Chapter 2 Prototype of technical boxes to increase productivity in native bee meliponaria (Scaptotrígona)

Capítulo 2 Prototipo de cajas técnicas para aumentar la productividad en la meliponaria autóctona (Scaptotrígona)

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Abstract

Obtaining different products derived from honey has become relevant in recent years in the State of Puebla and considering that Mexico is the fifth largest exporter of honey in the world, the need arises to generate breeding alternatives to improve the productivity of native bees; being the Tetragonisca Angustula bee the domesticated species of the northern region of the State and the main producer of sweet and viscous substances for human consumption. The general objective of this work is based on the design and construction of the physical prototype of a technified box model, making use of materials extracted from the region that are characterized by having various physical and mechanical properties adaptable to environmental conditions to favor the reproduction of the aforementioned native bee and improve the productivity rates of the different hive communities that make up the established meliponaria; The specific objectives are structured in 3 Phases; Phase 1 determines the optimal dimensions of the model considering the different areas that make up the nest, later it was designed using SolidWorks technological software; Phase 2 develops a qualitative study of the properties of the types of wood in the region considering the environmental characteristics for the reproduction of bees, likewise includes a quantitative analysis through a logistical intervention to include the variables that intervene in the generation of costs to acquire materials; Regarding Phase 3, the physical manufacture of the prototype is presented. The technified box will provide the Meliponarians with a means of safe housing, suitable to increase the reproduction of native bees; increased honey productivity in the region and providing a utility model for regional economic growth, based on operations (breeding and management) typical of Meliponiculture.

Meliponiculture, Bees, Prototype, Technified boxes

Resumen

La obtención de diferentes productos derivados de la miel ha cobrado relevancia en los últimos años en el Estado de Puebla y considerando que México es el quinto exportador mundial de miel, surge la necesidad de generar alternativas de crianza para mejorar la productividad de las abejas nativas; siendo la abeja Tetragonisca Angustula la especie domesticada de la región norte del Estado y la principal productora de sustancias dulces y viscosas para el consumo humano. El objetivo general de este trabajo se basa en el diseño y construcción del prototipo físico de un modelo de caja tecnificada, haciendo uso de materiales extraídos de la región que se caracterizan por tener diversas propiedades físicas y mecánicas adaptables a las condiciones ambientales para favorecer la reproducción de la mencionada abeja nativa y mejorar los índices de productividad de las diferentes comunidades de colmenas que conforman la meliponaria establecida; Los objetivos específicos se estructuran en 3 Fases; En la Fase 1 se determinan las dimensiones óptimas del modelo considerando las diferentes áreas que conforman el nido, posteriormente se diseñó utilizando el software tecnológico SolidWorks; En la Fase 2 se desarrolla un estudio cualitativo de las propiedades de los tipos de madera de la región considerando las características ambientales para la reproducción de las abejas, así mismo se incluye un análisis cuantitativo a través de una intervención logística para incluir las variables que intervienen en la generación de costos para adquirir los materiales; En cuanto a la Fase 3, se presenta la fabricación física del prototipo. La caja tecnificada proporcionará a los meliponicultores un medio de alojamiento seguro, apto para incrementar la reproducción de las abejas nativas; aumentando la productividad de la miel en la región y proporcionando un modelo de utilidad para el crecimiento económico regional, basado en operaciones (cría y manejo) propias de la Meliponicultura.

Meliponicultura, Abejas, Prototipo, Cajas tecnificadas

2.1 Introduction

Ramirez and Ortiz (1995) emphasize that the colonies of stingless bees, except for some species, have their nests in hollow tree trunks, the peasants cut them and hang them in the eaves of their houses, the honey extraction processes the performed in a rustic way, thus obtaining smaller amounts of this liquid approximately 600 ml in a period of time of 6 months, the applied system represents a latent risk for the hives due to the lack of the optimal housing infrastructure for the collection of the various products.

The bees that do not contain stinger distinguished as wild or native bees (Scaptotrigona) are mainly reproduced in meliponiculture, among the multiple species that make it up, the Tetragonisca Angustula stands out, which lives in permanent colonies formed by a variable number of young with hives. comprising dozens to one hundred thousand Rasmussen honey flies, 2003), these native individuals are relevant since they act as pollinators in the different ecosystems due to the fact that they make up the majority group of bees in the regions (Roubick. 1989. Slaa, 2006; García-Olivares, 2015).

Meliponiculture is a fruitful activity that means an income opportunity for workers in the northern region of the State of Puebla. However, it is limited by the lack of knowledge of the appropriate techniques for the exploitation, monitoring and strengthening of the hives. Currently there is a great variety in nest structures or hives and they are usually found in natural hollows of logs and rocks, or in constructions made by meliponicultores, these housing buildings are usually improvised and do not have the necessary requirements to protect honey flies from environmental conditions and external organisms, thus contributing to expose beehives to negative factors that cause low levels of productivity, infestation of pests. He honeycomb or hive must be a suitable medium for the reproduction and generation of different derived products, (pollen, propolis, honey, brood foot); Analyzing this requirement, the technified box prototype is created, the applied methodology is divided into 4 phases through which the physical design of a rational model is presented with divisions or rises that strengthen the nest structure using SolidWorks technological software, Subsequently, it is manufactured from thermal wood, seeking to preserve the temperature characteristics that promote an adequate environment for the development of the native bee, considering economic aspects that influence the acquisition of materials, the generation of the prototype provides a utility model suitable for be applied in the meliponarios, of the region at an accessible cost ensuring the reproductive conditions of the bee Tetragonisca Angustula and notably improving productivity levels.

2.1.1 Objectives

2.1.2 General Objective

Design and build a physical prototype of a technified box to improve the productivity of the native species Tetragonisca Angustula Scaptotrigona, making use of materials suitable for the reproduction and protection of the environmental conditions of the meliponarians located in the Sierra Norte of the State of Puebla.

2.1.3 Specific objectives

a) Determine the ideal dimensions of the box that allow the optimal development of the hive.

b) Identify the appropriate materials for the manufacture of the prototype and evaluate the costs presented.

c) Design prototype in SolidWorks design software.

d) Build physical prototype of technical box.

2.1.4 Justification

Regional economic development is driven by the performance of different activities that are attached to natural resources, the exploitation of these brings with it the contribution of means of subsistence for the economically active population: the Sierra Norte de Puebla is characterized by an extensive catalog from natural environments that promote the development of different species of flora, fauna and vegetation, being the Scaptotrigona bee of the Tetragonisca Angustula species one of the insects that encourages, the activity of the meliponiculture in the region; the productive operations of breeding and management are carried out in the meliponarios established in different parts of the territory making use of improvised hives that do not ensure the ideal productivity of the products derived from honey, causing that the annual profits do not represent positive benefits for the meliponic farmers; considering that there is already an opening for the development of the productive activity described, it is proposed to create a physical prototype of a technified box whose main function is to replace the current nests to adequately preserve reproduction and increase the productivity of the products derived from honey.

Within the various advantages of using the prototype of a technified box for the rearing of bees, we find that the design allows the constant evaluation of the state of the hive considering that a movable structure made up of 3 reproductive areas is handled: nest, super nest, honeycomb; Thus, the extraction of the sweet liquid is also facilitated, the hive is not damaged and it is kept in constant internal review to eliminate the sources that favor pests; in the same way, the thermoregulation of the temperature is maintained by increasing the amount of products that are produced inside pollen, propolis, honey, wax, etc. The economic use through the collection of the aforementioned products is aimed at human consumption and health: generating mixed with honey: dehydrated pollen; use of propolis as an antimicrobial agent and antioxidants in the treatment of bites, infected wounds, respiratory tract infections; production of wax candles and handcrafted figures.

In this way, the prototype manufactured is a utility model to increase the indexes of productivity of honey derivatives and generate higher profits for the meliponic farmers of the Sierra North of the state of Puebla.

