, the total deformation also increases as shown figure

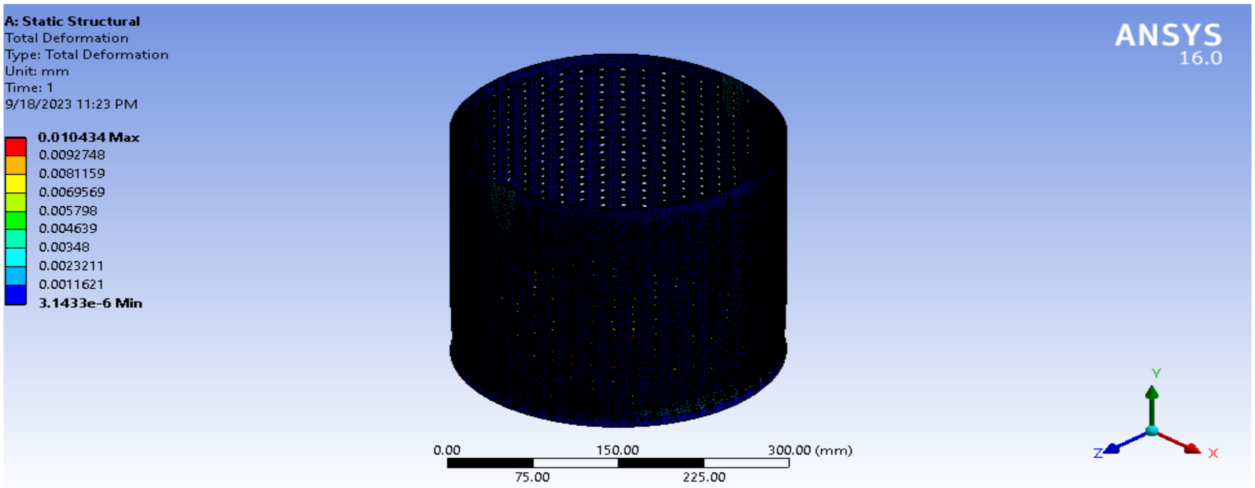


Figure 4 - 6 Total deformation of pressing chamber

4.1.3 Structural analysis of the threaded shaft

The 3-D model of the threaded shaft was developed in Solid Works and saved in IGES (initial graphics exchange specification) format for importing in ANSYS 16.0. A static structural analysis system was used for the analysis of the design. The model was imported using the command import external geometry file. The minimum edge length was 5.8846e-002 mm. There were 146954 nodes and 81090 elements in the mesh. Volume 2.1425e+005 mm³and mass 1.6819 kg.

Structural Steel is used as the material of the screw. Different parameters of structural steel are: Density ρ = 7,850K_g/m^3, Tensile yield strength = 250 MPa, Compressive yield strength = 250 MPa, Tensile ultimate strength = 460 MPa. The rotational velocity of the threaded shaft is 100 rpm which is around the Y-axis in the clockwise direction. The other two ends are bearing support assumed as frictionless support. These conditions define the full conditions of the constraints.

The stress acting on the threaded shaft was determined. After defining the analysis setting simulation is carried on for equivalent (Von-Mises) stress, maximum principal stress, maximum shear stress, and total deformation. By applying the force and momentum, the threaded shaft stress was analyzed in ANSYS as Figure 4.7.

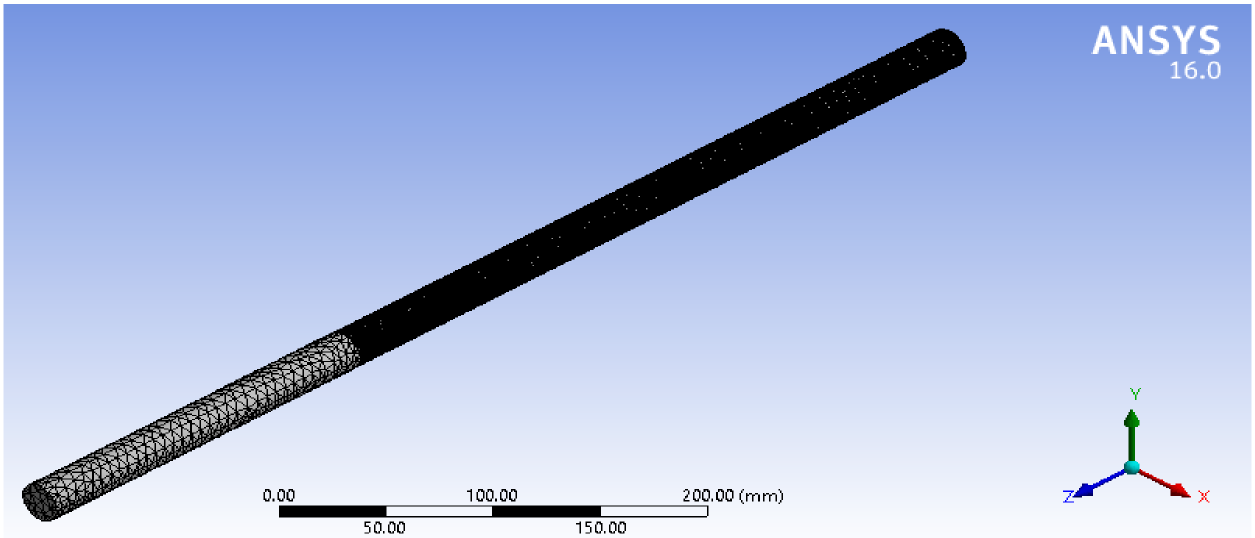


Figure 4 - 7 Mesh design of Threaded Shaft

Figure 4.8 shows the equivalent (von Mises) stress distribution contour the maximum Von Mises stress is 8.86 MPa and the minimum Von Mises stress is 0 MPa. From this simulation stress analysis of the threaded shaft, maximum stress is generated around the top of the threaded shaft.

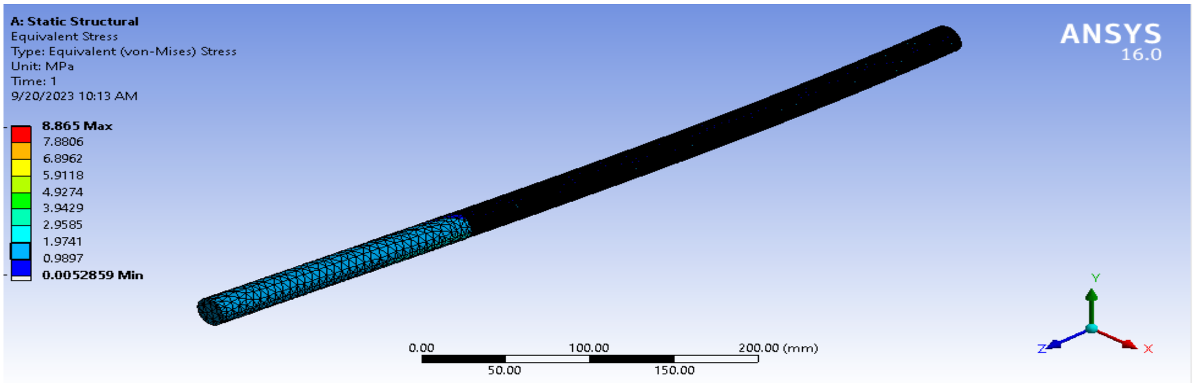


Figure 4 - 8 Equivalent (Von-Mises) stress of Threaded Shaft

Figure 4.9 shows the maximum principal stress distribution contour the maximum principal stress is 10.3 MPa and the minimum Von-Mises stress is -1.97 MPa. The negative sign shows stress is totally under compression.

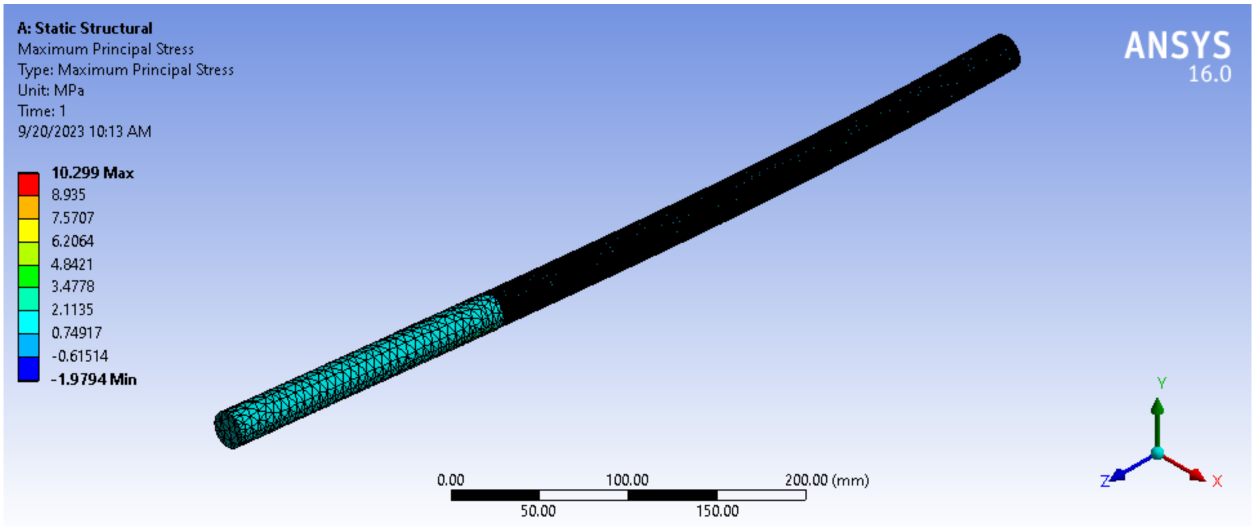


Figure 4 - 9 Maximum principal stress of Threaded Shaft

Figure 4.10 shows the total deformation contour along the threaded shaft due to the applied force and torque considered in this study. The total loads applied give the result of the maximum total deformation of 0.3 mm, which is found at the beginning of the threaded shaft. As the length of the threaded shaft increases, the total deformation also increases as shown figure

