Chapter 3 Prototype of ergonomic container of polyethylene LD-PE/PEAD for packaging honey from native bees

Capítulo 3 Prototipo de envase ergonómico de polietileno LD-PE/PEAD para envasar miel de abejas nativas

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DOI: 10.35429/H.2023.8.35.54

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Abstract

In the present work, the container prototype for melipona bee honey is shown, characterized by being operational and complying with the characteristics of interactivity, progressive improvement, flexibility for changes and functionality. In the experience of Garcerant (2019) the containers are physical means that preserve the organoleptic characteristics of the products, specifically the exposed model is oriented to contain a sweet liquid (honey), which is extracted from the meliponarios of the Sierra Norte of the State of Puebla and comes from native bees (Tetragonista Angustula), the need for the creation of this packaging arises due to the high packaging costs currently absorbed by regional bee growers, who, when observing high packaging costs, choose to sell honey to intermediaries in larger containers (19 liters) at low costs, significantly reducing their own profits from honey, which is harvested in two seasonal periods (april/august), what is described above brings with it the design of the container which is manufactured with high (Cap)/low (Body) density polyethylene (LD -PE/ PEAD), designed to contain a volume of 500 ml and preserve honey at a temperature ranging from 5°C to 25°C (Room temperature), being resistant to impacts and the introduction of external agents. The design of the container validates ergonomic aspects of use: 1) The opening-closing (flip flop lid), 2) Take-carry (Body shape), this prototype was made in the SketChup software, later it was printed in 3D and validated by technical viscosity tests, finally, the unit cost of the container was calculated, which amounts to a monetary value of $11.09, being 44.85% competitive in the commercial market and low cost for meliponiculturists.

Container, Polyethylene, SketChup, Ergonomics, Honey

Resumen

En el presente trabajo, se muestra el prototipo de envase para miel de abeja melipona, caracterizado por ser operacional y cumplir con las características de interactividad, mejora progresiva, flexibilidad para cambios y funcionalidad. En experiencia de Garcerant (2019) los envases son medios físicos que preservan las características organolépticas de los productos, específicamente el modelo expuesto está orientado a contener un líquido dulzoso (miel), mismo que se extrae de los meliponarios de la Sierra Norte del Estado de Puebla y proviene de las abejas nativas (Tetragonista Angustula), la necesidad para la creación de este envase surge debido a los altos costos de envasado que actualmente absorben los meliponicultores regionales, los cuales al observar costos altos de envasado, optan por vender la miel a intermediarios en contenedores de mayor tamaño (19 litros) a bajos costos, disminuyendo notablemente las ganancias propias por la miel, misma que se cosecha en dos periodos estacionales (abril/agosto), lo descrito anteriormente trae consigo el diseño del envase el cual está fabricado con polietileno de alta (Tapa)/baja (Cuerpo) densidad (LD-PE/PEAD), diseñado para contener un volumen de 500 ml y conservar la miel a una temperatura que va desde 5 °C y 25 °C (Temperatura ambiente), siendo resistente a impactos y a la introducción de agentes externos. El diseño del envase válida, aspectos ergonómicos de uso: 1) La apertura-cerrado (Tapa flip flop), 2) Tomar-transportar (Forma del cuerpo), este prototipo se realizó en el software SketChup, posteriormente se imprimió en 3D y se validó por pruebas técnicas de viscosidad, para finalizar se calculó el costo unitario del envase el cual asciende a un valor monetario de $11.09, siendo competitivo en un 44.85% en el mercado comercial y de bajo costo para los meliponicultores.

Envase, Polietileno, SketChup, Ergonomía, Miel

1. Introduction

In México and the world, the consumption of honey is a habit that has become very relevant in recent years. In Mexican homes, it is more common every day to have this important sweetener on our tables, which is composed of different properties that contribute notably to the nutritional diet of human beings, at this point of consumption it is important to take into account the needs of the people (Producers) who harvest this vital nectar, which are relevant to preserve current production levels, which supply our consumption needs.

These producers in the northern area of the State of Puebla are recognized as meliponiculturists, who individually or collectively make up meliponarios, which are physical establishments equipped to conserve, preserve and promote the reproduction of the melipona bee of the genus Tetragonista Angustula .

It is worth mentioning that this important productive activity in the region and area of influence serves approximately a total of 200 meliponarians present in different communities that make up the geographical area. Like any production process, it is notorious that there are problems which bring with them the following two effects: The increase in costs, and the loss of production, for two problems a common source of origin has been detected, which is born from the sale of honey to intermediaries, this in response to the fact that the honey grower does not have the means to package the product and tends to market it directly with intermediaries.

The intermediary is a natural person who adopts the role of buyer, offering meliponiculturists low prices for honey. This physical entity carries out the packaging process and direct marketing with the client, placing additional costs that exceed 50% of the original price. of the natural sweetener, this action triggers the problems mentioned above that harm the original producer (meliponiculturist).

As we can see, meliponiculturists do not carry out the direct sales process with the client, because they currently do not have the appropriate means to package honey. Taking this observation into account, in this work a prototype of an ergonomic LD-PE polyethylene container is made. / PEAD to package honey from native bees, this physical medium was manufactured through the following Phases: Phase 1) Exploratory study, Phase 2) Phase 2: Package design in specialized software (Ergonomics), Phase 3) Label design, Phase 4) Validation of packaging prototype, each of these stages contribute substantially to the creation of the standardized prototype, which was evaluated through a comparison with the costs of existing containers, and represents a significant saving of 44.85% (Automated production) being beneficial for the acquisition of meliponiculturists, also the material from which it is manufactured allows the conservation of the organoleptic properties of the honey, being resistant to impacts and preventing the entry of external organisms, however taking into consideration the different aspects for the ergonomic handling, the following functionalities are met: a) Take, transport, store, open and close, through the design and manufacture of the body of the container with a curvature shape and the implementation of a flip flop model lid. It is worth mentioning. To validate the usability of the prototype, viscosity tests were carried out confirming the conservation of the honey inside the container at room temperature, as well as simulated refrigeration processes.

2. Objetives

2.1 General objective

Design and build a physical prototype of ergonomic packaging, to package the honey obtained from meliponaria, with materials that preserve the organoleptic characteristics of honey and represent competitive sales costs, seeking to supply the growing demand for direct packaging means in the region and area of influence, as well as the reduction of intermediaries in the honey sale processes.

2.2 Specific objectives

a) Determine the optimal dimensions of the container to generate a capacity of 500 milliliters.
b) Identify the appropriate materials for the manufacture of the prototype.
c) Assessment of ergonomic aspects to consider during design.
d) Design prototype in SketChup design software**.**
e) Packaging cost projection.
f) Printing of physical prototype of ergonomic packaging.
g) Ergonomic packaging functionality validation.