2.1.5 Theoretical Framework

To understand the objective of this research, the theoretical foundations that support the formulation, design and manufacture of the prototype are described:

2.1.6 Meliponicultura in Mexico

It is identified as a viable, simple and easily executed economic activity within production systems, environmentally sustainable that allows the provision of environmental services to agroecosystems through pollination and registered products, with great local demand and high price. González (2004) describes meliponiculture as the cultivation of native bees without stinging activity that dates back to times before the arrival of the Spanish, the honey flies of America come from the Meliponini tribe, this group of bees lack stinger and their nests are structured horizontally. They are considered the main group of domesticated honey flies in America, they are characterized by performing social activities within the multiple hives where they multiply; the hierarchical structure is divided into three levels: the queen, workers and drones; these maintain a positive relationship for the improvement and protection of the nests (Harriet, 1999).

The history of meliponiculture in Mexico, was born in the Peninsula of Yucatán, and extends towards the Sierra Norte de Puebla (Cuetzalan). The Huastecas (especially Potosina), Totonacapan in Veracruz; the interest to reproduce this harvesting technique has been awakened among the coffee-producing inhabitants, seeking to take advantage of the different products provided by the species of honey flies (Figure 2.1 Types of melipona bees) that make up the colonies of the meliponarios. It can be seen in the regions of the Mexican tropics distinguished before (except for the Yucatan Peninsula), currently, it is being effecting with another genus of Mexican bee, named in the Nahua language "Pisil Nekmej ", and in Totonac language" Táxkat ". The meliponicultores of the Huasteca collects the qualifier of Yakeme (Manzo 2009). Scaptotrigon bees like Zoogenetic resource contributes to pollination processes; guaranteeing the food security of the region in which they are established.

Figure 2.1 Types of melipona bees

Plebela sp	• Renowned as: Fly bee, it is very small black or gold, it´s nest contains a small wax entrance (piquera).
Lestrimelitta sp	• Renowned as: Cayasán, Lemon bee, it is small black in color and it´s nest contains a small wax entrance (piquera)
Melipona Favosa	• Renowned as: Erereú, is Medium (10 to 11 mm), black in color and reddish hair, with light stripes on the abdomen, its nests; muddy entrance with radial stripes and covered nests in trees.
Trigona Tetragonista Angustula	• Renowned as: Negrillo, is medium, black, slender, its nest contains a wax entrance, covered in various sites.
Melipona Fulviventris	• Renowned as: Moro-Moro, is medium, dark in color, thorax with reddish hair we and fulvo-colored abdomen, its nest contains a radiated mud entrance with hole for a single bee and nests covered in tree cavities.

Source: Own elaboration with data obtained from Quezada Euan, J. J. (2018). Abejas sin aguijón de México (1st ed.). México: Universidad Autónoma de Yucatán. (Original work published 2018)

2.1.7 Nests of Scaptotrigona of the species Tetragonisca Angustula

The nests of these bees are in any cavity or container that they find available in natural conditions, they prefer cavities in living trees in the same way they make their hives suspended from branches using abandoned bird nests or in the ground, underground. The materials used for the construction of brood combs are propolis and batumen. Propolis is a flexible mixture, composed of wax and vegetable resins, the bathumen is a solidified material made up of clay, vegetable resins and seeds.

2.1.8 Parts of a nest

The parts that make up the nests are different according to the species. For the case analyzed, it is recommended to build as floors that allow the passage of a bee in the entry and exit gate in order to avoid infestations of plagues: nest, supernido, melario and piquera. Internally, the honeycomb must be composed of thin sheets of propolis that surround the brood or nest area. The cells must be cylindrical, arranged from one side to the other in an orderly manner. The food storage compartment is located on the edge of the nest, outside the breeding area, it is made up of propolis cups, which acquire an oval appearance, where the bees collect honey and pollen separately. Similarly, the construction of the waste area must be located outside the breeding and food storage areas.

2.1.9 Prototype

The etymological definition of the term "prototype" is constituted by the Latin prefix of Greek origin "protos" which means "the first" and "types" which means "type, impression, figure or model" (Etymologies, 2016), considering what has been described previously defined as: the first version of a new type of design or model that is built to understand the behavior of the problem and its possible solutions in a real environment (Maner, 2013), this can be perceptible or also a virtual unit, for example, a computer program. The most notable characteristics that represent it are:

1. Limited functionality over a period of time: Nature and purpose manufacturing should be clear during the cycle of use.

2. High degree of user participation which evaluates the operation. provides improvements and specifies requirements.

3. High degree of analysis: Considering that users cannot indicate the requirements to have experience with the system.

2.1.10 Classification of prototypes

Lacalle (2006) and Walter Maner (2013) propose a simple classification, establishing "fidelity" as a measurement indicator that corresponds to the level of similarity of the variables of appearance and functionality of the model (Table 2.1 Prototype classification scheme).

Table 2.1 Prototype classification scheme

Prototype type	Variable	Features
Low fidelity	Appearance	They are quick in their development and use different materials to those of the final product, cheap, simple and easy to produce useful in the early stages of development and during the conceptual design.
High fidelity	Appearance	Similar to the final product, they use the same materials, they provide a detailed idea of the product, including characteristics such as cost, quality and performance.
Exploratory	Functionality	Applied to clarify project goals, identify requirements, examine design alternatives or investigate a large and complex system, it allows initial conceptual ideas to be compared with design expectations and requirements.
Experimental	Functionality	It allows the validation of certain specifications of the product that is being designed and constitutes an intermediate element for the realization of certain pilot tests.
Operational	Functionality	It is iterative, progressively improved and becomes the design final supports applying changes.

Source: Own elaboration with data obtained from La calle (2006) y Walter Maner (2013)

2.1.11 High-tech boxes for bees

The incorporation of the rational boxes through the physical prototype presented in the research facilitates the operational activities in meliponiculture, both the biological material management (colonies) in relation to divisions and production management (efficient harvest) of honey and other goods such as pollen, and propolis. At the present there are multiple models of rational boxes, the boxes with divisions and built with wood with an average thickness of 2.5 cm, are the most used, the different models are described below:

1. Caja Maria: according to Monteiro (2000), it is a box with a simple structure, which shows a fixed central brood chamber and two removable chambers for storing honey and pollen, facilitating harvesting without damaging the nest, built mainly of wood.

2. UTOB box: box developed by the University of Utrecht in Trinidad and Tobago, it consists of two sectors, for the brood chamber and another for the honey and pollen production chamber. The separations of the chambers allow to isolate the food store from the nest, which allows reduce colony stress at harvest time (Sommeijer, 1999).

3. Arturom box: it consists of a base for a brood chamber, divided into two 7.5 cm sections. Tall each separated, a central hole of 5 cm in diameter. Above the brood chamber is placed a rise separated by strips with spaces for the bees to climb and build the honey and pollen pots (Mejia, 2006).

4. Improved Brazilian box: vertical box modified according to the Portugal Araujo design with sections Disassembled, it consists of two compartments for the brood chamber and two risers for the production of honey. The measurements are: brood chamber 14 X 14 X 10 cm and 4 cm thick, the production chamber are 18 X 18 X 8 am and 2 cm thick (Baquero and Stamatti, 2007 and Guzmán et al., 2011).

5. Simple box (traditional box): consists of an elongated drawer without divisions, with a movable upper part (Mejía, 2006). These boxes are traditionally used in various areas of the South Region, the measurements of this box are variable and can reach up to 100 X 21 X 25 cm.

The importance of the use of these physical means for reproduction is that they provide an optimal space in which zootechnical conditions are not affected by climatic changes and in the same way the colonies are difficult to access for pests and / or enemies. (Baquero & Stamatti. 2007).