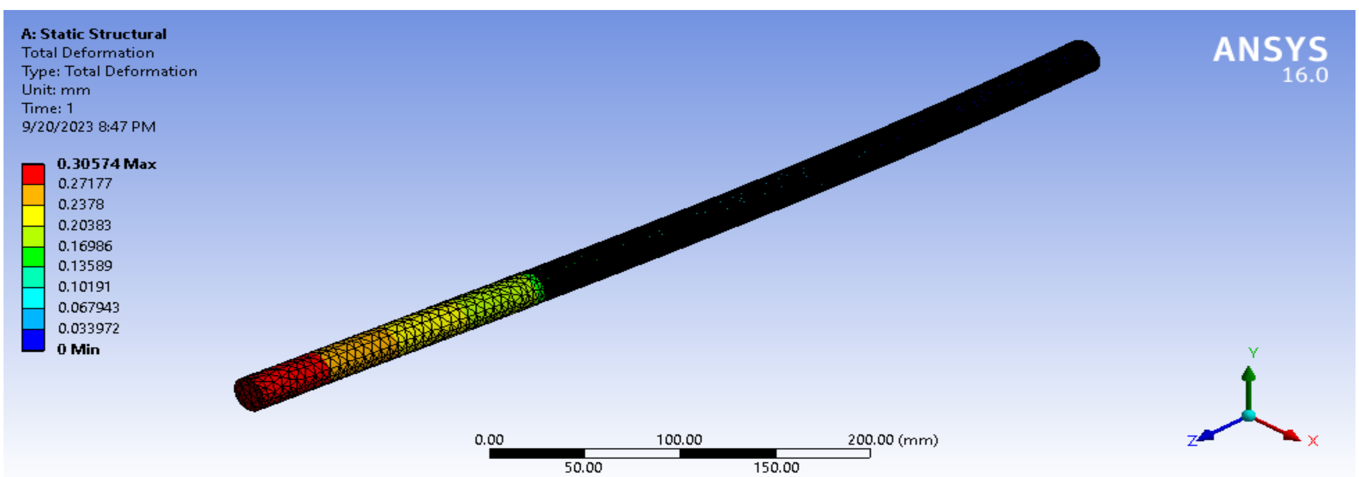


Figure 4 - 10 Total deformation of Threaded Shaft

4.2 performance evaluation of screw press honey extractor

The result of the performance evaluation of the designed and fabricated Screw press honey extractor in comparison with that of the traditional extraction method (Sieve and Debela shash) is shown in Table 4.3.

Table 4 - 1 Test results of different extraction methods

Expt No	Weight of sample before extraction (kg)	Weight of extracted honey, kg (W1)	Volume of honey extracted (L)	Weight of residues, kg	Time taken (min)	Method of extracted	Extraction Efficiency (%)	Extraction Capacity $\left(\frac{Kg}{hr}\right)$
1	3	2	1.38	0.85	10	S	66.67	12.04
2	3	2.55	1.76	0.4	16	S	85	9.58
3	3	2.53	1.75	0.39	14	S	84.33	10.54
Mean	3	2.36	1.63	0.54	13.33		78.66	10.72
4	3	2.32	1.6	0.6	250	DSh	77.33	0.55
5	3	2.41	1.67	0.5	260	DSh	80.33	0.55
6	3	2.15	1.49	0.8	235	DSh	71.66	0.54
Mean	3	2.29	1.58	0.63	248.33		76.44	0.54
7	3	2.45	1.69	0.5	5	SP	81.66	29.51
8	3	2.42	1.67	0.48	3	SP	80.66	48.4
9	3	2.43	1.68	0.49	4	SP	81	36.81
Mean	3	2.43	1.68	0.49	4		81.10	38.24
S = Sieve		**DSh = Debela Shash**		**SP = Screw Press**				

4.2.1 Extraction Capacity for Sieve Method

Figure 4 - 11 Sieve extraction method

The extraction capacity was determined by finding the ratio of input of the crude honey to the time taken [43]

i.e. Extraction capacity = $\frac{Total\,Weight\,of\,extracted\,honey\,(Kg)}{Time\,taken\,(hr)}$ ---------------------------- 16

CE = $\frac{Wha}{Tt}$

, where CE is the Extraction Capacity $(Kg¿¿hr)¿$

Wha is the weight of the honeycomb after extraction of honey (Kg)

Tt is the time taken for honey extraction ($hr¿$

The weight of honeycomb before extraction of honey = 3 Kg +3 Kg +3 Kg = 9 Kg, the weight of honeycomb after extraction of honey = 2 Kg +2.5Kg +2.53 Kg = 7.08Kg and Time taken = 10 +16 +14 = 40 minute = 0.66 *hr*

Therefore EC = $\frac{7.08}{0.66} = 10.72\frac{Kg}{hr}$

4.2.2 Extraction Efficiency for Sieve Method

The extraction efficiency was calculated by finding the ratio of the weight of the honeycomb after extraction of honey to the weight of the honeycomb before extraction of honey times a hundred[43]

Extraction Efficiency = $\frac{Total\ weight\ of\ honeycomb\ after\ extraction\ of\ honey\ (Kg)}{Total\ weight\ of\ honeycomb\ before\ extraction\ of\ honey\ (Kg)}$ *100 --------------- 17

$$\eta_E = \frac{Wha}{Whb} * 100$$

, where η_E is Extraction Efficiency (%)

Whb is the weight of the honeycomb before extraction of honey

$$\therefore \eta_E = \frac{7.08}{9} * 100 = 78.66\ \%$$

4.2.3 Extraction Capacity for Debela Shash Method

Figure 4 - 12 Debela shash extraction method

The weight of honeycomb before extraction of honey = 3 Kg +3 Kg +3 Kg = 9 Kg, the weight of honeycomb after extraction of honey = 2.32 Kg +2.41 Kg +2.15 Kg = 6.88 Kg, and Time taken = 250 + 260 + 235 = $745'$ = 12.41 *hr*

$$CE = \frac{Wha}{Tt} = \frac{6.88}{12.41} = 0.55\ \frac{Kg}{hr}$$

4.2.4 Extraction Efficiency for Debela Shash Method

$$\eta_E = \frac{Wha}{Whb} * 100 = \frac{6.88}{9} = 76.44\ \%$$

4.2.5 Extraction Capacity for Screw press method

Figure 4 - 13 Screw press extraction method

The weight of honeycomb before extraction of honey = 3 Kg +3 Kg +3 Kg = 9 Kg, the weight of honeycomb after extraction of honey = 2.45 Kg +2.42 Kg +2.42 Kg = 7.3 Kg, and Time taken = 5 + 3 + 4 = $12' = 0.2\ hr$

$$CE = \frac{Wha}{Tt} = \frac{7.3}{0.2} = 36.5\ \frac{Kg}{hr}$$

4.2.6 Extraction Efficiency for Screw press method

$$\eta_E = \frac{Wha}{Whb} *100 = \frac{7.3}{9} = 81.11\ \%$$

Figure 4 - 14 Extracted honey

Descriptive analysis using SPSS Statics 20 version is used to analyze the result. Analysis of variance (ANOVA) was also used to test if there were any statistical differences between the means of the three methods of honeycomb extraction used for the experiment.

From Table 4.4 the formulas shown were utilized in determining the F-values for the honeycombs extraction method and the results summarized as shown in

Table 4 - 2 ANOVA – for the performance evaluation of honey extraction methods

Parameters	Source of Variation	The sum of squares (SS)	Degrees of Freedom (DF)	Mean squares (MS)	F ratio	P- value
Weight extracted (kg)	Between treatments Within treatments Total	.029 .230 .259	2 6 8	.015 .038	.384	.697
Time (Min)	Between treatments Within treatments Total	115010.889 337.333 115348.222	2 6 8	57505.44 4 56.222	1022.824	.000
Extraction efficiency (%)	Between treatments Within treatments Total	32.689 255.394 288.084	2 6 8	16.345 42.566	.384	.697
Extraction capacity (Kg/hr)	Between treatments Within treatments Total	2281.634 184.558 2466.192	2 6 8	1140.817 30.760	37.088	.000
Volume extracted (L)	Between treatments Within treatments Total	.013 .110 .124	2 6 8	.007 .018	.355	.715
Residue (Kg)	Between treatments Within treatments Total	.031 .185 .216	2 6 8	.016 .031	.507	.626

Table 4 - 3 Mean and standard deviation values for the performance evaluation of honey extraction methods

	Mean ± Standard deviation					
Treatments	Weight	Time	Extraction	Extraction	Volume	Residue

	extracted		Efficiency	Capacity	Extracted	
Sieve	2.36±.31	13.33±3.05	78.66±10.39	10.72±1.23	1.63±.21	.54±.26
Debela Shash	2.29 ±.13	248.33±12.58	76.44±4.40	.54±.00	1.58±.09	.63±.15
Screw Press	2.43 ±.01	4.00±1.00	81.10±.50	38.24±9.52	1.68±.01	.49±.01

Table 4.3 shows, the mean and standard deviation for the sieve honey extraction method of Weight extracted (Kg), the time elapsed (minute), extraction efficiency (%), extraction capacity (Kg/hr), volume extracted (L) and residue (Kg) are 2.36±.31, 13.33±3.05, 78.66±10.39, 10.72± 1.23, 1.63±.21 and .54±.26 respectively, and for Debela Shash honey extraction method the values are 2.29 ±.13, 248.33±12.58, 76.44±4.40, .54±.00, 1.58±.09 and .63±.15 respectively. And for the Screw Press honey extraction method the values are 2.43 ±.01, 4.00±1.00, 81.10± .50, 38.24±9.52, 1.68±.01, and .49±.01 respectively.