3. Justification

Honey is an adjuvant to human health thanks to its chemical composition, since it is rich in vitamins and minerals, carbohydrates, amino acids and water. A study recently carried out by Tesla magazine states that, thanks to the presence of hydrogen peroxide, flavonoids, phenolic acids and glucose oxidase, honey is a powerful antibacterial element. In addition to having anticancer and antioxidant properties, its positive effect has been demonstrated in conditions related to the respiratory and digestive systems, among others (Campo and Hincapié 2023). Official records by the Agro-Food and Fisheries Information System (SIAP) exposed that in the year 2022 the production of honey in the state of Puebla was 2 thousand 449 tons of honey.

This being the eighth producer nationwide, and having as main producers the municipalities of Cuetzalan del Progreso, Atlixco, Acatzingo, Chalchicomula de Sesma, Izúcar de Matamoros, Puebla, Tlacotepec de Benito Juárez, Pantepec, Huauchinango and Pahuatlan (Gobierno de México, 2023). Specifically, the municipality of Huauchinango Puebla has approximately 200 melipona bee hives.

Due to the above and considering the 200 meliponarios in the Huauchinango region, projecting an annual production of 480,000 ml, which require a container for their commercialization, which protects their chemical and physical properties, is manageable, attractive to the client, ergonomic, of accessible materials, a container prototype was created that satisfies the aforementioned needs, taking into account that the meliponiculturists of the region and area of influence require this standardized container that identifies the northern zone of the State of Puebla, so that each meliponario have the possibility of bottling their own honey, and obtain higher profits by selling directly with the client, reducing the sales control that exists up to now by intermediaries, who acquire honey at low costs, carry out the process of packaging and sell with additional costs that add up to approximately 50% with respect to the cost paid to meliponiculturists.

Due to what has been described above, it is imperative to use a container that preserves the organoleptic characteristics of honey and maintains an affordable price for meliponiculturists. It is important to mention that there are currently containers oriented to be honey containers, but currently they handle costs that They range from $12.9 to $27.275., being costs that significantly increase the cost of sale and decrease profits, so by manufacturing a container with a lower cost ($11.09) the benefit will be profitable, thus also allowing meliponiculturists to carry out Individually, the packaging process ensured the preservation of 100% of the organoleptic characteristics of honey.

4. Theoretical Framework

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

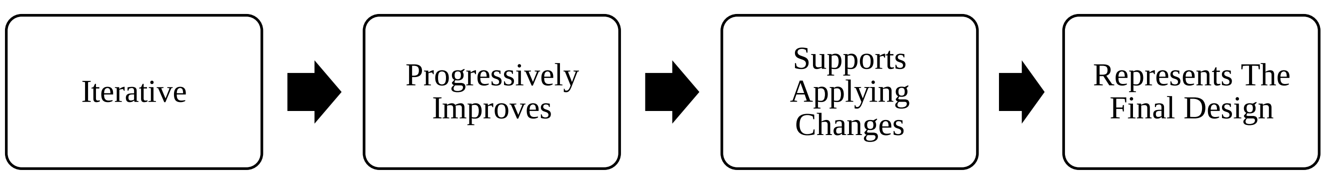
4.1. Prototype

A prototype in the experience of Luque (2019), is a physical medium that allows observing the interaction of quantitative and qualitative variables for the formulation of a physical product. Through the generation of the prototype, the different factors are combined to know in a real way the resources that will be used for the presentation of the physical good, in general, a prototype exposes the reality of the product with a manufacturing level that goes from an artisanal process to semi-automated processing.

4.2. Types of prototypes

Specifically, Soto, Bones and Santos (2021) consider the existence of 5 types of prototypes, which are: Low fidelity, high fidelity, exploratory, experimental and operational, the type of prototype developed in this work being the type operational which contains the following characteristics (Figure 1 Characteristics of the operational prototype):

Figure 1 Characteristics of the operational prototype



Source of Consultation: Soto, Bones and Santos (2021)

4.3. Technical requirements (resources) for the manufacture of prototypes

It is important to mention that for the realization of the prototype exposed in this work the following resources were used:

a) Human resources: These means are directly related to the interaction of the personnel, which carries out administrative and operational functions, actions that directly contribute to the physical formation of the product, for this reason the human factor turns out to be the means required for the transformation. raw material and inputs, being essential to have skills and competencies that substantially add to the operational process (Guerrero, 2017).
b) Material resources: They are considered as the physical means (raw material, inputs), which allow the manufacture of the product, these resources are essential to supply the production lines and are requested according to material requirements plans proposed by the designer and the manufacturer production area.
c) Financial resources: They are commonly known as economic capital from public or private sources, which is intended for the acquisition of material resources and payment for the service of human resources, this type of resource is directly monitored by senior management. and it is assigned through accounting items to cover the expenses of each of the areas, as well as its use and allocation is audited to ensure proper functioning (Santos, 2008).

4.4. Packaging prototype

Once the type of prototype has been determined (Operational prototype), the manufacturing approach is then denoted, which is oriented to the design of a container. Garcerant (2019) indicates that packaging is the means to preserve the organoleptic characteristics of products, mentioning that the design of a container must always be at the forefront, taking into account that packaging is as old as humanity itself. because humans use them to contain and preserve food for longer periods of time.

4.5. Materials for the manufacture of packaging

Specifically, a container designed and manufactured with the correct materials will bring with it quality products, the type of material from which it is made being relevant, the plastic materials used for the preparation, the properties and its main applications are (Table 1 Properties and applications of materials plastics):

Table 1 Properties and applications of materials plastics

Material	Properties	Applications in the packaging manufacturing sector
Low Density Polyethylene (LD-PE)	1. Resistance to impacts and sudden movements. 2. Acceptable stability to high temperature exposures. 3. Standard hermeticity to entry/exit of water vapor. 4. It exposes light to light brown color. 5. Resistance to the introduction of chemical substances.	Special containers for prepared meals.
High Density Polyethylene (PEAD)	1. Resistance to temperature variations. 2. Excellent rigidity and impact resistance. 3. Hermetic for the entry of steam and water. 4. Sensitivity to the introduction of acids and alkalis. 5. Transparent hue.	Containers for: – Food products. – Technical articles.
Polyester	1. Resistance to extreme temperatures and tears. 2. Hermetic to the entry of gas, aromas and water vapor. 3. Transparent hue.	Vacuum packaging for: – Fresh meat. – Prepared to fry. – Stews.
Polyvinyl Chloride (Rigid PVC)	1. Hermetic to the entry of gas, aromas and water vapor. 2. Resistance to mechanical actions. 3. Resistance to the entry of oils and fats. 4. Transparent with possibility of color change. 5. Metallizable.	Containers for: – Food products. – Frozen products.
Polyvinyl Chloride (PVDC)	1. Excellence in transparency. 2. Sealable. 3. Sterilizable. 4. Boiling resistance.	Containers for: – Food products.