2.1.12 Supplier analysis

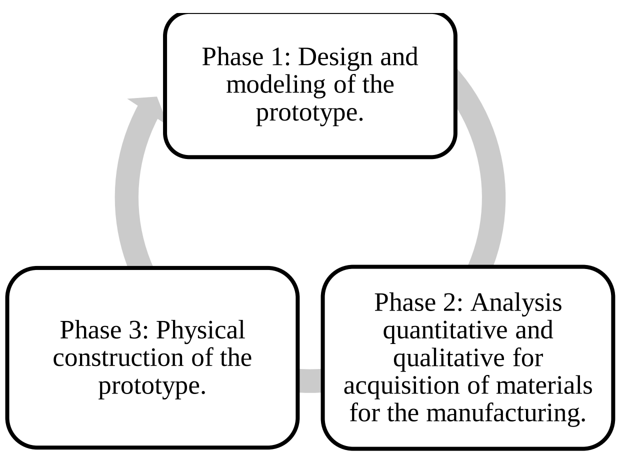
According to Cameiro (2004) a supplier is a business entity that supplies the company with goods and / or services necessary for its use in the production of goods and / or services of the company. The particularities of a supplier's product, as well as the points of proximity with the value chain of a company, can significantly disrupt costs and thus the differentiation of a company from the competition. Suppliers are responsible for offering supplies efficiently, early and quickly, as well as the possibility of coordination, reduction of traction costs, inventory costs and risks. Suppliers support the suitability of the companies they supply, establish jobs, promote the exchange of products with others, contribute to the multiplicity of the workforce and the economy, and affirm the technological persistence between natural resource processors and the rest of the industry (Torres, 2009).

According to (Hernández, 2014) Once the supply sources have been identified, we proceed to the choice of suppliers that are best suited to the demand, based on a series of criteria, as a result, a list of optimal suppliers is obtained. This process is only carried out for the acquisition of the products that are most commonly purchased, since it has an economic cost and is only profitable if the final savings obtained is greater than the investment made in the search for suppliers for the company. In this sense and considering what is described, logistics interventions are applied for the analysis and selection of suppliers, considering the different costs derived for the purchase and transport of raw materials for the production of technified boxes for the Meliponarians.

2.1.13 Methodology to be developed

The methodological description that allowed the design and manufacture of the presented prototype was developed from 3 phases (Figure 2.2 Phases of the methodological process corresponding to the investigation).

Figura 2.2 Phases of the methodological process corresponding to research



Source: Own Elaboration

2.1.14 Phase 1: Design and modeling of the prototype

Using the theoretical reference consulted, the areas that will make up the technical box are defined in the first instance, following a vertical building superimposed between 7 zones:

1. Base legs.

2. Base.

3. Nest.

4. Super nest.

5. Melario.

6. Top.

7. Fastener.

The measurements are determined and the characteristics of the different zones are described, specifying the dimensions for further consideration in the scaled design in SolidWorks Software (Table 2.2 Description and dimensions of parts that make up the prototype).

Table 2.2 Description and dimensions of parts that make up the prototype

Part	Features	Dimensions
Base legs	They contribute the stability of the box the contemplating the control of sudden movements.	2 cm x 4 cm x 22 cm.
Base	It allows the colony of bees that inhabit the hive to develop suitable environmental conditions for reproduction.	2 cm x 22 cm x 22 cm
Nest	Contains the hive brood foot.	7.5 cm x 23 x 23 cm
Super nest	This zone allows the separation of the hive into two sections to create a new nucleus or a new hive.	6.5 cm x 23 cm x 23 cm
Melario	In this area is the honey, during the extraction process the analyzed area is slightly detached without being affected.	8 cm x 23 cm x 23 cm
Top	Ensures permeability, protecting the content of the hive, providing ideal environmental characteristics for improving the productivity of bees.	2 cm x 23 cm x 23 cm
Fastener	Allows manipulation and movements to move the hive.	2 cm x 2 cm x 19 cm.

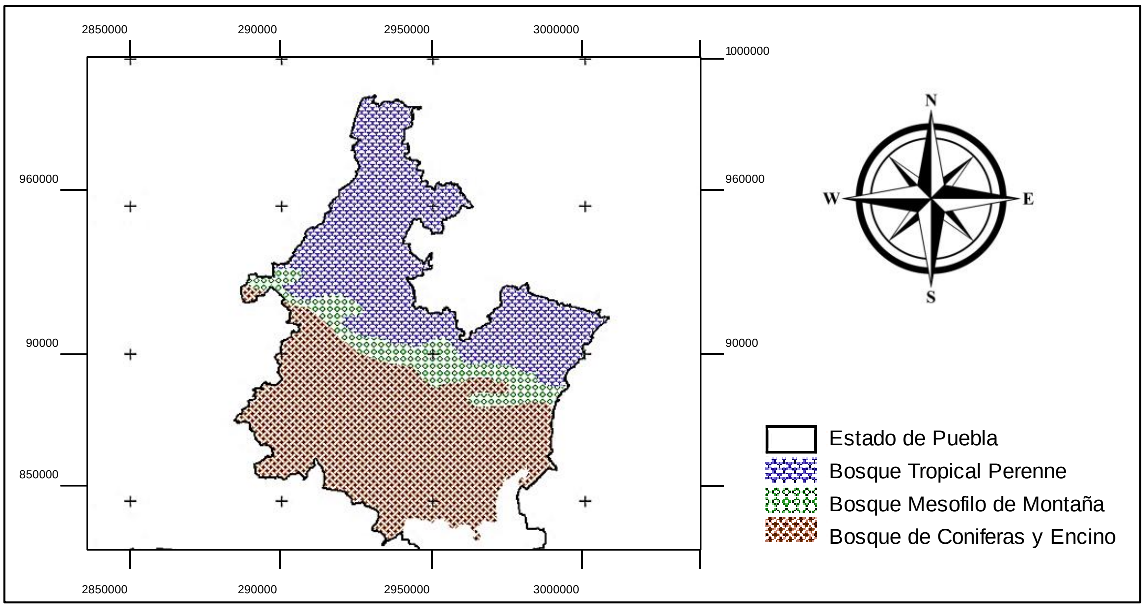
Source: Own elaboration

2.1.15 Phase 2: Quantitative and qualitative analysis for the acquisition of materials for manufacturing.

2.1.16 Qualitative analysis

Making an analysis through the application of exploratory research, we proceeded to determine the different types of wood existing in the Sierra Norte, highlighting those whose thermal properties allow the regulation of environmental conditions in the region. Considering that the natural vegetation is contained in tropical evergreen forests, mountain mesophilic forests, and coniferous and oak forests. (Rzedowski, 1992; INEGI, 2005) (Figure 2.3 Types of concurrent forests in the Sierra Norte de Puebla) a comparative study is carried out between the different woods present in the region and the area of influence, since the aim is to achieve the appropriate environment For the development of melipon bees Tetragonisca Angustula, the physical and mechanical properties that allow the accumulation of heat in the wood are analyzed, the density and moisture content being variable that determine the environment conducive to reproduction (Table 2.3 Qualitative analysis of the characteristics of the different wood models of the region).