Table 4- 4 Mean and standard error values for the performance evaluation of honey extraction methods

	Mean ± Standard error					
Treatments	Weight extracted	Time	Extraction Efficiency	Extraction Capacity	Volume Extracted	Residue
Sieve	2.36±.18	13.33±1.76	78.66±6.00	10.72±.71	1.63±.12	.54±.15
Debela Shash	2.29 ±.07	248.33±7.26	76.44±2.54	.54±.00	1.58±.05	.63±.08
Screw Press	2.43 ±.00	4.00±.57	81.10±.29	38.24±5.49	1.68±.00	.49±.00

Table 4.4, the mean and Standard error for the sieve honey extraction method of Weight extracted (Kg), the time elapsed (minute), extraction efficiency (%), extraction capacity (Kg/hr), volume extracted (L), and residue (Kg) is 2.36±.31, 13.33±3.05, 78.66±10.39, 10.72±1.23, 1.63± .21 and .54±.26 respectively, and for Debela Shash honey extraction method the values are 2.29 ±.13, 248.33±12.58, 76.44±4.40, .54±.00, 1.58±.09 and .63±.15 respectively. And the Screw Press honey extraction method the values are 2.43 ±.01, 4.00±1.00, 81.10±.50, 38.24±9.52, 1.68 ±.01, and .49±.01 respectively.

Table 4 - 5 Post-Hoc testing for the performance evaluation of honey extraction methods

Multiple Comparisons

Dependent Variable	(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Weight extracted	Sieve	Debela shash	.06667	.15984	.910	-.4238	.5571
		Screw press	-.07333	.15984	.892	-.5638	.4171
	Debela shash	Sieve	-.06667	.15984	.910	-.5571	.4238
		Screw press	-.14000	.15984	.674	-.6304	.3504
	Screw press	Sieve	.07333	.15984	.892	-.4171	.5638
		Debela shash	.14000	.15984	.674	-.3504	.6304
	Sieve	Debela shash	-235.00000*	6.12221	.000	-253.7846	-216.2154
		Screw press	9.33333	6.12221	.345	-9.4513	28.1180

Time elapsed to extract 3 kg of crude honey	Debela shash	Sieve	235.00000*	6.12221	.000	216.2154	253.7846
		Screw press	244.33333*	6.12221	.000	225.5487	263.1180
	Screw press	Sieve	-9.33333	6.12221	.345	-28.1180	9.4513
		Debela shash	-244.33333*	6.12221	.000	-263.1180	-225.5487
Extraction efficiency	Sieve	Debela shash	2.22667	5.32702	.910	-14.1181	18.5714
		Screw press	-2.44000	5.32702	.893	-18.7848	13.9048
	Debela shash	Sieve	-2.22667	5.32702	.910	-18.5714	14.1181
		Screw press	-4.66667	5.32702	.674	-21.0114	11.6781
	Screw press	Sieve	2.44000	5.32702	.893	-13.9048	18.7848
		Debela shash	4.66667	5.32702	.674	-11.6781	21.0114
Extraction Capacity	Sieve	Debela shash	10.17333	4.52840	.141	-3.7210	24.0677
		Screw press	-27.52000*	4.52840	.002	-41.4144	-13.6256

	Debela shash	Sieve	-10.17333	4.52840	.141	-24.0677	3.7210
		Screw press	-37.69333*	4.52840	.000	-51.5877	-23.7990
	Screw press	Sieve	27.52000*	4.52840	.002	13.6256	41.4144
		Debela shash	37.69333*	4.52840	.000	23.7990	51.5877
Volume extracted	Sieve	Debela shash	.04333	.11079	.920	-.2966	.3833
		Screw press	-.05000	.11079	.896	-.3899	.2899
	Debela shash	Sieve	-.04333	.11079	.920	-.3833	.2966
		Screw press	-.09333	.11079	.693	-.4333	.2466
	Screw press	Sieve	.05000	.11079	.896	-.2899	.3899
		Debela shash	.09333	.11079	.693	-.2466	.4333
Residue	Sieve	Debela shash	-.08667	.14335	.823	-.5265	.3532
		Screw press	.05667	.14335	.919	-.3832	.4965

	Debela shash	Sieve	.08667	.14335	.823	-.3532	.5265
		Screw press	.14333	.14335	.604	-.2965	.5832
	Screw press	Sieve	-.05667	.14335	.919	-.4965	.3832
		Debela shash	-.14333	.14335	.604	-.5832	.2965

Table 4.5 shows the Tukey Post-Hoc Test indicates which group differences are statistically significant. For each treatment, a difference is computed between the average of that treatment and the average of every other treatment. Every one of these differences is tested for statistical significance.

DISCUSSION

The result of the performance evaluation of the designed and fabricated screw press honey extractor in comparison with that of the traditional extraction method is shown in Table 4.1. The average extraction capacity for the screw press honey extractor method, defined as the rate at which honey was extracted from the crude honey with time, was 38.24$Kghr^{-¿¿}$. This is significantly higher (p<0.05) than the extraction capacity calculated for the sieve and debela shash method which was 10.72$Kghr^{-¿¿}$ and 0.54 $Kghr^{-¿¿}$ of honey respectively. A similar result was reported by [20], who designed a hand-driven screw press for honey extraction. The average extraction capacity of 2.71$Kghr^{-¿¿}$ of honey was reported for the traditional method using the weight and sieve and press method with an average extraction capacity of 32.58 $Kghr^{-¿¿}$of honey was reported for the designed hand-driven honey extractor press. The extraction efficiency which indicates equipment performance was 81.10 % for the designed Screw press honey extractor, 78.66 % for the sieve method, and 76.44 % for Debela shash method. The mean extraction efficiency of the honey extractor was not significantly different between treatments (p>0.05). The work of,[20] also reported an extraction efficiency of 56.3 % for the traditional method and 70.6% for hand-driven screw press for honey extraction. Furthermore, Debela shash and sieve methods have problems with them requiring high heat and repeated contact to extract crude honey, and various insects catch on, which reduces the quality of the honey when compared with Screw press. The results of the extraction capacity and extraction efficiency show a clear improvement of the designed screw press honey extractor over that of the traditional method. Furthermore, bubbles were not observed in the honey collected from the honey extractor, unlike the honey from the traditional extraction method. The bubbles have been attributed to air being trapped in the honey and reduce significantly the market value of honey.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

There are different honey extraction methods to extract honey from different hives for different purposes. In this study, a manual screw press crude honey extractor was designed and optimized. Screw press design includes the selection of appropriate materials, design of mechanical parts to specifications, and analysis of their stresses.

In the design of the manual screw press honey extractor, the threaded shaft, pressing chamber, turning bar, and pressing chamber base was made.

To achieve a safe screw press, a stress analysis of the threaded shaft and press chamber was performed. It is used to determine the stress concentration zone, find the maximum stress, and compare its value with the value obtained in the design analysis. Stress concentration area and maximum value set with contour plot obtained by ANSYS stress analysis.

Performance evaluation of the screw press was performed and compared the use of 3.0 kg of crude honey was in each case with traditional honey extraction methods (i.e. Sieve and Debela shash).

The average extraction capacity and extraction efficiency of the screw press is 38.24$Kghr^{-¿¿}$and 81.10% respectively. For the sieving method, the average extraction capacity and efficiency were 10.72$Kghr^{-¿¿}$and 78.66 % respectively, and the average extraction capacity and efficiency of Debela shash were 0.54$Kghr^{-¿¿}$and 76.44 % respectively are reported. These mean values are significantly different at the 5% significance level.

5.2 Recommendations

The study's recommendations for further research include:

- The design needs to be improved by including motorized that can be used to reduce the wastage of labor and human time.
- Food-grade plastic materials should be used in the structure of the extractor to reduce the cost of purchasing stainless steel materials.
- Physicochemical analysis performed showed that the properties of honey extracted using the designed screw press gave more desirable results than honey extracted using traditional methods (i.e. Sieve and Debela shash) within international export standards were not addressed in this study.