Source of Consultation: Benavides, Sigcha and Milton (2013)

According to the properties of the plastic materials for the manufacture of containers, it was decided to make the prototype using high (Cover)/low (Body) density Polyethylene (LD-PE/ PEAD), because they have the ideal characteristics for the preservation and conservation of honey, emphasizing the property of resistance to temperature variations, taking into account that honey is a viscous liquid that solidifies at low temperatures, and there are minimum temperatures in the State of Puebla ranging from 5 °C to 15 °C. In the same way, it is extremely beneficial that the material is highly resistant to impacts, and shows tightness for the entry of external agents.

4.6. Software design

The exposed work was designed in a 3D modeling program, this program is called SketChup, specifically the program manages a friendly and easy-to-use interface for the user, allowing a faithful design of the product, because the tools it contains They model all kinds of volumes.

SketChup was born in 2000 and is characterized by providing exceptional results to design. Currently, this program is a benchmark in the world of 3D modeling. Being free, it includes a gallery of objects and images that optimize the designer's work hours (Catalan, 2017).). Within the complements of this software we find the following two functions:

1. Pluggins: Variety of tools or subprograms that include preloaded drawings such as Roofs, pieces of different materials, parts of the human body, etc.

2. Renders: Includes modeling through geometry that exposes photorealistic representations, also in this function it integrates tools to create layouts.

The exposed benefits of the SketChup program bring with it that the prototype of ergonomic high and low density polyethylene container LD-PE (Body of the container)/PEAD (Lid of the container) to package honey from native bees, is designed in this software evidencing the following advantages: a) Ease of interpretation of the design tools (smooth and flexible learning curve), b) Graphic and visual design tools (Simple and intuitive), c) Infinite resources available (Tutorials, courses and free training), d) Availability of the largest library of 3D models (Textures), e) Precision in the introduction of measures and dimensions for the design of the products, f) Generation of models to print on 3D printers (Sheets, lay Out to build and print).

4.7. 3D Printing

3D printing allows transforming digital designs into tangible products, through the generation of layer prints, the most common 3D printing methods are: Casting, laser, and injection (Jorquera, 2016), for the present work the printing model was used by injection by the type of filament selected for manufacturing (High and low density polyethylene LD-PE / PEAD). This type of technology allows users or designers to become product creators within the field of engineering, industry and education.

4.8. Ergonomics in packaging design

Ergonomics is defined by the Spanish Ergonomics Association as the set of scientific and technical knowledge that is applied so that work, systems, products and the environment adapt to the physical and mental capacities and limitations of the end user, to originate adequate adaptations ergonomics is introduced from the design of products, machinery, tools, devices. Taking into account the importance of the ergonomic introduction in the design of the products, the design of the container was carried out, according to the experience of Benavides, Sigcha and Milton (2013), the design of the container must take into account the relationship between the user and the product, with the main objective of adapting the container to reduce fatigue and errors when using it, as well as ensuring the closing process and product transport. It is important to mention that the goal of ergonomics applied between the container and the consumer must strictly comply with the following adaptations (Functions) (Figure 2 Ergonomic adaptations (Functions) of the container):

Figure 2 Ergonomic Adaptations (Functions) of the container

Physical and chemical suitability (Functions)	• Compatibility. • Chemical properties. • No interaction with contaminants. • Endurance. • Air tightness.
Ergonomic suitability (Functions)	• Driving. • Transport. • Assurance. • Hitch. • Storage. • Stowage

Source of Consultation: Benavides, Sigcha and Milton (2013)

4.9 Containers for honey products

These containers have as main focus to preserve the healthy and natural attributes of honey, through models adaptable to ergonomic designs that are useful and do not represent high manufacturing costs, the containers for this type of product are identified by the following 6 variables (Table 2 Measurement variables of packaging for honey products):

Table 2 Measurement variables of packaging for honey products

Variable number	Description	Measurement factors	
Variable 1	Functions	Basic	– Contain – Protect – Keep
		Communications	– Inform – Communicate – Persuade
Variable 2	Application	– Multiple – Collective	
Variable 3	Consistency	– Flexible packaging – Semi-rigid packaging – Rigid packaging	
Variable 4	Materials	– Paper/cardboard (20%) – Glass (30%) – Plastic and its variants (50%)	
Variable 5	Shape	– Abstract – Organic – Basic	
Variable 6	Color	– Transparent – Hue – Brightness range – Saturation or intensity range	

Source of Consultation: Quisiguiña (2022)

4.10 Production of honey from native bees

Currently in Huauchinango Puebla the Tetragonista Angustula melipona bee has been identified as a native bee (Figure 3 Tetragonista Angustula melipona bee from the Sierra Norte region of the State of Puebla), this is a medium-sized Negrillo honey fly that inhabits the meliponaria Located in the northern region of the State of Puebla and area of influence, this native bee produces a total of 800 milliliters of honey quarterly, which is a sweet, non-fermented substance with a complex physical composition because it depends on directly from the feeding of this type of bee (Otero, Meneses and Águila, 2017), according to the report presented on May 20, 2021 by the Government of México.

The State of Puebla is the eighth national producer of honey, The main producers being the municipalities of Cuetzalan del Progreso, Atlixco, Acatzingo, Chalchicomula de Sesma, Izúcar de Matamoros, Puebla, Tlacotepec de Benito Juárez, Pantepec, Huauchinango and Pahuatlán, (Gobierno de México, 2023). As we can see, native bees contribute a large amount to the generation of honey and by-products, which is why the generation of means to package this valuable product is relevant, seeking to preserve the organoleptic characteristics and the innocuousness of this sweet mixture.