Figure 2.3 Concurrent Forest types in the Sierra Norte de Puebla



Source: Estado actual de los mamíferos silvestres de La Sierra Norte de Puebla – Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Figura-8-La-vegetacion-natural-de-la-Sierra-Norte-de-Puebla-esta-compuesta_fig7_299331269 [accessed 3 Feb, 2021]

Table 2.3 Qualitative analysis of the characteristics of the different wood models in the region

Features		Types of wood White Pine	Cedar	Jonote o chaca
Physical properties	Color	White tree and yellow-brown heartwood,	Sapwood from light pink to yellow. Heartwood yellow even to reddish Brown.	Light color
	Defects	It has abundant knots, normally healthy.	Exposure of knots in varying dimensions, with accumulations of resin.	The wood presents knots.
	Fibrous Structure	Straight	Straight, presentation of spaces intertwined.	Straight
	Grain	Half	Half	Thin
	Density	500 kg/m^3	490-520 kg/m^3	560 kg/m^3
	Humidity	12% humidity	12% humidity	12% humidity
	H ardness	1,8 – 2,1 in the test of Monnin.	2 in the test of Monnin.	3,2 in the test of Monnin.
	Durability	Not durable against insects. Perceptive to the aggression of fungi and insects.	Its natural structure is tenacious to the aggression of fungi and insects, it is durable and smells of resin root; so it is considered suitable for exteriors.	Durable against fungi and insects in suitable environmental conditions.
	Dimensional stability.	Volumetric shrinkage coefficient: 0,38%	Volumetric shrinkage coefficient: 0,34%	Volumetric shrinkage coefficient: 0,38%
Mechanical properties.	Compression.	434 kg/cm^2	415 kg/cm^2	490 kg/cm^2
	Static bending.	874 kg/cm^2	753 kg/cm^2	850 kg/cm^2
	Elasticity	90.000 kg/cm^2	90.000 kg/cm^2	103.000 kg/cm2
General	Work ability	Drying process soon. Risk of cracks and imperfections.	Late drying, low probability of blemishes. High risk of amber oozing.	Quick drying, with risk of damage.
	Price	Low to moderate.	Moderate.	Moderate.

Source: Own elaboration with data obtained CONAFOR. (2007). Fichas técnicas tecnológicas y usos de maderas comercializadas en México (Vol. II)

The increase in humidity in the composition of the wood influences the specific heat, considering that the caloric capacity of pine is similar to that of brick, however, the density of wood represents 1/3 with reference to brick. (Wood Products, 2018), the density of jonote or chaca wood is higher than the density of pine and cedar, maintaining 12% humidity; This means that the heat content is higher in the jonote material (Figure 2.4 Jonote wood), as well as the mechanical properties: compression, static bending and elasticity, present greater benefits compared to other materials.

Figure 2.4 Jonocote wood

Source: Own elaboration

2.1.17 Quantitative analysis

We proceeded to determine the set of necessary materials (Jonote wood, acetates, wire for meliponiculture, nails) to acquire them, considering that the costs must be feasible for the economy of the region, a logistical intervention was applied for the selection of suppliers considering the variables that directly intervene in the generation of direct indirect costs: fuel performance and price (Km/L), travel distance (Km), annual maintenance cost projection, load unit usage period (min), cost of booths, unit cost of raw materials and supplies, with an insurance cost of 40% with respect to the unit value of the transported cargo (Table 2.4 Logistical intervention for selection of suppliers).

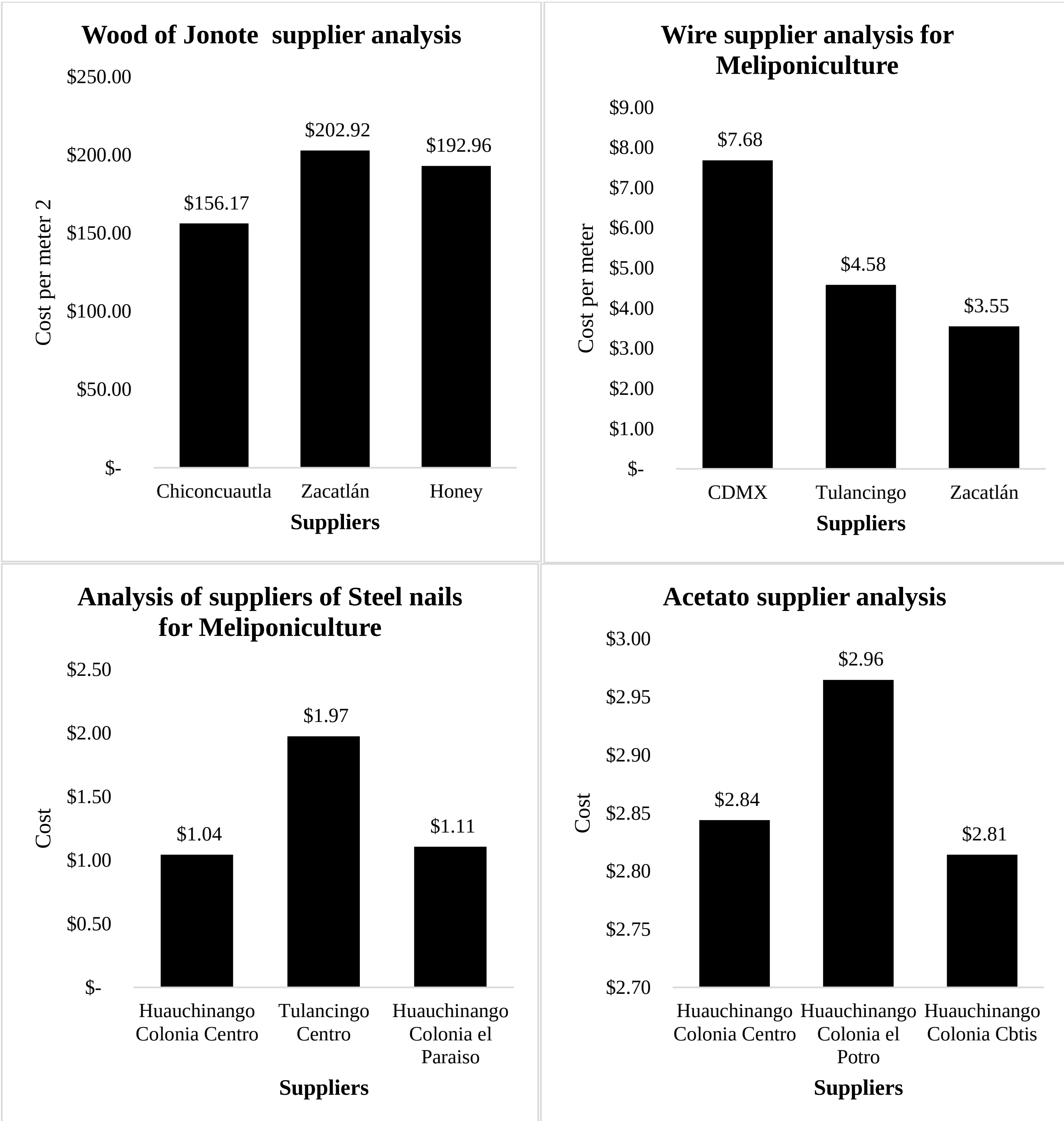
Table 2.4 Logistics intervention for supplier selection

	Jonocote wood			Wire for Meliponiculture			Steel nails for Meliponiculture			Acetates		
Suppliers	Chiconcuautla	Zacatlán	Honey	CDMX	Tulancingo	Zacatlán	Huauchinango Centro	Tulancingo Centro	Huauchinango El Paraíso	Huauchinango Centro	Huauchinango El Potro	Huauchinango Cbtis
Pieces	1	1	1	100	100	100	100	100	100	100	100	100
Fuel efficiency (km/l)	14	14	14	14	14	14	14	14	14	14	14	14
Distance (KM)	38.3	60.5	69	173.6	54.1	60.5	2.8	54.5	4.2	2.8	5.4	6
Annual maintenance cost ($)	$ 1,200	$ 1,200	$ 1,200	$ 2,200	$ 2,200	$ 2,200	$ 879	$ 879	$ 879	$ 400.00	$ 400.00	$ 400.00
Charging unit usage time (MIN)	89	82	400	149	61	82	11	62	14	11	16	20
Booths cost	$ -	$ -	$ -	$ 220.00	$ 73.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Unit cost of parts (m^2, unidades)	$ 240	$ 270	$ 210	$ 6.9	$ 7.5	$ 6.5	$ 2.5	$ 2.8	$ 2.6	$ 7.00	$ 7.20	$ 6.80
Minutes annual	518400	518400	518400	518400	518400	518400	518400	518400	518400	518400	518400	518400
Fuel cost	$ 59.97	$ 94.73	$ 108	$ 2.718	$ 0.847	$ 0.947	$ 0.044	$ 0.853	$ 0.066	$ 0.0438	$ 0.0845	$ 0.0939
Maintenance cost	$ 0.206	$ 0.190	$ 0.926	$ 0.006	$ 0.003	$ 0.003	$ 0.000	$ 0.001	$ 0.000	$ 0.00008	$ 0.00012	$ 0.00015
Toll cost	$ -	$ -	$ -	$ 2.200	$ 0.730	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Insurance cost (40% of unit cost)	$ 96	$ 108	$ 84	$ 2.76	$ 3	$ 2.60	$ 1	$ 1.12	$ 1.04	$ 2.80	$ 2.88	$ 2.72
Total cost	$ 156.17	$ 202.9	$ 193.0	$ 7.68	$ 4.58	$ 3.55	$ 1.04	$ 1.97	$ 1.11	$ 2.84	$ 2.96	$ 2.81