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APPENDICES

Appendix A**: Standard Dimensions of Screw Threads**

Designation	*Pitch mm*	*Major or nominal diameter Nut and Bolt (d = D) mm*	*Effective or pitch diameter Nut and Bolt (d_p) mm*	*Minor or core diameter (d_c) mm*		*Depth of thread (bolt) mm*	*Stress area mm^2*
				Bolt	*Nut*		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Coarse series							
M 0.4	0.1	0.400	0.335	0.277	0.292	0.061	0.074
M 0.6	0.15	0.600	0.503	0.416	0.438	0.092	0.166
M 0.8	0.2	0.800	0.670	0.555	0.584	0.123	0.295
M 1	0.25	1.000	0.838	0.693	0.729	0.153	0.460
M 1.2	0.25	1.200	1.038	0.893	0.929	0.158	0.732
M 1.4	0.3	1.400	1.205	1.032	1.075	0.184	0.983
M 1.6	0.35	1.600	1.373	1.171	1.221	0.215	1.27
M 1.8	0.35	1.800	1.573	1.371	1.421	0.215	1.70
M 2	0.4	2.000	1.740	1.509	1.567	0.245	2.07
M 2.2	0.45	2.200	1.908	1.648	1.713	0.276	2.48
M 2.5	0.45	2.500	2.208	1.948	2.013	0.276	3.39
M 3	0.5	3.000	2.675	2.387	2.459	0.307	5.03
M 3.5	0.6	3.500	3.110	2.764	2.850	0.368	6.78
M 4	0.7	4.000	3.545	3.141	3.242	0.429	8.78
M 4.5	0.75	4.500	4.013	3.580	3.688	0.460	11.3
M 5	0.8	5.000	4.480	4.019	4.134	0.491	14.2
M 6	1	6.000	5.350	4.773	4.918	0.613	20.1

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
M 7	1	7.000	6.350	5.773	5.918	0.613	28.9
M 8	1.25	8.000	7.188	6.466	6.647	0.767	36.6
M 10	1.5	10.000	9.026	8.160	8.876	0.920	58.3
M 12	1.75	12.000	10.863	9.858	10.106	1.074	84.0
M 14	2	14.000	12.701	11.546	11.835	1.227	115
M 16	2	16.000	14.701	13.546	13.835	1.227	157
M 18	2.5	18.000	16.376	14.933	15.294	1.534	192
M 20	2.5	20.000	18.376	16.933	17.294	1.534	245
M 22	2.5	22.000	20.376	18.933	19.294	1.534	303
M 24	3	24.000	22.051	20.320	20.752	1.840	353
M 27	3	27.000	25.051	23.320	23.752	1.840	459
M 30	3.5	30.000	27.727	25.706	26.211	2.147	561
M 33	3.5	33.000	30.727	28.706	29.211	2.147	694
M 36	4	36.000	33.402	31.093	31.670	2.454	817
M 39	4	39.000	36.402	34.093	34.670	2.454	976
M 42	4.5	42.000	39.077	36.416	37.129	2.760	1104
M 45	4.5	45.000	42.077	39.416	40.129	2.760	1300
M 48	5	48.000	44.752	41.795	42.587	3.067	1465
M 52	5	52.000	48.752	45.795	46.587	3.067	1755
M 56	5.5	56.000	52.428	49.177	50.046	3.067	2022
M 60	5.5	60.000	56.428	53.177	54.046	3.374	2360
Fine series							
M 8 × 1	1	8.000	7.350	6.773	6.918	0.613	39.2
M 10 × 1.25	1.25	10.000	9.188	8.466	8.647	0.767	61.6
M 12 × 1.25	1.25	12.000	11.184	10.466	10.647	0.767	92.1
M 14 × 1.5	1.5	14.000	13.026	12.160	12.376	0.920	125
M 16 × 1.5	1.5	16.000	15.026	14.160	14.376	0.920	167
M 18 × 1.5	1.5	18.000	17.026	16.160	16.376	0.920	216
M 20 × 1.5	1.5	20.000	19.026	18.160	18.376	0.920	272
M 22 × 1.5	1.5	22.000	21.026	20.160	20.376	0.920	333
M 24 × 2	2	24.000	22.701	21.546	21.835	1.227	384
M 27 × 2	2	27.000	25.701	24.546	24.835	1.227	496
M 30 × 2	2	30.000	28.701	27.546	27.835	1.227	621
M 33 × 2	2	33.000	31.701	30.546	30.835	1.227	761
M 36 × 3	3	36.000	34.051	32.319	32.752	1.840	865
M 39 × 3	3	39.000	37.051	35.319	35.752	1.840	1028

Note : In case the table is not available, then the core diameter (d_c) may be taken as 0.84 d, where d is the major diameter.

(Source: Khurmi and Gupta, 2005)

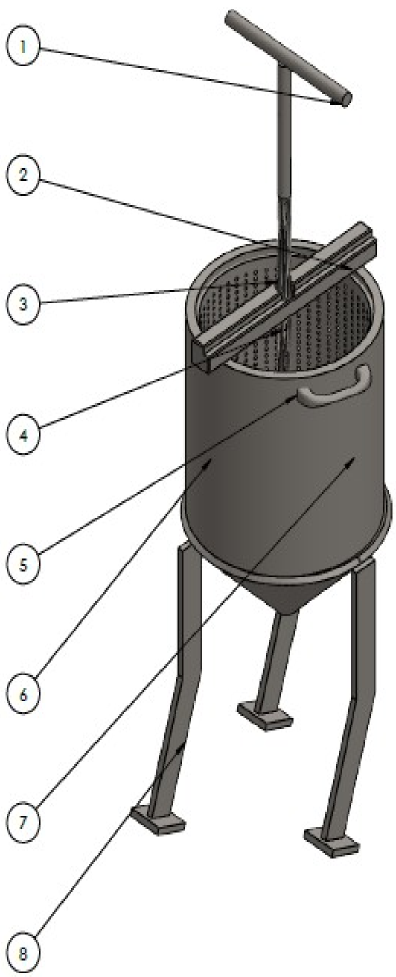
B.AISI 304 Stainless Steel properties and values

Property	Value	Units
Elastic Modulus	190000	N/mm^2
Poisson's Ratio	0.29	N/A
Shear Modulus	75000	N/mm^2
Mass Density	8000	kg/m^3
Tensile Strength	517.017	N/mm^2
Compressive Strength		N/mm^2
Yield Strength	206.807	N/mm^2
Thermal Expansion Coefficient	1.8e-05	/K
Thermal Conductivity	16	W/(m·K)

Table 1 Stainless Steel properties and values

(Source: solid work 2020 AISI 304 Stainless Steel properties)

Appendix B: Design Optimization and Assembly Drawings of Screw Press Honey Extractor

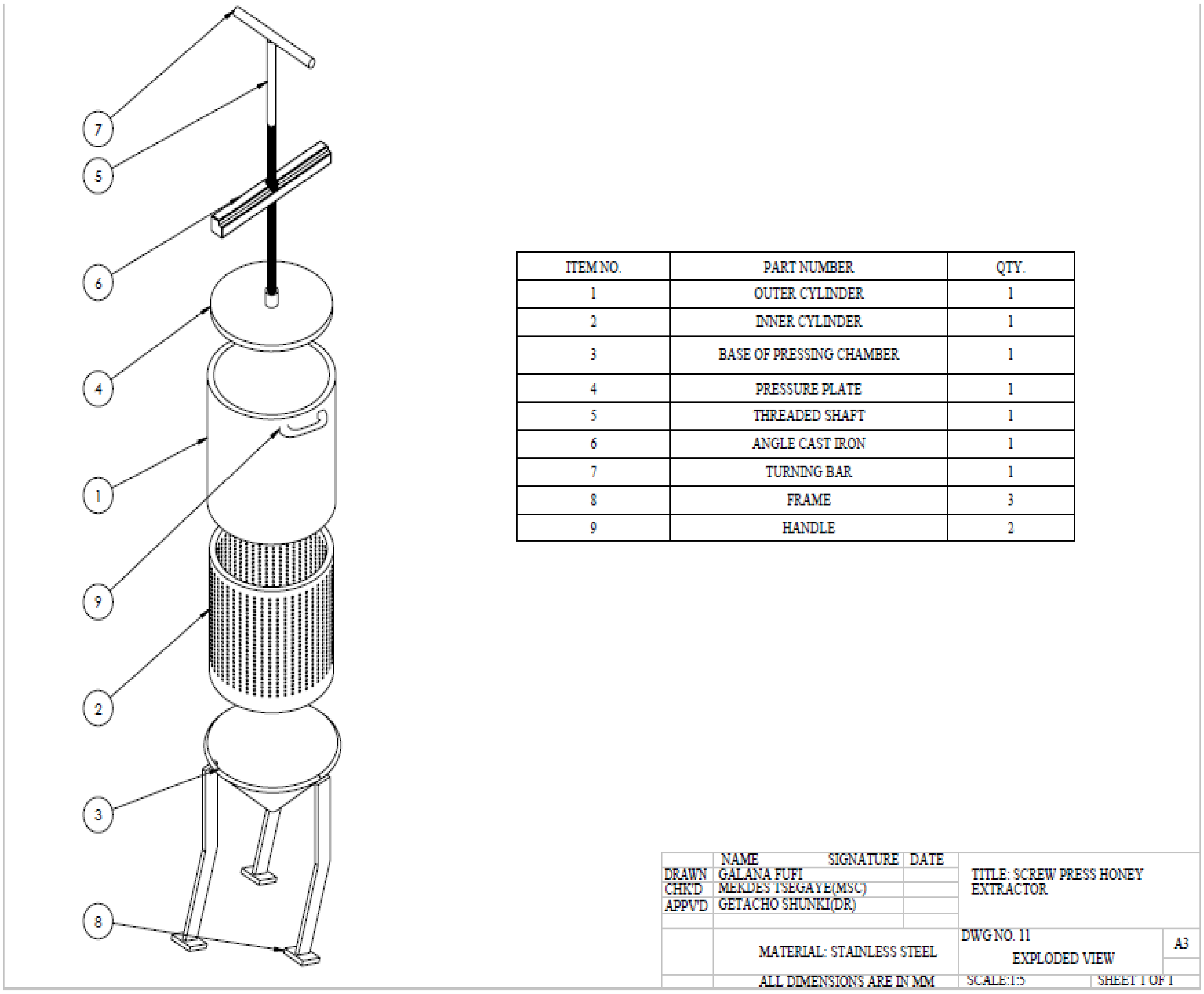


ITEM NO.	DESCRIPTION	QTY.
1	Turning bar	1
2	Inner Cylinder	1
3	Angle Cast iron	1
4	Threaded Shaft	1
5	Handle	2
6	Base of Pressing Chamber	1
7	Outer Cylinder	1
8	Frame	3
9	Pressure Plate	1