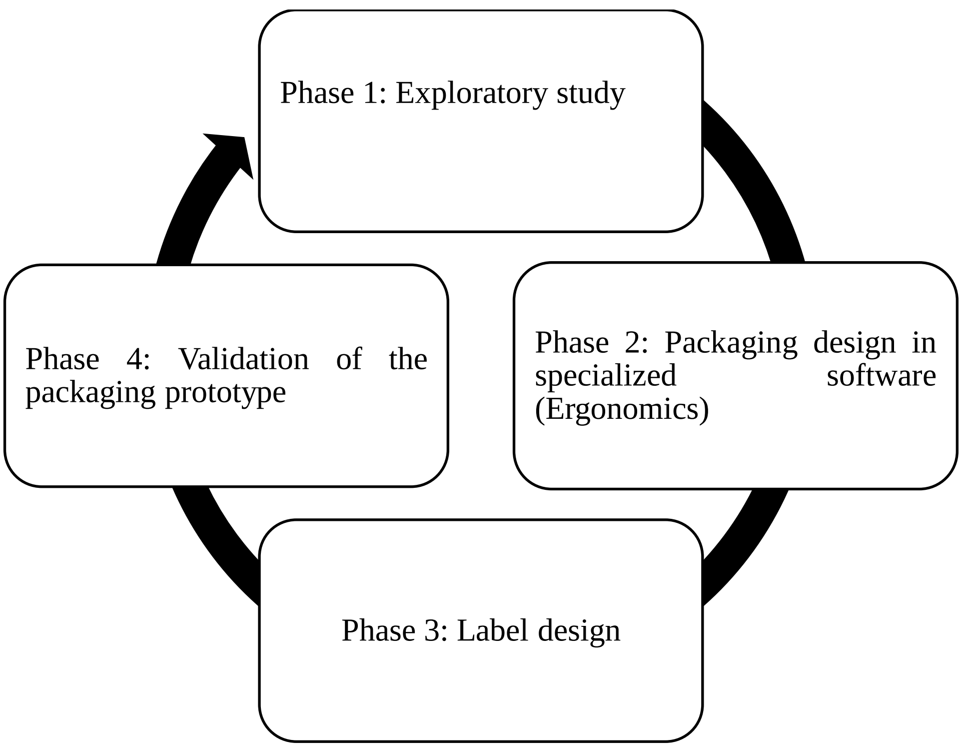
Figure 3 Tetragonista Angustula melipona bee from the Sierra Norte region of the State of Puebla

Source of Consultation: Own Elaboration

5. Methodology to develop

The methodological description that allowed the design and manufacture of the Prototype of ergonomic container of polyethylene LD-PE/ PEAD to package honey from native bees, was developed from the following 5 phases (Figure 4 Phases of the methodological process corresponding to the investigation).

Figure 4 Phases of the methodological process corresponding to the investigation



Source of Consultation: Own Elaboration

5.1 Phase 1: Exploratory study

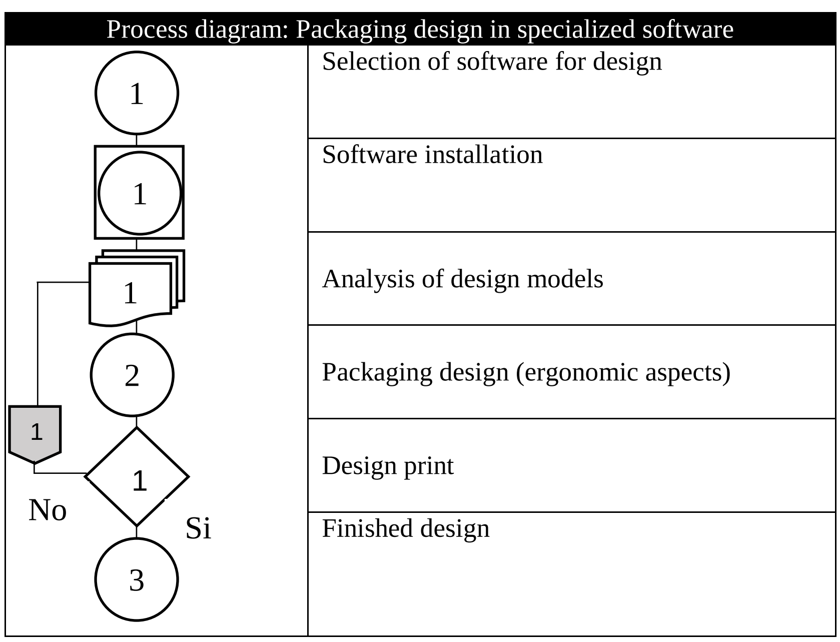
Several authors have made proposals for the manufacture of honey containers, seeking that the packaging processes notably preserve the characteristics of honey, such is the case of the cooperative "Abriendo caminos", which in 2015 requested support to create a center of honey packaging seeking to unify the organic characteristics involved in the production process, as a result of this research a machine was generated that represented a high investment cost of both material and care (2 operators per shift) (Proserpi and Milani , 2015) . , in this same line of research in the project called "Economic and financial market analysis to install a honey collection and packaging center in Delicias, Chihuahua, México", the prevailing need to generate a suitable packaging environment for honey, which is currently collected in approximately 14,115 hives with a total of 443.3 tons of sweet liquid, considering that the packaging is carried out by intermediaries, a feasible proposal was generated through the creation of a bottle center which processes weekly 200 liters of honey (Soto, Magana , Kiessling , Licon, Hernández and Villarreal, 2010). This solution is feasible and consistent with the present project, in response to the solution from the generation of a physical environment that works as container for honey, taking into account that producers need to reduce costs and preserve to a great extent the organoleptic characteristics of honey. In accordance with the previously reviewed and exposed literature, it was decided to use the plastic container as the main raw material, with the aim of avoiding a break in the transportation of the product and the estimation of the prices is more viable, taking into account that the PET containers they are non-toxic and preserve the content without any type of addition or alteration to its structure, the production of this material requires less energy consumption, which also reduces polluting gases, on the other hand, it is also 100% recyclable, making it an environmentally friendly plastic.

The container will be a plastic bottle, specifically high and low density polyethylene LD-PE/ PEAD will be used, to optimally preserve the properties of melipona honey. Now, taking care of the ergonomic aspects for the opening and closing of the container, a flip top lid model is used. This flip top system contains an internal crown that allows greater movement and safe preservation of the product, providing greater comfort to the user and avoiding the generation of honey waste. To finish the exploratory study, it is concluded that the sweet product will be packaged and will have a 100% natural liquid presentation, which will be offered in a single presentation and size, with a content of 500 ml, considering that the packaging will be in cardboard boxes because they expose greater ease of transportation, technically each box will have a quantity of 24 containers of honey and the secondary packaging is made up of pallets, non-stick film and strapping.

5.2. Phase 2: Packaging design in specialized software

Within this phase, the following activities were carried out (Figure 5 Process diagram: Packaging design in specialized software).

Figure 5 Process diagram: Packaging design in specialized software



Source of Consultation: Own Elaboration

5.2.1. Selection of design software

An analysis of the advantages and disadvantages of commercial design programs is carried out, this analysis allows determining that the ideal software is SketchUp, because it is a graphic design and modeling program in three dimensions (3D) based on faces. Rosado and Guerrero (2022) indicate that this software package is used for modeling environments for urban planning, architecture, civil engineering, industrial design, scenic design, GIS, video games or movies, it is also convenient to mention that it manifests the following advantages : 1) Attractive interface that creates interest and facilitates the designer's work, 2) Develops a playful and motivating character in the designer through the integration of technological resources, 3) Intuitive interface because it has a reduced number of commands compared to other design programs, but it provides all the essential tools to build models of exceptional quality (Hernández, 2014).