Source: Own elaboration

Using the cost calculation, the supplier selection process was carried out applying a statistical analysis to determine the ideal option for the acquisition of inputs, the results indicate that the supplier for jonote wood is the municipality of Chiconcuautla with a cost of $ 156.17, the wire for meliponicultura will be purchased in the CDMX with a value of $ 3.55, the nails will be purchased at Huauchinango Centro at a cost of $ 1.04, and the acetates will be purchased at Huauchinango Cbtis with a price of $ 2.81 (Figure 2.5 Statistical analysis for selection of suppliers).

Figure 2.5 Statistical analysis for selection of suppliers



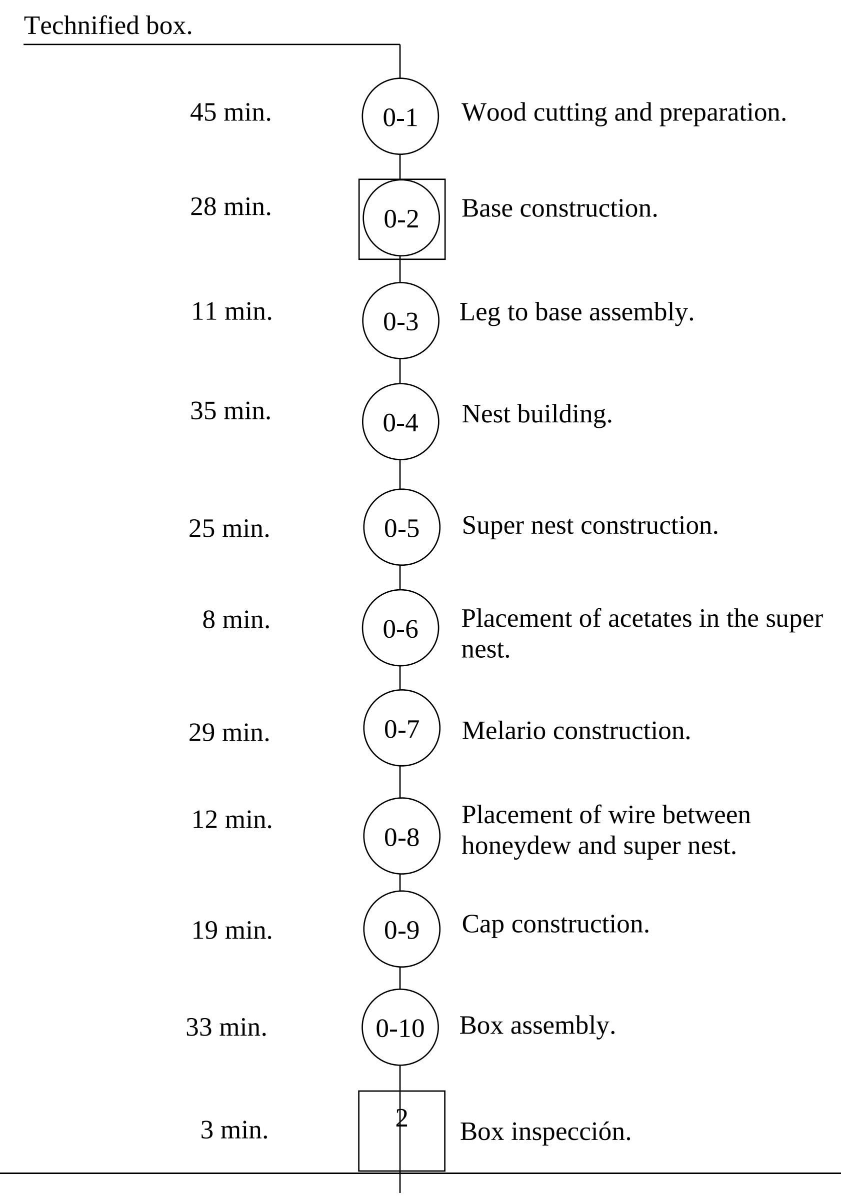
Source: Own elaboration

2.1.18 Phase 3: Physical construction of the prototype

Derived from the design and modeling, as well as the physical acquisition of the materials, we proceed to build the prototype; determining the working method with the creation of the process diagram in which the optimal activities and the standard time for manufacturing were established (Figure 2.6 Process diagram for technified box). Once the optimal work process was established, the model was physically built (Figure 2.7 Physical construction of the prototype).

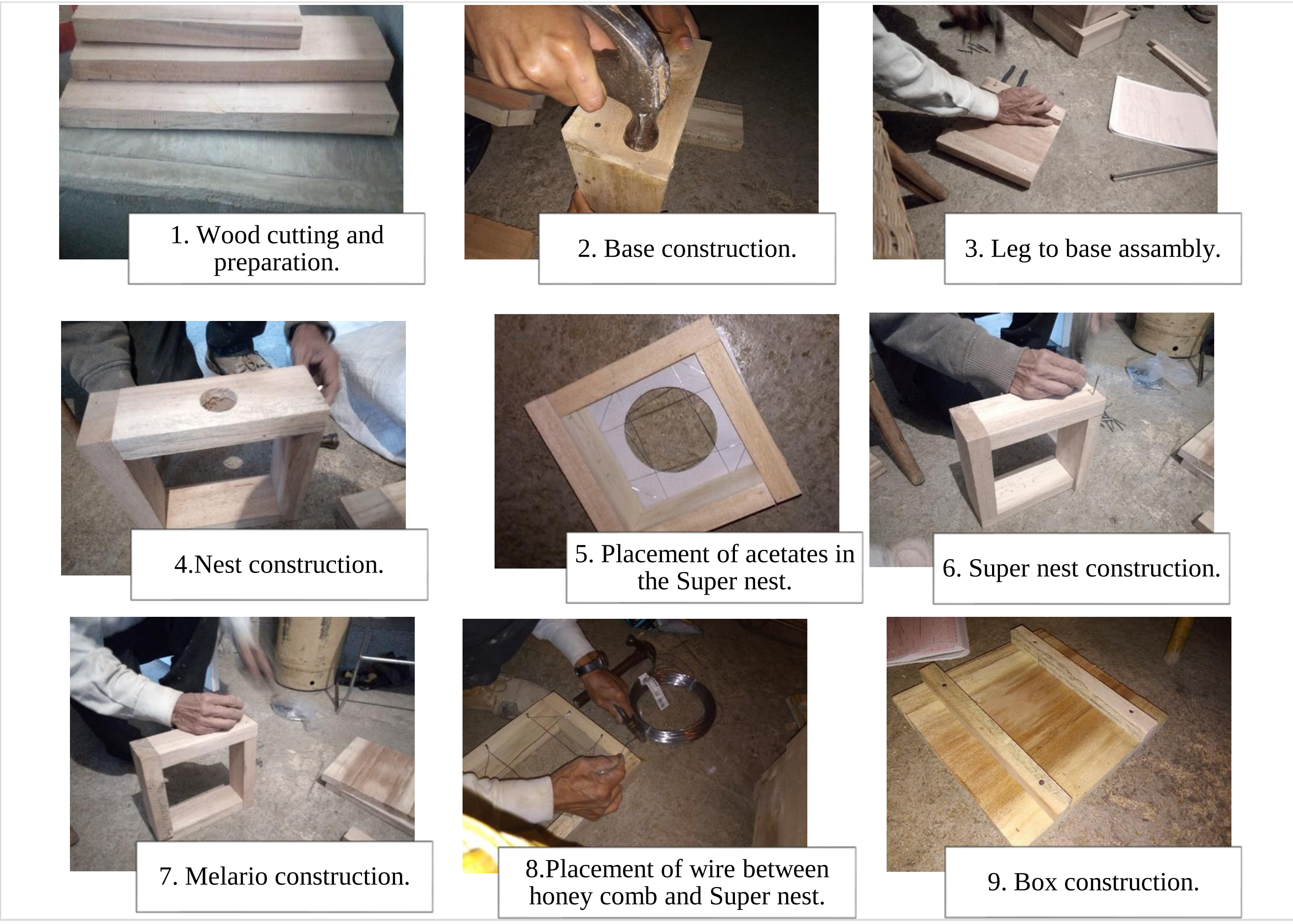
Figure 2.6 Process diagram for technified box