	NAME	SIGNATURE	DATE	TITLE: SCREW PRESS HONEY EXTRACTOR
DRAWN	GALANA FUFI			
CHK'D	MEKDES TSEGAYE(MSC)			
APPV'D	GETACHO SHUNKI(DR)			
		MATERIAL: STAINLESS STEEL		DWG NO. 1 3D Assembly drawing A3
				SCALE:1:5 SHEET 1 OF 1

Figure 1: Screw Press Honey extractor assembly and parts

(Source: Author, 2023)



ITEM NO.	PART NUMBER	QTY.
1	OUTER CYLINDER	1
2	INNER CYLINDER	1
3	BASE OF PRESSING CHAMBER	1
4	PRESSURE PLATE	1
5	THREADED SHAFT	1
6	ANGLE CAST IRON	1
7	TURNING BAR	1
8	FRAME	3
9	HANDLE	2

Figure 2 Exploded view of the designed Screw Press honey extractor

(Source: Author, 2023)

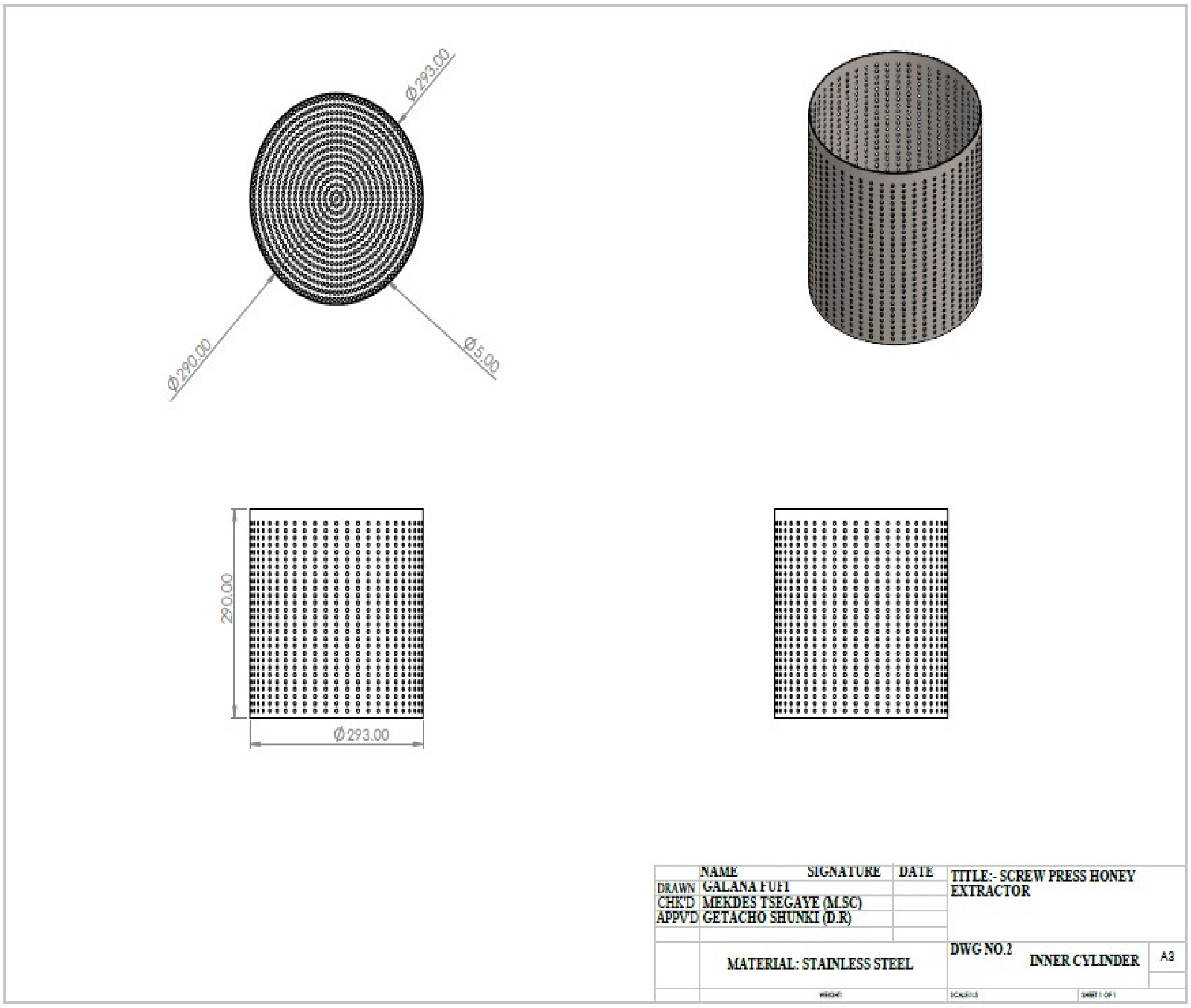


Figure 3 Views and dimensions of the pressing chamber (Inner cylinder)

(Source: Author, 2023)

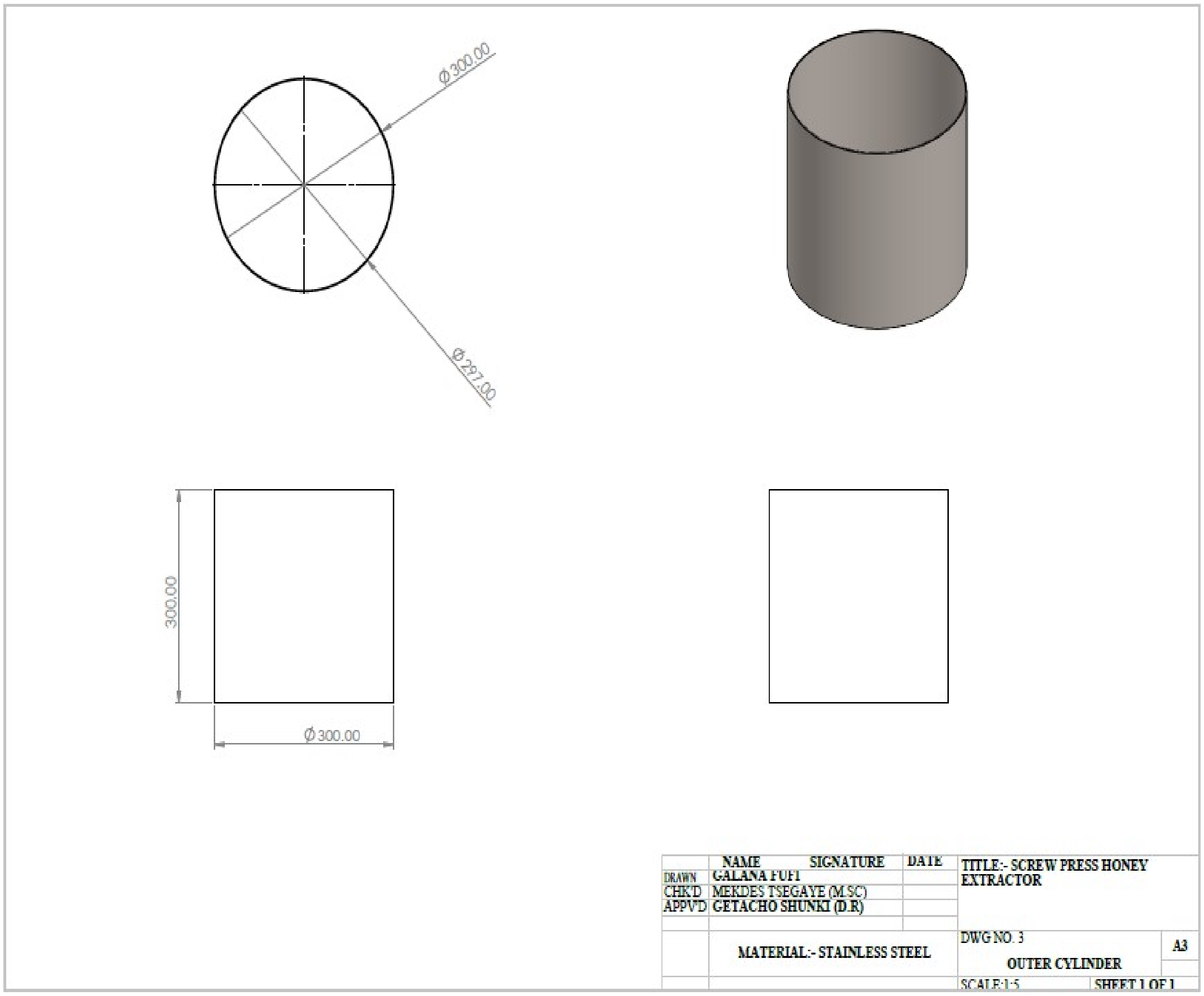


Figure 4 Views and dimensions of the outer cylinder

(Source: Author, 2023)