5.2.2. Software installation

Once the software is selected, the package is installed on the hardware with the following technical requirements: a) 1 GHz processor, b) 4 GB of RAM, c) 500 MB of free disk space, d) 3D graphics card with 512 MB of memory and hardware acceleration capacity, compatible with OpenGL 3.1. Taking these characteristics into account for the proper functioning of the design process.

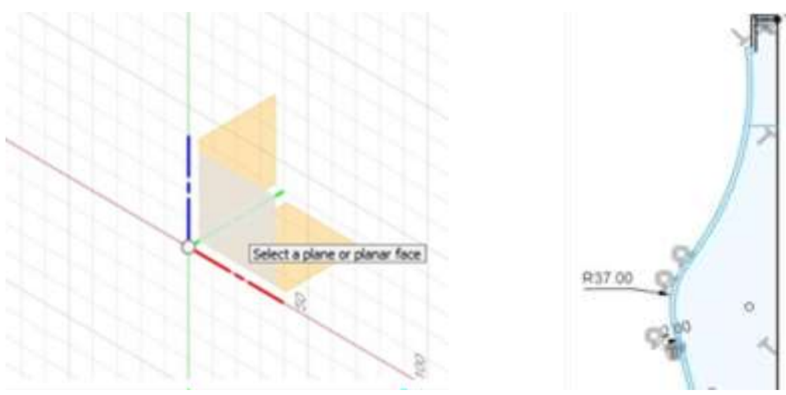
5.2.3. Analysis of design models

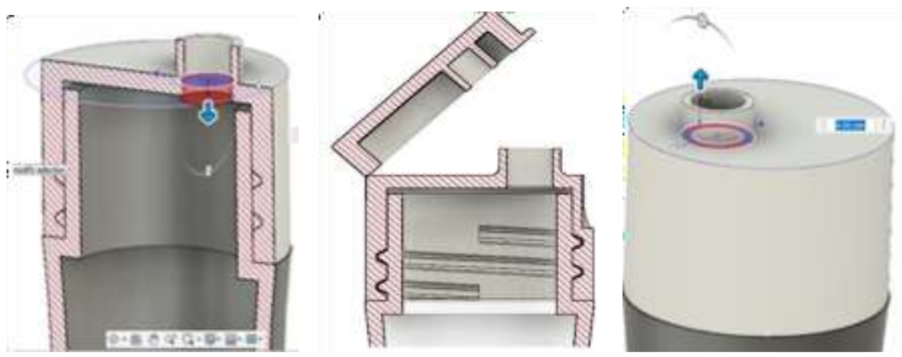
Different models of existing containers were analyzed, taking into account that the proposed container must contribute to: a) Good ergonomic handling, b) total closure of the container, c) lower cost of sale than the existing cost of other similar products, d) preservation and preservation of the organoleptic characteristics of honey.

5.2.4. Container design

The container design was carried out through the following steps (Table 3 Container design procedure):

Table 3 Container design procedure

Description	Visual representation
Plane generation (Create Sketch) and design using lines and vectors of the base shape of the model.	
360° revolution of the model profiling and application of materials to differentiate packaging components	

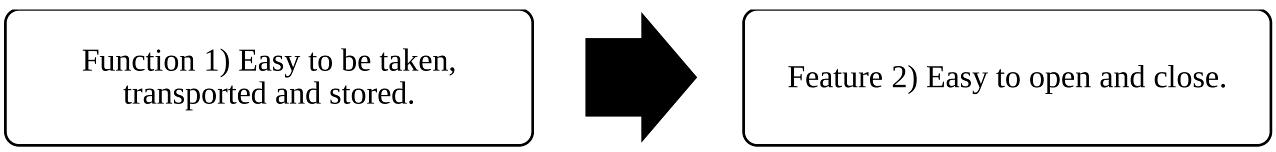
Packaging nozzle nut design	
Flip flop system design	

Source of Consultation: Own Preparation

5.2.4.1. Ergonomic aspects

The contextualization aimed at ergonomics for the design of the container was based on the fulfillment of the following two functions (Figure 6 Ergonomic aspects of the container):