PROCESS OPERATIONS DIAGRAM			
Manufacturing:	Technified box.	Method:	Actual
Area:	Production.	Total time (min)	248
Operator:	1	Total time (hours)	4.13
Elaboration:	-		



Source: Own elaboration

Figure 2.7 Physical construction of the prototype



Source: Own elaboration

In the same way, the effectiveness of the design was assessed by subjecting the built prototype to various environmental conditions in a sampling period of 30 days, the recorded observations are recorded below (Table 2.5 Abstract of Recorded Observations):

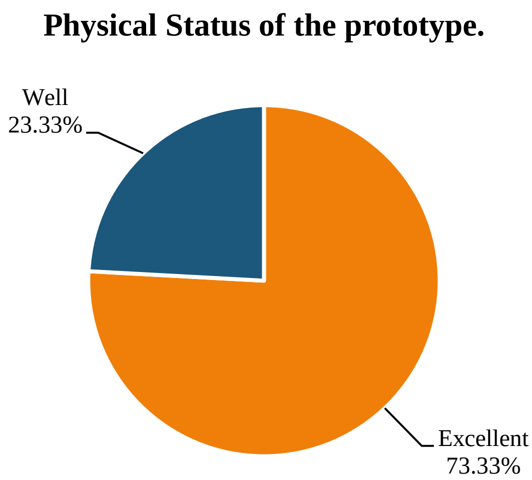
Table 2.5 Summary of registered observation

Period	Precipitation rainy.	Wind	Sunny	Cloudy	Physical state of the box
Day 1					Excellent
Day 2					Excellent
Day 3					Excellent
Day 4					Excellent
Day 5					Excellent
Day 6					Excellent
Day 16					Excellent
Day 17					Well
Day 18					Well
Day 19					Well
Day 24					Excellent
Day 25					Excellent
Day 26					Excellent
Day 27					Excellent
Day 30					Well

Source: Own elaboration

The statistical analysis corresponding to the observation days shows us that the exposure of the boxes to different environmental conditions categorizes an Excellent condition in 73.33% presenting non-significant changes in the physical structure; Likewise, the condition of Good is presented in 23.33% considering possible changes, with regular criticality that in the long term will cause deterioration in the boxes (Graphic 2.1 Physical status of the prototype).

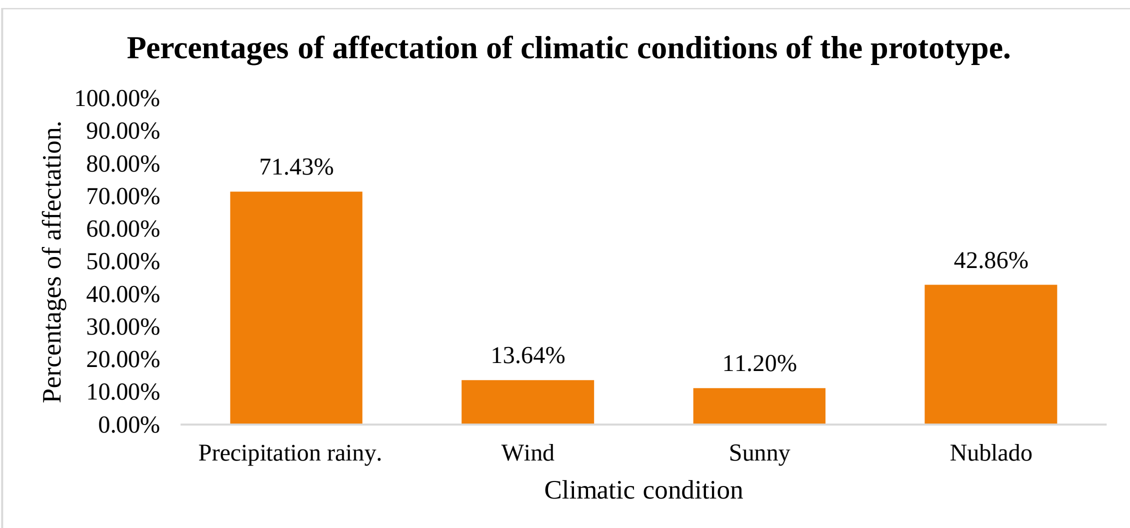
Graphic 2.1 Physical status of the prototype



Source: Own elaboration

By means of statistical research, the percentage of influence with respect to the affectation of the physical conditions of the technical box is exposed: the different atmospheric events that are exposed with the study carried out are represented by precipitation and condensation: rain and drizzles (Rainy precipitation), humidity and mist (condensation), as well as sunny and wind weather. The rainy precipitations affect mainly the conditions of the manufactured model (71.43%), followed by the cloudy climate (42.86%), since these climates considerably increase the increase in humidity of the environment and with it the affectation of the box; Thus, it is also deduced that the environmental factors of sunny and wind do not present critical participation (Graphic 2.2 Analysis of the impact of climatic conditions).

Graphic 2.2 Analysis of the impact of climatic conditions



Source: Own elaboration

The information obtained will be useful to us, since it will allow us to formulate an improvement plan for the conservation of the box and thus fully ensure its resistance to weather conditions.

2.2 Results

The results observed in Phase 1 are shown with the scaled design in the SolidWorks software of the proposed prototype, the model exposes each of the parts that make up the hive (Figure 2.8. Technified box model in SolidWorks software):

- Base: The assigned shape is square in order to take advantage of the adaptability of bees: generating a medium that reduces stress levels in the reproduction processes.

- Nest: This area is assigned for the brood foot, placing a circular opening that provides the entry of oxygen.