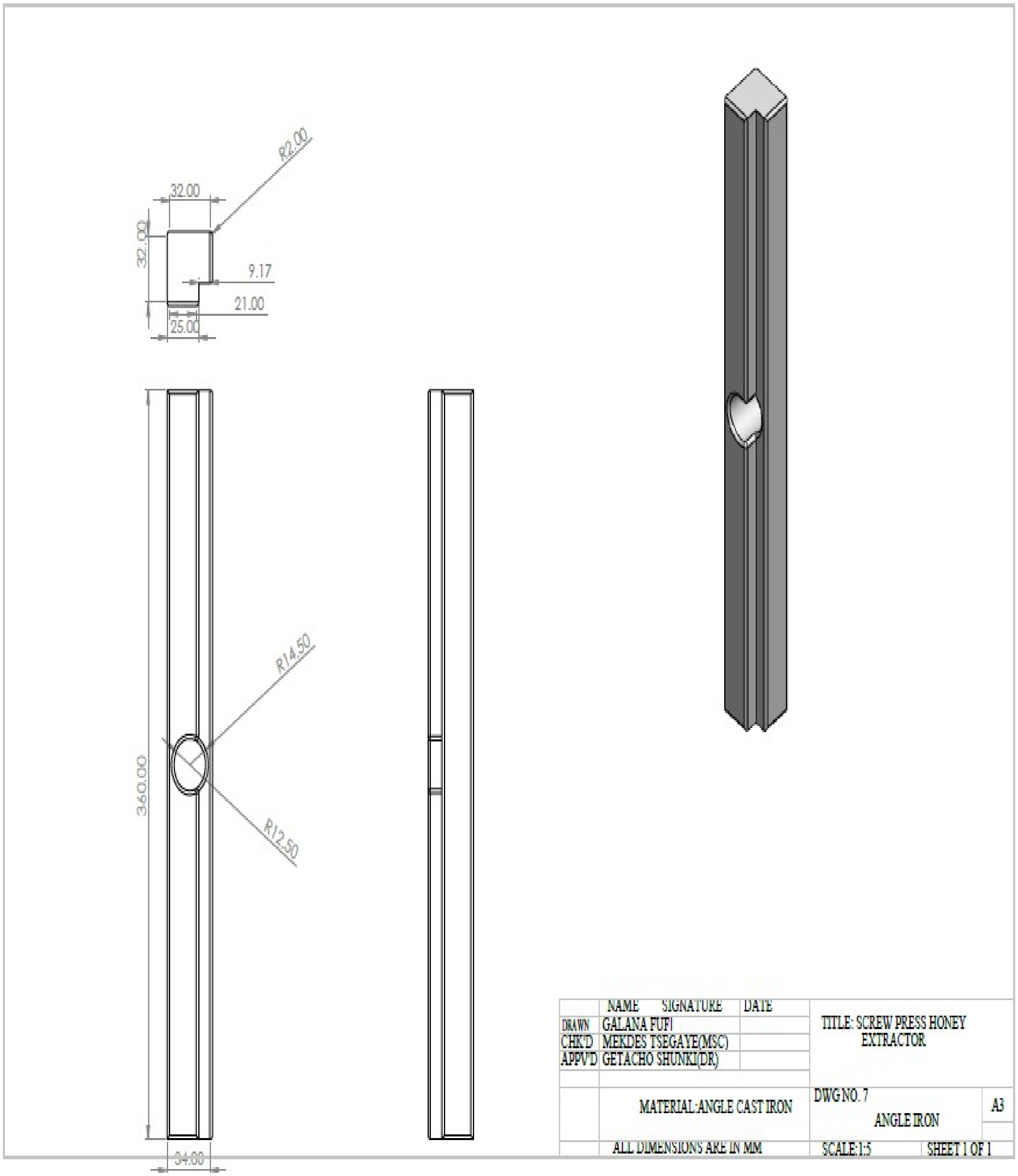


Figure 5 Views and dimensions of the Angle iron

(Source: Author, 2023)

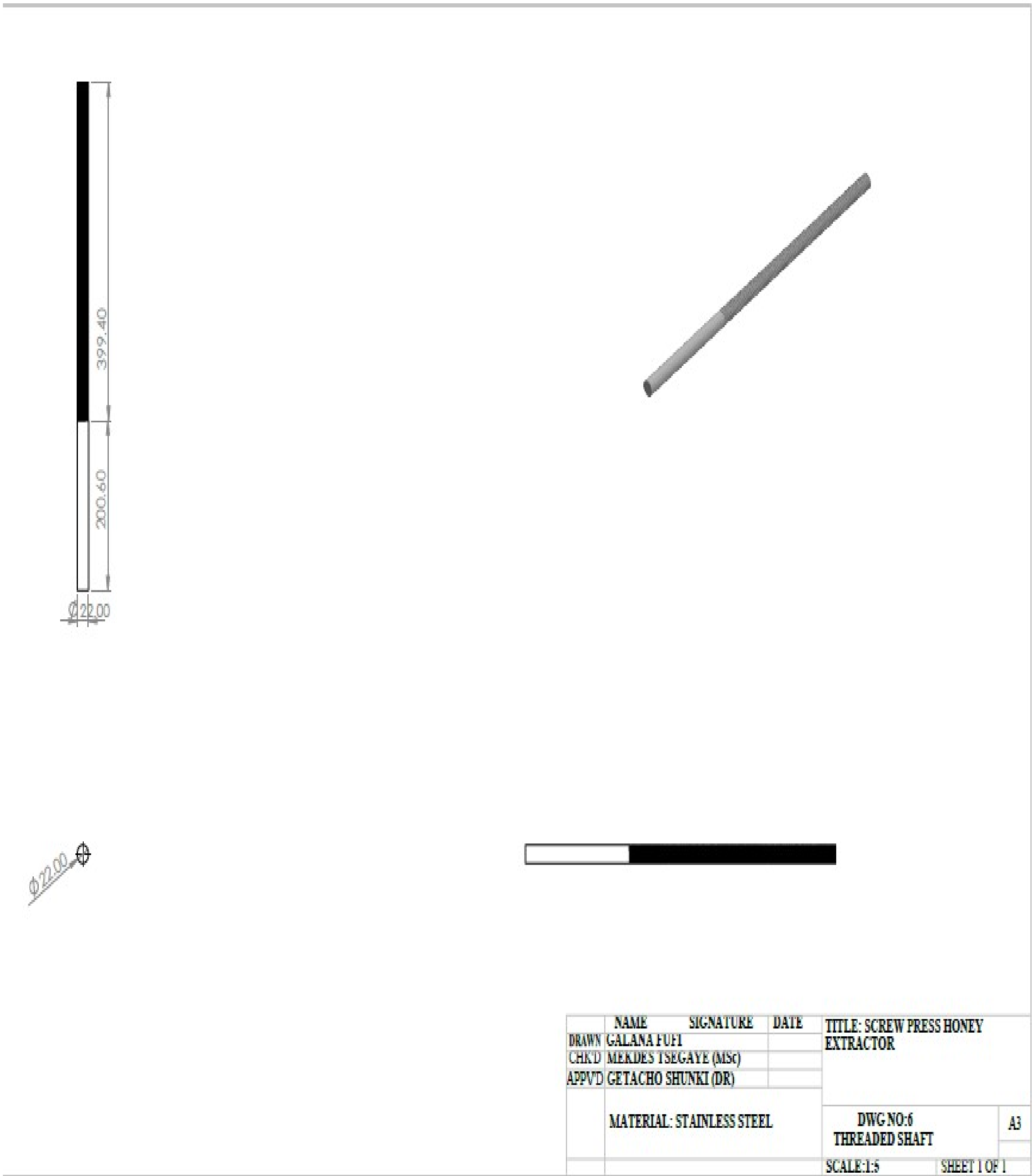


Figure 6 Views and dimensions of the threaded shaft

(Source: Author, 2023)