Figure 6 Ergonomic aspects of the container

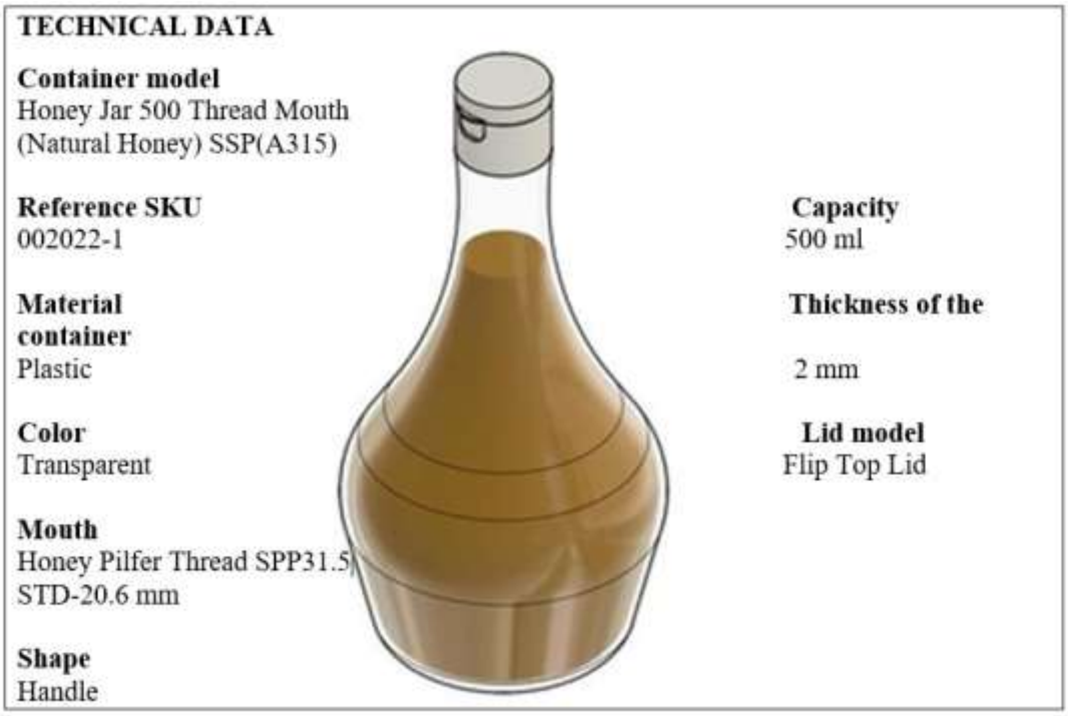


Source of Consultation: Own Elaboration

5.2.4.1.1. Function 1) Ease of being taken, transported and stored

The designed container is made up of different parts, within which the wavy profiling of the container body stands out, which is made of low-density polyethylene (LD-PE), this profiling has as its main objective compliance with the following ergonomic aspect: That the user takes the container in a safe way with the use of the whole hand (Sufficient space (9 cm) to take with the use of the 5 fingers, secure and close a fist) and transport it preserving the content of the honey, keeping Taking into account a maximum grip diameter of 10 cm between the first and third phalanxes, these characteristics are displayed below (Figure 7 Technical data of the container to be taken, transported and stored).

Figure 7 Technical data of the container to be taken, transported and stored



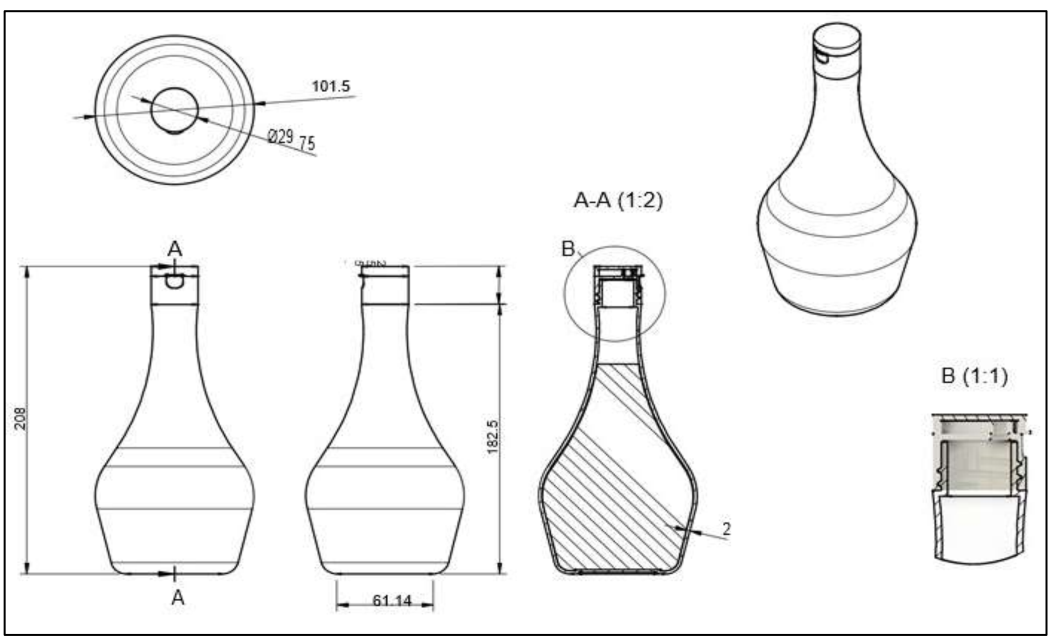
Source of Consultation: Own Elaboration

5.2.4.1.2. Function 2) Ease of opening and closing

Once the importance of the lid of the container had been analyzed, it was designed using the flip-flop model made from high-density polyethylene (PEAD), taking into account the following ergonomic principles (Figure 8 Technical data of the container to open and close):

– Principle 1) Determine the type of grip: According to the activity carried out, the ergonomic grip is known as: Hook (Hook): It is a type of power grip that refers to the shape that the fingers acquire when executing it. They can intervene from the index to the little finger, with a flexed position around the object, placing the hand in the shape of a hook (hence the name of the grip). The MCP joint is extended and the IFP and IDP have a certain flexion (Cepriá, 2016).
– Principle 2) Force of the grip type: To comply with the clamping pressure, the following forces are assigned for the ring finger 4 N, and for the index finger 7 N.

Figure 8 Technical data of the container to open and close



Source of Consultation: Own Elaboration

5.2.5. Design printing

The prototype was printed using 3D printing technology taking into account the properties of high/low density polyethylene, which are: a) Transparency, b) Steam and water tightness, c) Resistance to cold, d) Good rigidity and impact resistance, e) Low sensitivity to alkalis and acids. However, with respect to the technical characteristics of the printing process, the validation of the following variables was taken into account: Layer thickness, porosity, contour and screen angle, these variables are described below (Table 4 Design print characteristics):

Table 4 Design print characteristics

Characteristic	Description
Layer thickness	Thickness of each layer of filament that is deposited in the nozzle of the 3D printer, transversally.
Porosity	It is established according to the vacuum volume of 500 ml, with respect to the total volume of the printed prototype, the minimum porosity between each filament is 50% (Body) and the maximum porosity is 67% (Lid), with respect to the filament caliber.
Outline	It counts the number of filaments that the 3D printer deposits on the outside of the geometric construction of the prototype. For this prototype, 3 contours are used. Contour 1 and 2 belong to the body of the container and close in the center of the prototype, contour 3. refers to the cover.
Raster angle	An angle of 90° was used for the extruder to deposit the filaments in each of the printing layers.

Source of Consultation: Own Elaboration

5.3. Phase 3: Label design

Within the commercial field , in the experience of Estrada, Cantú , Torres and Barajas (2020), labeling is a determining process for product packaging, since its main objective is that consumers have access to general product information, for For this reason, the product label was designed under the idea of communicating the identity of the brand directly related to the packaged honey product (Figure 9 Packaging label).

Figure 9 Packaging label

Source of Consultation: Own Elaboration

5.4. Phase 4: Validation of the container prototype

Validation tests: 3 tests were carried out to validate the usability of the manufactured container (Figure 10 Validation tests).