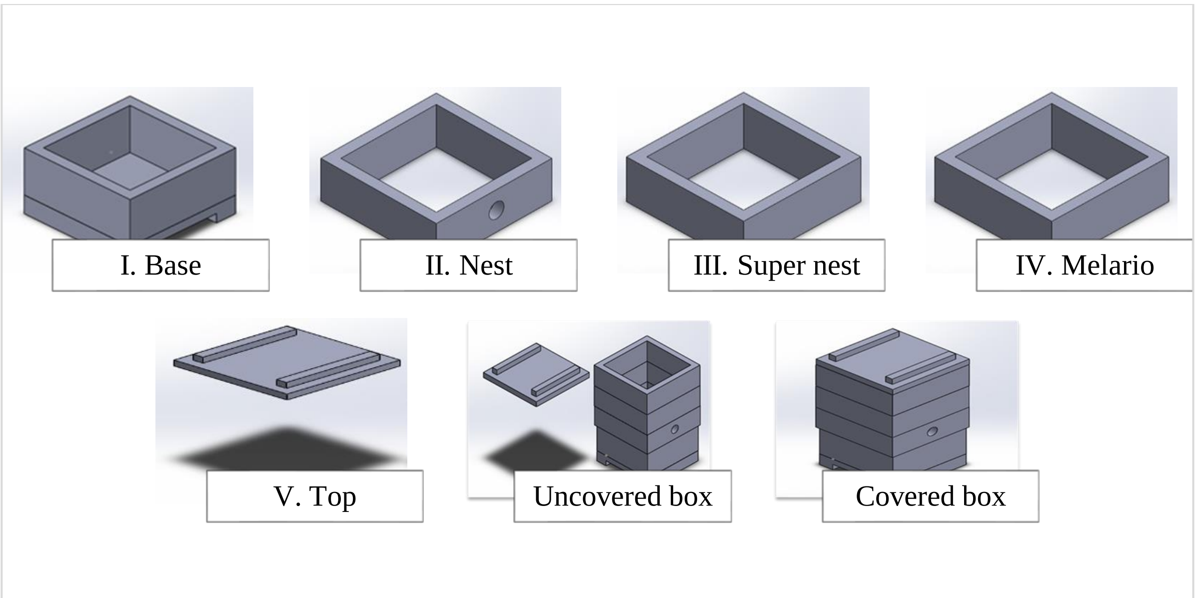
- Super nest: In order to obtain a greater quantity of breeding for the generation of new nuclei, sectioned elements are included (wire for meliponiculture, acetates); to develop a communication space between nest and super nest.

- Melario: Within this area originates the sweet and sticky substances from which later the honey and some of its derivatives will be extracted.

- Top: Being very necessary to have a closed space for the development of bees, a cover is also included whose main purpose is to regulate the temperature of the created hive. After the design of components, the assembly is carried out to form the prototype full.

After the design of components, the assembly is carried out to form the prototype full.

Figure 2.8 Technified box model in SolidWorks software

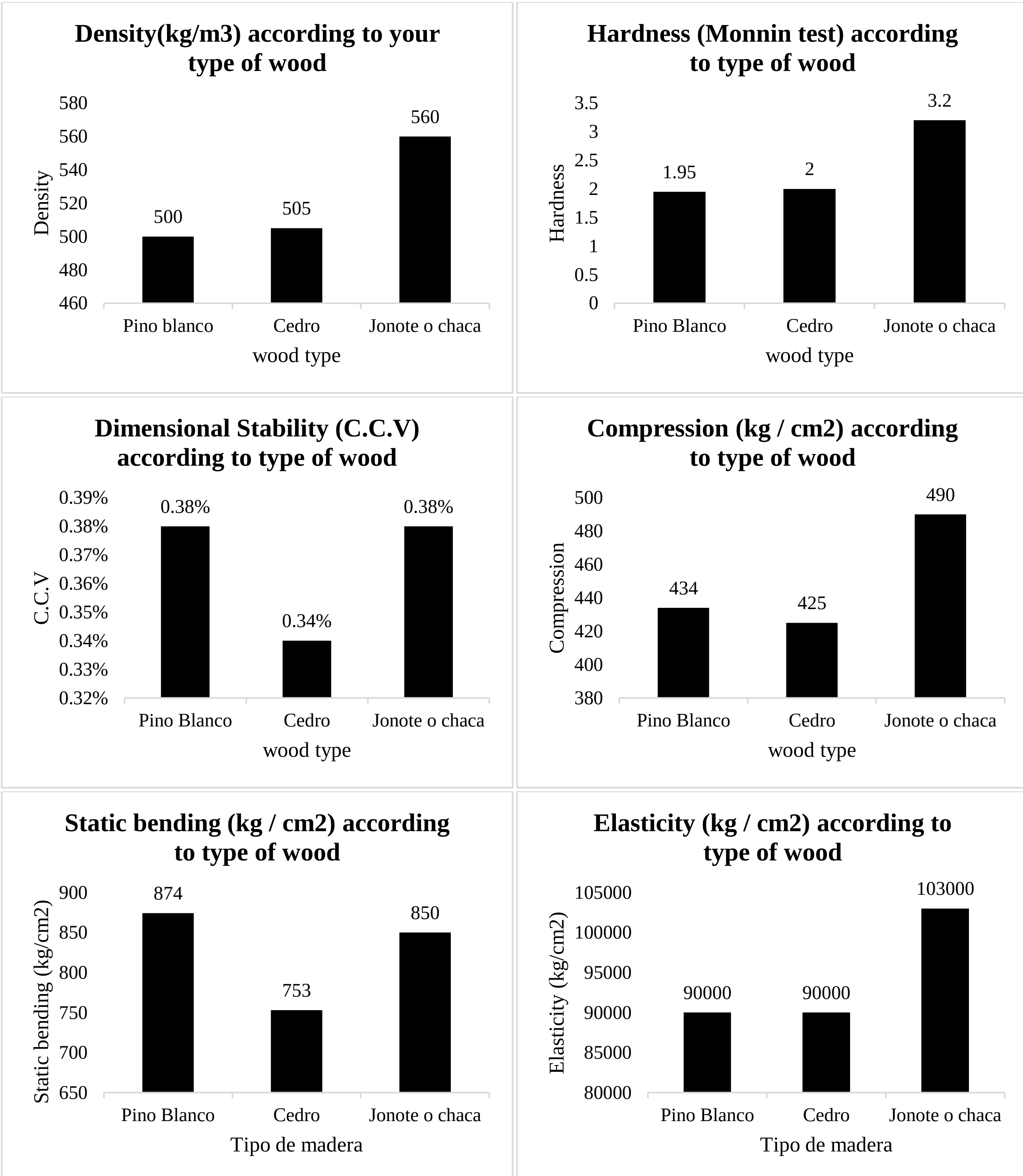


Source: Own elaboration using SolidWorks Software 2017

The effects obtained for Phase 2 according to the qualitative analysis of the types of wood existing in the region and the area of influence allowed us to observe the general, physical and mechanical characteristics, concluding that for jonote wood: the density (Km / m³) is of 560, 12% higher than that of white pine, this factor presents a Monnin index of 3.2, 64% more with respect to white pine, the dimensional stability is equal to the pine indicator; Similarly, there is 13% more understanding (Km / cm²) with respect to the lower index, for the elasticity factor (Km / cm²) it remains 14.4% higher than the 2 elements analyzed (Figure 2.9 Statistical analysis of the general, physical and mechanical characteristics of wood in the regíón): the aforementioned conditions consider jonote or chaca wood as the optimal acquisition option as the main input to manufacture the prototype.

Using the logistical intervention, we proceeded to determine the optimal suppliers (Table 2.6 Selection of suppliers) to buy the set of required materials, Chiconcuautla being the supplier of jonote wood with a unit price of $ 156.1729, the town of Tulancingo the supplier of wire for meliponicultura with a value of $ 10,652, for nails and acetates Huauchinango was selected with a cost of $ 5,220 and $ 5,628 respectively; accounting for a raw material purchase value of $ 177,673.