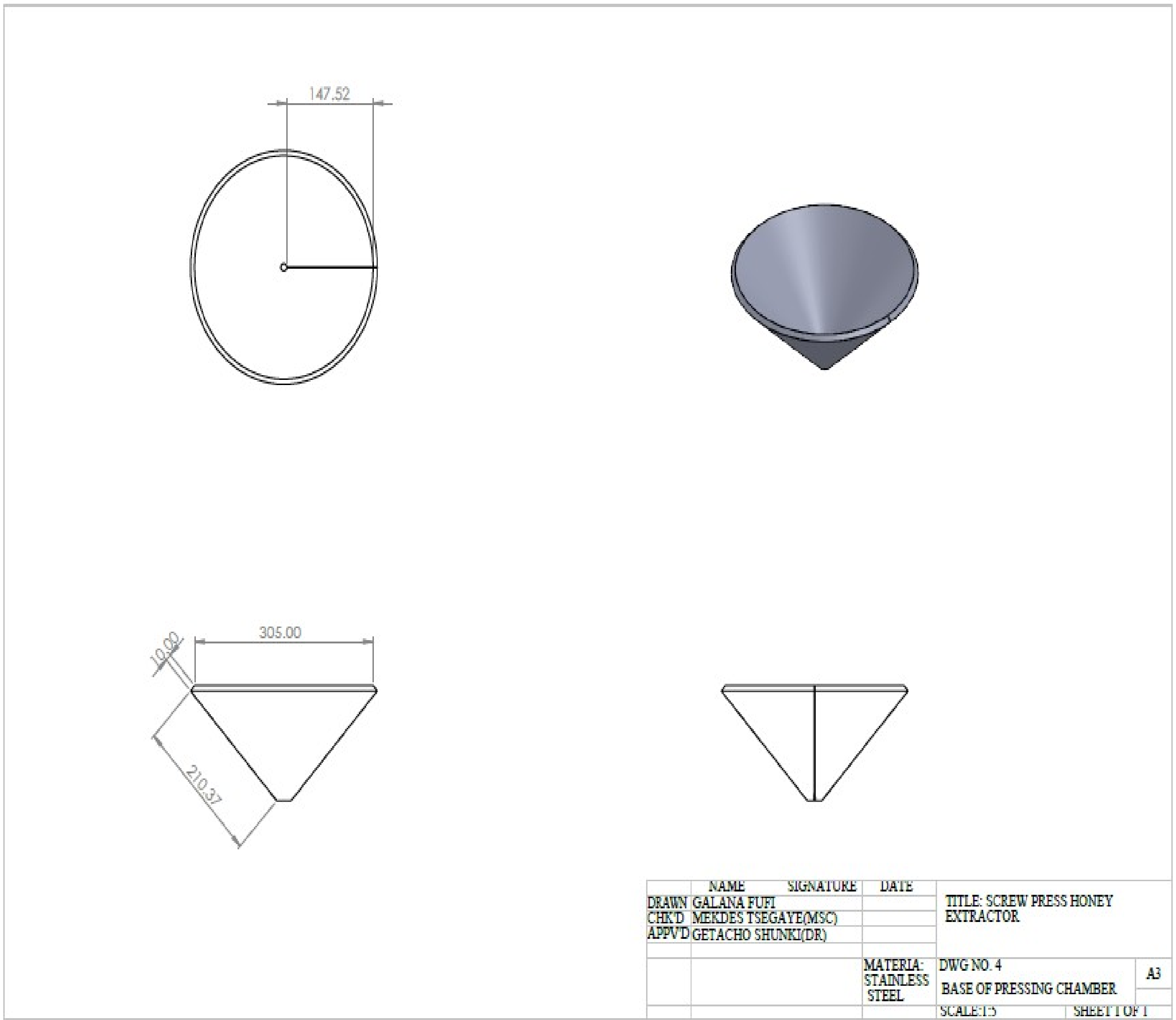


Figure 7 Views and dimensions of the pressing chamber base

(Source: Author, 2023)

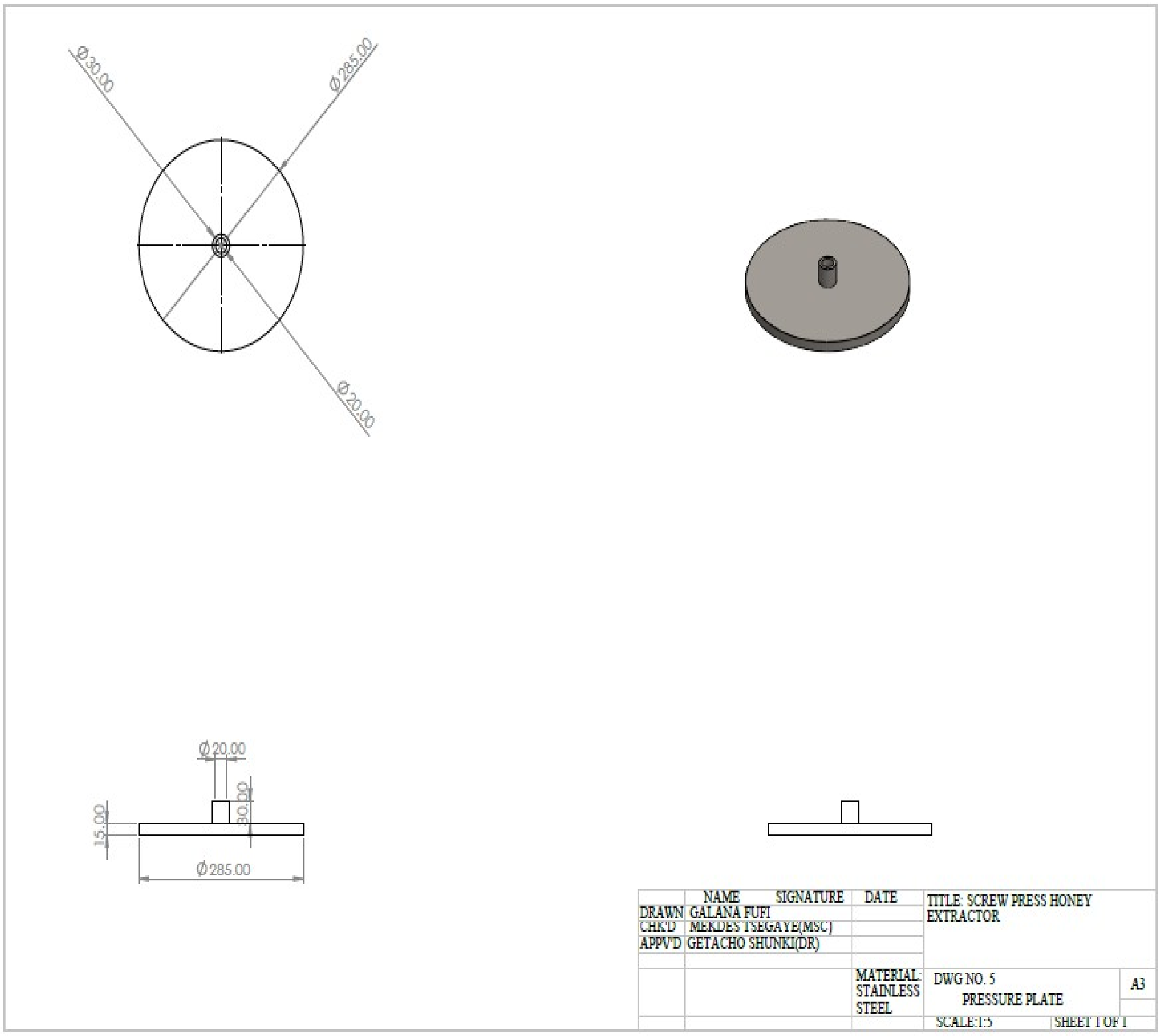


Figure 8 Views and dimensions of the pressure plate

(Source: Author, 2023)