Figure 10 Validation tests

Source of Consultation: Own Elaboration

Taking into account that melipona bee honey establishes an interval of 18.1% to 24% water (Fonte, Díaz, Machado, Blanco, Demedio and García, 2013), validation tests were carried out for the following variables: Y= Viscosity (Poises), X_1= Temperature °C, X_2= Fall time, the quantitative results of these variables are shown below (Table 5 Quantitative results of validation tests):

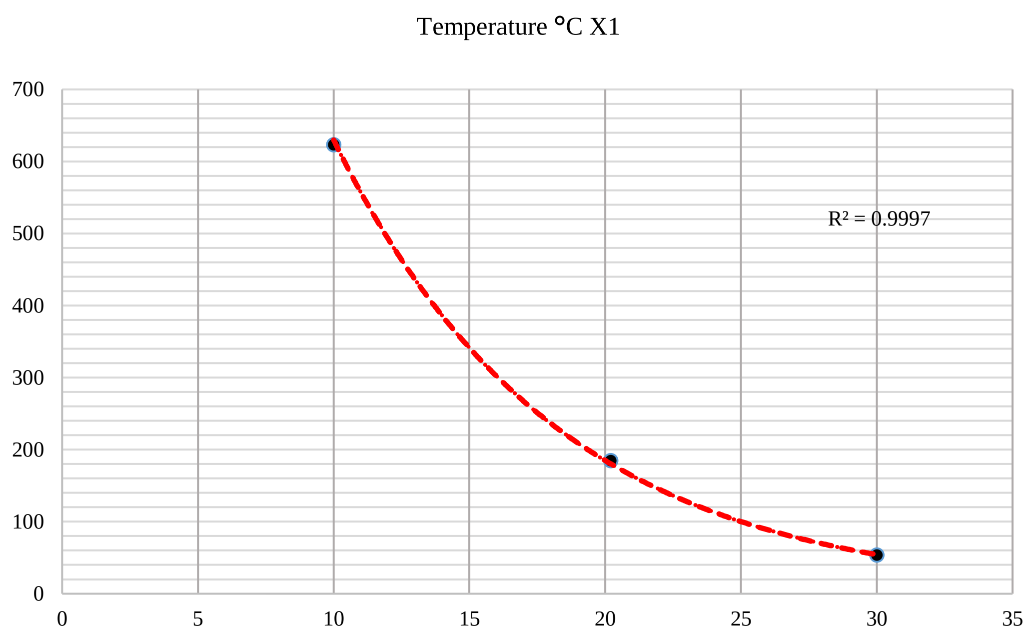
Table 5 Quantitative results of validation tests

Viscosity (Poises) Y	Viscosity (Pascal/second) (Pa *s)	Temperature °C X_1	Time Seconds X_2
622.9	62.29	10	00:15.28
184.5	18.45	20.2	00:07.35
53.66	5.366	30	00:03.83

Source of Consultation: Own Elaboration

Subsequently, the correlation analysis is carried out, in the first instance the existing correlation between the variables of Y= Viscosity (Poises), X_1= Temperature °C is studied, the results obtained are shown below (Graph 1 Correlation analysis Y= Viscosity (Poises), X_1= Temperature °C):

Graph 1 Correlation analysis Y= Viscosity (Poises), X_1 = Temperature °C



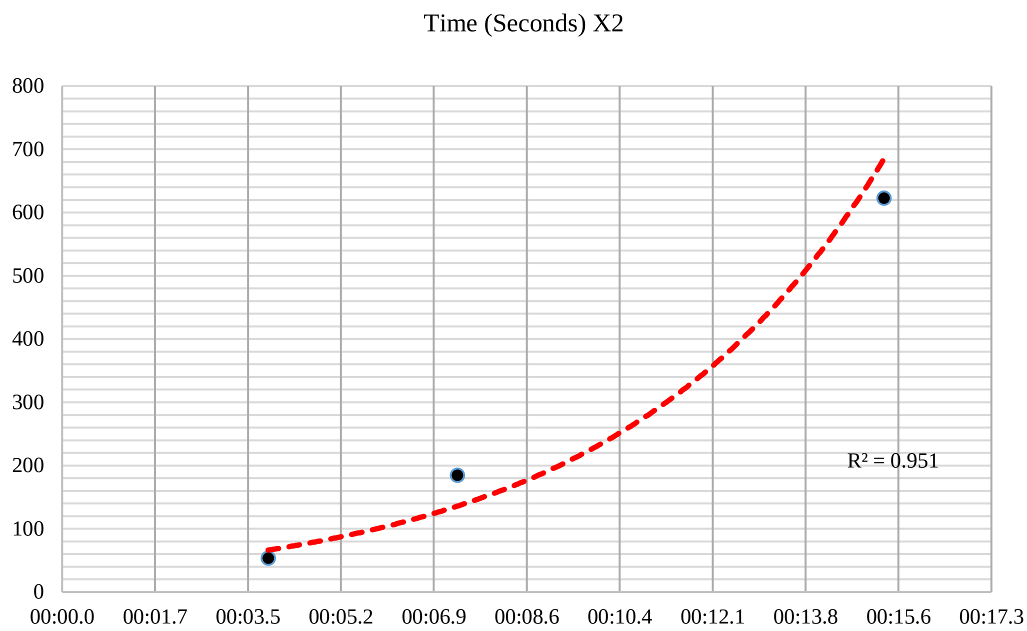
Source of Consultation: Own Elaboration

The interpretation of the first correlation analysis allows confirming the non-Newtonian behavior of the pseudoplastic type that honey has, which is based on the following principle: "Honeys exhibit crystallization over time" (Ramos, Jordán, Pablo, Espinoza and Añaños, 2014).

This behavior is notorious because the correlational study indicates that the lower the temperature °C, the lower the viscosity value (Poises) of the honey contained in the designed container, it is important to mention that these tests validate a strong positive correlation with R^2 = 0.9997, indicating that the container maintains the viscosity characteristics according to the temperature variable and to the principles of food chemistry established for honey (Badui, 2006).

Subsequently, the second correlation analysis is carried out between Y= Viscosity (Poises), X_2= Fall time, evidencing the result that is presented below (Graph 2 Correlation analysis Y= Viscosity (Poises), X_2= Fall time):

Graph 2 Correlation analysis Y= Viscosity (Poises), X_2= Fall time



Source of Consultation: Own Elaboration

The interpretation of the second correlation analysis indicates that the lower the falling time (Seconds), the lower the viscosity value (Poises) of the honey contained in the designed container, it is important to mention that these tests validate a strong positive correlation with a R^2 = 0.951, indicating that the container maintains the viscosity characteristics according to the time variable.

6. Results

The results are evident below:

6.1. Result 2

6.1.1. Physical prototype

The design of the container prototype was elaborated in the SketchUp program for the 500 ml honey product, it is mentioned that the lid was manufactured using the Flip Top model with a high-density polyethylene (PEAD) liner, the body of the container was It was manufactured from low-density polyethylene (LD-PE), the label was made in the Photoshop program, the final model was printed using 3D technology (Figure 11 Physical container prototype).