Figure 2.9 Statistical analysis of the general, physical and mechanical characteristics of wood in the region



Source: Own elaboration using SolidWorks Software 2017

Table 2.6 Selection of suppliers

Selection of suppliers				
Materials	**Supplier**	**Unit price**	**Required quantity**	**Subtotal**
Jonote Wood	Chiconcuautla	$ 156.1729	1	$ 156.173
Wire for Meliponiculture	Tulancingo	$ 3.5507	3	$ 10.652
Steel nails for Meliponiculture	Huauchinango Colonia Centro	$ 1.0440	5	$ 5.220
Acetates	Huauchinango Colonia Centro	$ 2.8141	2	$ 5.628
TOTAL				**$ 177.673**

Source: Own elaboration using SolidWorks Software 2017

The process of elaboration and documentation of the work system for the manufacture of the technified box through the diagram of operations carried out in Phase 3, allows to determine the Standard Time with a total of 248 minutes or 4.13 hours necessary for the construction; If you want to sell the model, you proceed to calculate the cost of sale: raw material cost- $ 177,673 + labor cost $ 36.92 (Salary for Puebla in Mexico 2021) - $ 152.60: the total cost is $ 330,273 considering a margin of 40% profit, the resulting cost of sale is $ 462.3822 comparing the costs of boxes for Melipona bees (Table 2.7 Analysis of brands, models and prices established by the main suppliers of technified boxes for Meliponiculture in México) manufactured Chilpancingo, Guerrero of $ 699.00 and in Lázaro Cárdenas, Quintana Roo of $ 800.00, it is deduced that the cost decreases in an interval from 36.03% to 73.01% respectively; in such a way that the prototype presented is a utility model that satisfactorily meets the quality and cost requirements.

Table 2.7 Analysis of brands, models and prices established by the main suppliers of technical boxes for Meliponiculture in México

Mark	Model	Provider location	Price
Mielguayab	Melipona	Chilpancingo, Guerrero	$ 728.00
Melipona-Scaptotrigona	Melipona	Chilpancingo, Guerrero	$ 699.00
Ana honey	Lamstrong	Comitán De Domínguez, Chiapas	$ 920.00
Madera	Langstroth	Toluca, Estado De México	$ 1,343.56
Mundo Melífero	Langstroth	Mérida, Yucatán	$ 560.00
Na Chab	Langstroth	Ocosingo, Chiapas	$ 989.00
Ingenieria y Ecosistemas	Melipona	Lázaro Cárdenas, Quintana Roo	$ 800.00
Maderas de pino	Tecnificada	Del Bravo, Guerrero	$ 615.00

Source: Own elaboration with data from https://www.mercadolibre.com.mx/

Once the prototype was manufactured and validated (Figure 2.10 Technified box), 15 models were installed within a meliponary of the region (Figure 2.11 Extraction of honey and its derivatives) the results were beneficial, considering an increase in the levels of honey production, contemplating that at the beginning of the analysis an average production of 600 mm was recorded in one period. 6 months; At the end of the first semester after the implementation of the technical boxes, an average of 800 ml per hive was harvested, increasing production by 33.33%, for the second period 975 ml were collected with a benefit of 62%: the production of derived products such as propolis, pollen and wax (Figure 2.11 Extraction of honey and its derivatives). Regarding the internal affectation of the hive, the indices of affectation by external agents were reduced, at the end of the first semester 2 affected hives were detected and for the second period 1 hive with affectation was observed.

Figure 2.10 Technified box

Source: Own elaboration

Figure 2.11 Extraction of honey and its derivatives

Source: Own Elaboration

2.3 Appreciation

To the Higher Technological Institute of Huauchinango and the Industrial Engineering Division for the facilities provided for the preparation of the chapter presented.

2.4 Conclusions

A quantitative and qualitative analysis was carried out by means of which a technified box model for melipon bees was designed, considering the existing theoretical references regarding the breeding of the species of bees. Through exploratory research, variables that make up optimal physical, mechanical and functional characteristics for meliponiculture in the region were analyzed, determining that the appropriate wood for the construction of the technified box is jonote or chaca wood. Identifying the foregoing, the economic requirements of the materials were established, taking into account the acquisition and transportation values of each one, with this the total cost of the box was calculated without considering the cost of labor, being $ 177,673 (Mexican pesos). Next, the prototype was physically built, in reference to what was obtained in the scale design of the SolidWorks design software, it is relevant to mention that to obtain the total cost of the prototype, the standard time of the process was calculated through the diagram of process operations, in this way it is concluded with a cost of sale of $ 462.3822 being a lower value with respect to other boxes currently marketed with similar characteristics and functionality. Finally, the resistance and effectiveness of the box was validated, exposing it to a sampling of 30 days under climatic conditions of the region, the result of this statistical analysis indicates that the greatest affectation is contributed by rainy precipitations, the above generated the formulation of proposals improvement for the location of this prototype in open or closed environments.

The physical development of the technified box brought multiple benefits that are reflected in the increase in the productivity of honey and its derivatives, as well as the decrease in the levels of affectation by pests, preserving in a safe way the native bee species Tetragonisca Angustula de la Sierra Norte del Estado de Puebla: in the same way, an efficient work system was created for the physical construction of the model that, by presenting a competitive cost, would create a new source of employment to promote the economic and sustainable development of the región.

2.5 References

CONAFOR. (2007). Fichas técnicas tecnológicas y usos de maderas comercializadas en México (Vol. II). Retrieved from https://www.conafor.gob.mx/biblioteca/catalogo-maderas-tomo2.pdf

G. Quesada-Euan, J. J. (2019). *Stingless Bees of Mexico: the biology, management and conservation of an ancient heritage.* S.L.: Springer.

García López, David; Quintanar Isaías, Alejandra; López Binnqüist, Citlalli (2012). Guía características y usos de la madera de jonote en la carpintería (Trema micrantha). Universidad Autónoma Metropolitana-Iztapalapa y el Centro de Investigaciones Tropicales de la Universidad Veracruzana.

García Martínez A. (2008). *Apicultura* (). Madrid: Ministerio De Medio Ambiente Y Medio Rural Y Marino. Secretaría General Técnica. Centro de Publicaciones, Dl.

Guízar-Nolazco, E., Granados-Sánchez, D., & Castañeda-Mendoza, A. (2010). Flora y vegetación en la porción sur de la Mixteca Poblana. Revista Chapingo Serie Ciencias Forestales y del Ambiente, 16 (2). 95-118 pp.

Hernández White, C. (2014). *MF1004_3, Gestión de proveedores*. Málaga Nuevos Negocios En La Red D.L.

Jiménez, E. M. (2017). *Manejo y mantenimiento de colmenas*. Madrid Mundi-Prensa.

Kasal, B. (2014). *In situ assessment of structural timber.* Germany: Springer.

Manuel Carneiro Caneda. (2004). *La responsabilidad social corporativa interna: la "nueva frontera" de los recursos humanos*. Pozuelo De Alarcón, Madrid: Esic Editorial.

Márquez-Cruz, U., López, C. y Negreros-Castillo, P. 2011. Una especie multiusos del trópico mexicano *Trema micrantha* (L.) Blume. Revista de la Facultad de Ciencias de la Universidad Nacional Autónoma de México. *Ciencias* 101: 16-22. En línea: http://redalyc.uaemex.mx/redalyc/pdf/644/Resumenes/64419046003_Abstract_2.pdf

Mercado libre. (2021). Caja Tecnificada | MercadoLibre.com.mx. Retrieved April 12, 2021, from Mercadolibre.com.mx website: https://listado.mercadolibre.com.mx/caja-tecnificada#D[A: caja%20tecnificada]

Miguel Guzmán, M., Balboa, C., Vandame, R., Luisa Albores, M., & González Acereto, J. (2011). *Manejo de las abejas nativas sin aguijón en México: melipona beecheii y scaptotrigona mexicana: manual técnico*. México: Colegio De La Frontera Sur.

Quezada Euan, J. J. (2018). *Abejas sin aguijón de México* (1st ed.). México: Universidad Autónoma de Yucatán. (Original work published 2018)

Quintanar-Isaías, A., Jacobo Villa M.A., López, C., Flores-Hernández, N., Jaramillo, P. y De la Paz, O.C. 2012 La madera de *Trema micrantha* (L.) Blume de Veracruz. *Madera y Bosques* 18(2):

Wood Products. (2018, June 21). Propiedades térmicas de la madera. Retrieved February 3, 2021, from Wood Products website: https://www.woodproducts.fi/es/content/propiedades-termicas-de-la-madera