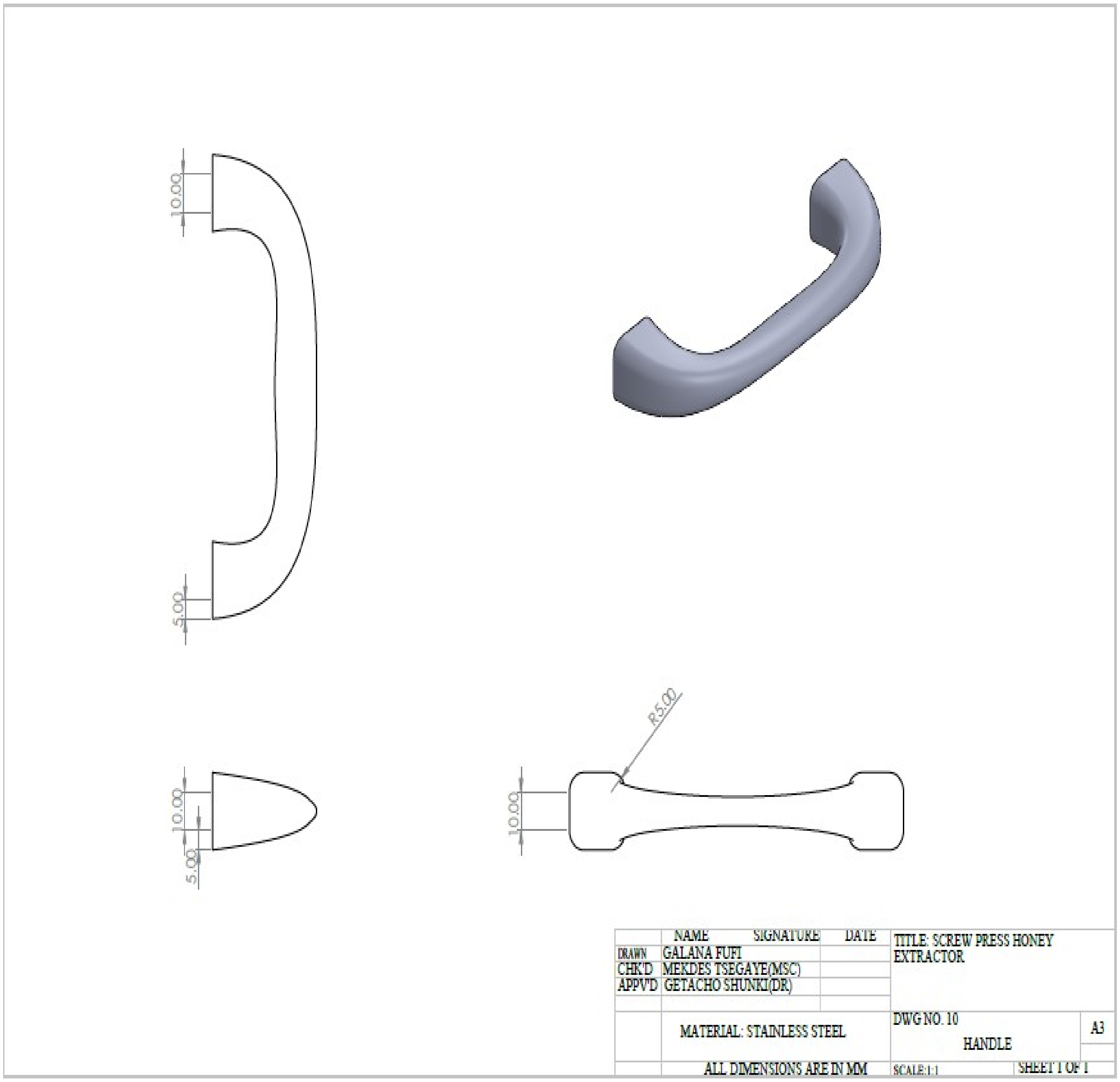


Figure 9 Views and dimensions of the handle

(Source: Author, 2023)

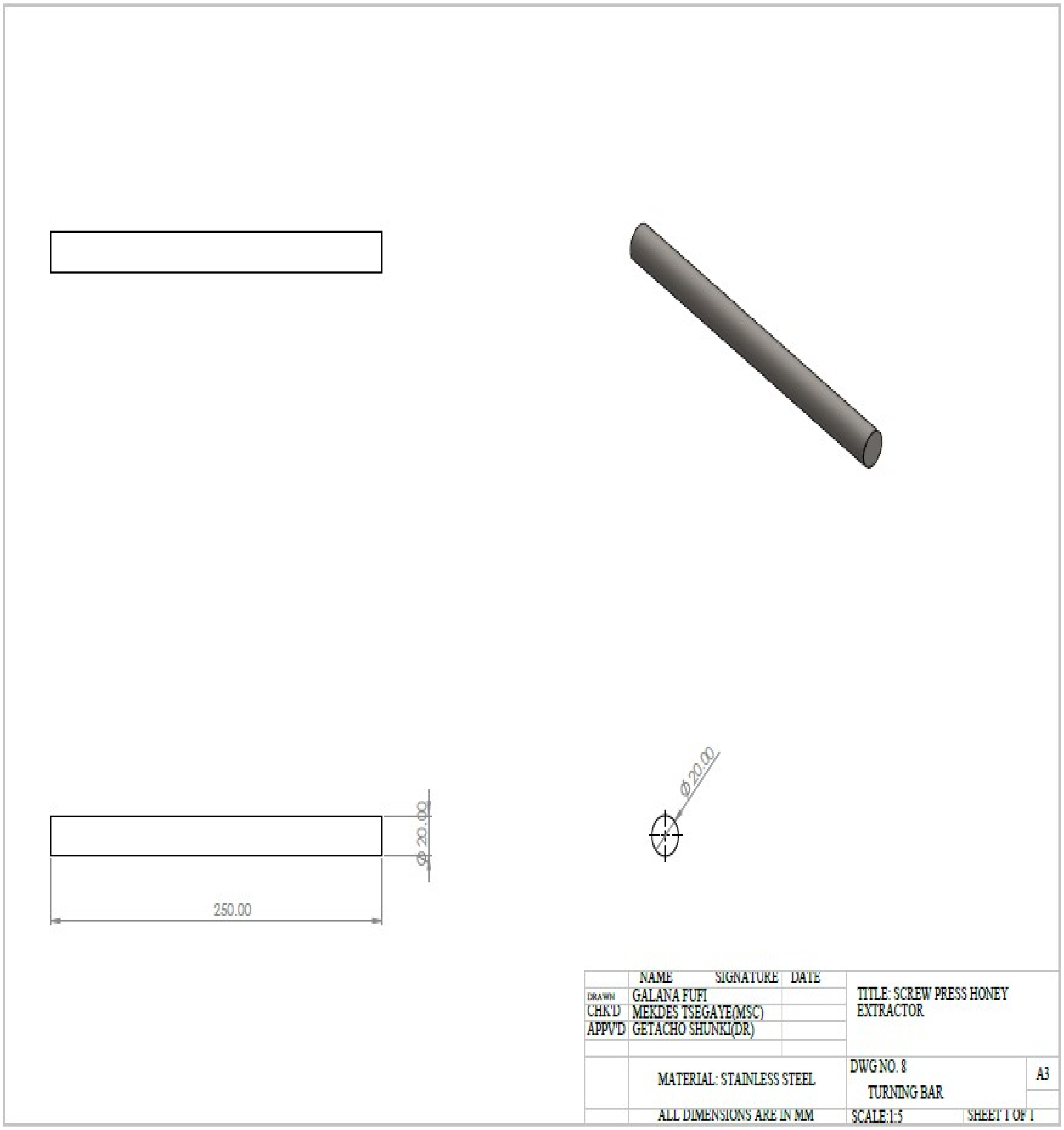


Figure 10 Views and dimensions of the turning bar

(Source: Author, 2023)

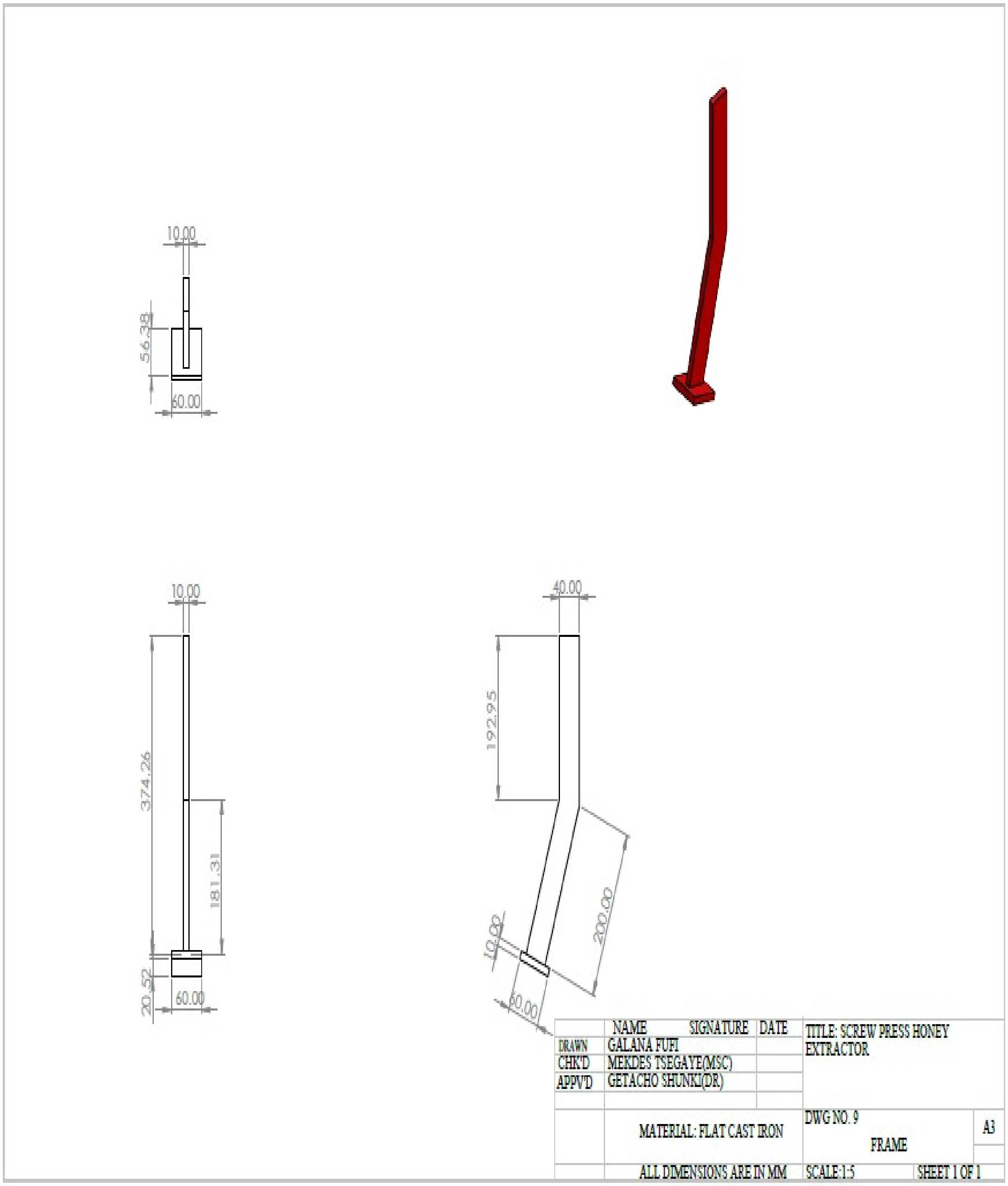


Figure 11 Views and dimensions of the frame

(Source: Author, 2023)