Figure 11 Physical container prototype

Source of Consultation: Own Elaboration

Taking into account the need to generate a physical environment to package the honey produced in the meliponarios, a validated ergonomic container prototype was created, which will be used by meliponiculturists in the region, avoiding additional costs resulting from intermediaries, which until Currently, their main activity is the purchase of honey at low prices from meliponiculturists (in 19-liter drums) and later they package it in smaller units, registering payments for the acquisition of honey that are low for meliponiculturists, for which this container prototype will make it possible to carry out the packaging directly by the meliponiculturists and obtain greater profits for the honey from the native bees of the region.

6.2. Result 2

6.2.1. Costing (Automated process projection)

The manufacturing process of the packaging model requires the initial economic intervention of the following factors (Table 6 Costing (Automated process projection)):

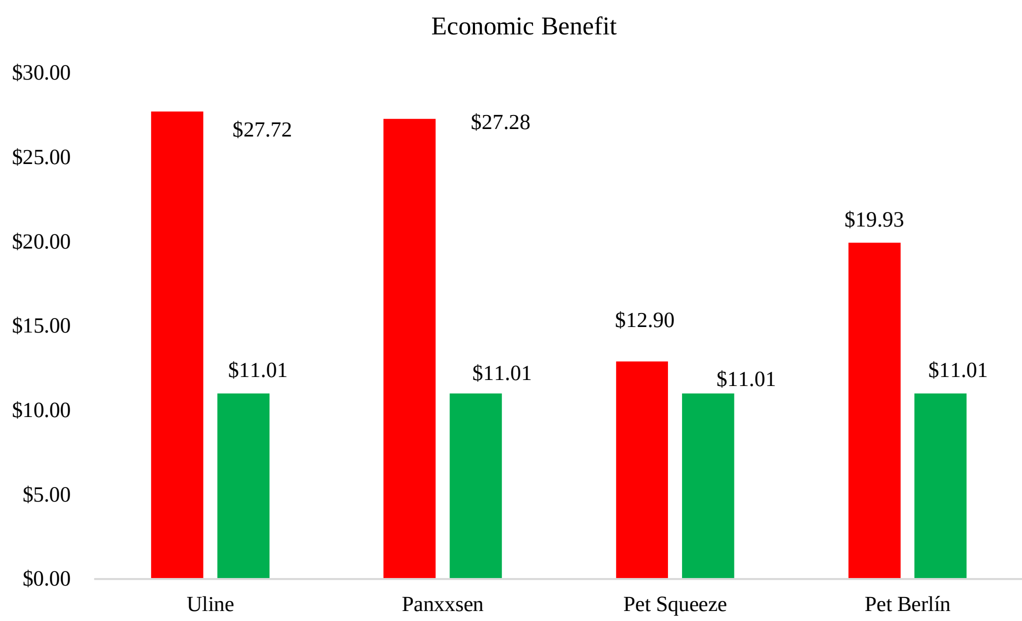
Table 6 Costing (Automated process projection)

Investment cost in machinery and equipment (20 thousand hours of use)	
Injection/printing machine **Automated process.	$160,200.14/ $8.01 per print/jetting hour
Unit value per day/lot	$64.08
Product manufacturing cost (It is raised per batch of 200 containers x working day (8 hours))	
Low density polyethylene LD-PE	$1062.47
Matt PEAD high density polyethylene for flip flop cover	$467.19
Label (Front/back)	$0.20 front, $0.20 back = $0.40 per unit/$80 per lot
Unit value per lot/day	$1609.66
Fixed Costs (Monthly)	
Repairs and maintenance	$1,200.00 monthly/$300 weekly/$50 daily
Office supplies	$4,00.00 monthly/$1000 weekly/$166.6 daily
Supplies	$1,000.00 monthly/$250 weekly/$41.66
Salaries	$270.00 per working day
Unit value per day	$528.26
Total value per batch of 200 pieces	$2202
Unit value per package	$11.01

Source of Consultation: Own Elaboration

Taking into account the above information, a cost per container of $11.09 is deducted, it is important to mention that an automated process must be considered to reach the goal of 200 containers per working day**,** the cost turns out to be a competitive advantage compared to the costs of products similar, this advantage is shown below (Figure 12 Cost comparison with existing packaging brands):

Figure 12 Cost comparison with existing packaging brands



Commercial brand	Cost	Container Cost	Profit Margin
Uline	$27.72	$11.01	60.28%
Panxxsen	$27,275	$11.01	59.6%
Pet Squeeze	$12.9	$11.01	14.65%
Pet Berlin	$19.93	$11.01	44.75%
Average			44.85%

Source of Consultation: Unline.mx. (2023), Mercado Libre (2023)

7. Acknowledgments

To the Instituto Tecnológico Superior of the Huauchinango and the Division of Industrial Engineering for the facilitations provided for the preparation of the presented chapter.

8. Financing

This work has been financed by the academic body of the Industrial Engineering career ITESHUAU-CA-4 Optimization of production systems of the National Technological Institute of México / Higher Technological Institute of Huauchinango for financial support.

9. Conclusions

The development of this work shows a feasible solution that arises from the prevailing need to support meliponiculturists in the Northern Zone of the State of Puebla, since through previous analysis it has been detected that they do not have the financial means to acquire packaging containers. high cost, which is why they proceed to market honey wholesale to people who are known as intermediaries, causing economic losses due to the low costs resulting from these negotiations, in the Sierra Norte of the State of Puebla this productive activity provides economic resources to a approximately 200 families, the same ones that currently own meliponarios, for which a community project was sought through the application of Industrial Engineering (Design, ergonomic analysis, costing, validation tests, etc.) to improve conditions economics of honey producers in this geographical area.

Taking this assignment into account, the design and manufacture of a container prototype was carried out with easily accessible materials and designed in specialized SketChup software. This design is of the operational type, which is why it adapts to the capacity needs of each meliponary. In the first instance, a model with a capacity of 500 ml is presented, but it can be molded to future capacities suggested by producers. This designed model takes into account ergonomic aspects to preserve the organoleptic properties of the sweetener, significantly improving through these aspects the functions of taking, transporting, storing, opening and closing.

As is evident, one of the factors that causes the sale to intermediaries is focused on the high costs of the current containers, for which, contemplating this requirement, the costing of the automated process is carried out taking into account all the elements that intervene, the costing The resulting cost is $11.09 per unit, this cost for meliponiculturists is accessible and opens up a wide portfolio of possibilities for their acquisition, causing them to be in charge of carrying out the packaging process, and later sell directly to producers. customers, bringing with it the reduction of extra costs and greater customer acquisition. However, within the possibilities for improvement, the development of good packaging practices is highly recommended, making use of methodologies/work instructions that document the packaging process, seeking to preserve the safety characteristics of honey.

Finally, the high effectiveness of this work is concluded by linking a community need with Industrial Engineering tools to create a community project that directly benefits the economic sector of regional meliponiculture.

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