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Design of a Prototype Packaging for Wax-Honey Frames Produced at The Nektar Company: A Sustainable Proposal for The Preservation and Marketing of Bee Products

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ABSTRACT

Beekeeping is a strategic activity for food security, biodiversity conservation, and rural economic development. Products derived from this activity require handling and preservation systems that guarantee their safety and quality during storage and marketing. The objective of this research was to design a functional packaging prototype for beeswax frames produced by the Nektar company, with the aim of improving the product's physical protection, facilitating its transport, and enhancing its commercial presentation. The methodology included documentary research, analysis of the product's physical characteristics, selection of food-grade materials, structural design of the packaging, and preliminary validation through functional testing. The developed prototype incorporated features of mechanical resistance, vibration protection, thermal control, ergonomics, and sustainability through the use of recyclable and biodegradable materials. The results showed that the packaging reduced physical damage to the beeswax frames during storage and transport, in addition to improving the product's visual and commercial appeal. Furthermore, the design promotes food safety and logistical efficiency within the marketing chain. It is concluded that the development of specialized packaging constitutes a viable strategy to increase the competitiveness of beekeeping companies, generate added value and promote sustainable practices in the agri-food sector.

KEYWORDS: beekeeping, sustainable packaging, beeswax, food safety, innovation, marketing.

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INTRODUCTION

Beekeeping is an agricultural activity of great economic, environmental, and social importance due to its contribution to food production, ecosystem conservation, and income generation in rural communities (Crane, 1990; FAO, 2021). Honey and its derivatives have high commercial demand for their nutritional and functional properties, which has driven the development of new conservation, processing, and marketing strategies (Bogdanov et al., 2008; Khalil et al., 2010). Among hive products, beeswax frames represent a differentiated and high-value-added alternative, as they allow producers to offer consumers a more natural and less processed product (Molan, 2001). Consequently, the food industry has shown increasing interest in the design of functional and sustainable packaging capable of protecting food during storage and distribution (Robertson, 2016; Han, 2014). Packaging not only serves a containment function but also contributes to preserving food safety, extending product shelf life, and improving market acceptance (Marsh & Bugusu, 2007). Furthermore, packaging is a fundamental element within marketing strategies, as it directly influences consumer perception and purchasing decisions (Silayoi & Speece, 2007). Sustainability is also a key consideration, representing one of the main challenges in food packaging design due to the environmental impact of conventional plastic materials (Verghese et al., 2015). Consequently, the use of biodegradable and recyclable materials has gained importance in the food and

agricultural industries (Siracusa et al., 2008). Several studies highlight that consumers show a greater preference for products with environmentally friendly and responsible packaging (Magnier & Schoormans, 2015; Steenis et al., 2017).

Beekeeping products have unique characteristics that make them difficult to handle and preserve, especially those made with beeswax, due to their fragility and susceptibility to changes in temperature, humidity, and contamination (White, 1975; Ball, 2007). Beeswax possesses physical properties that can be affected by heat and improper handling, leading to deformation or loss of product quality (Tulloch, 1980). Therefore, the design of specialized packaging for beeswax frames must consider aspects related to mechanical resistance, thermal control, safety, and ergonomics (Brody et al., 2008). In this regard, the development of packaging technologies for agri-food products has reduced post-harvest losses and improved logistical efficiency in the supply chain (Yam et al., 2005). Furthermore, the implementation of smart and functional packaging contributes to maintaining food quality and safety (Restuccia et al., 2010). For delicate products such as beeswax frames, packaging must minimize vibrations and physical damage during transport, as well as facilitate storage and commercial display (Robertson, 2016). Innovation in the agri-food sector in this area is considered a key factor in strengthening the competitiveness of small and medium-sized enterprises (OECD & Eurostat, 2018). The design of new packaging represents a form of product and process innovation, as it allows for the optimization of logistical and commercial activities (Kotler & Keller, 2016). For this reason, beekeeping companies require technological alternatives that respond to current market demands and sustainability requirements (FAO, 2021).

In Mexico, beekeeping is of great economic and ecological importance, especially in southeastern states such as Campeche and Yucatán (SAGARPA, 2017). The region has favorable conditions for the production of high-quality honey and derived products with export potential (SIAP, 2023). However, one of the sector's main challenges is the limited incorporation of value-added technologies related to the presentation, preservation, and marketing of bee products (González-Acereto et al., 2006). Several studies indicate that food packaging must fulfill functions of protection, information, convenience, and commercial promotion (Coles et al., 2003; Hanlon et al., 2011). Furthermore, the structural design of the packaging must be adapted to the specific characteristics of the product to prevent damage during handling and distribution (Brody et al., 2008). In natural products like honeycomb, physical stability and safety depend largely on storage conditions and the type of packaging used (Bogdanov et al., 2008). Currently, markets indicate a growing preference for artisanal and natural products with innovative and sustainable packaging (Magnier & Crié, 2015). Modern consumers not only evaluate food quality but also aspects related to sustainability and packaging design (Steenis et al., 2017). Therefore, companies require differentiating strategies that integrate technological innovation and environmental responsibility (Verghese et al., 2015). For all these reasons, this study aimed to design a prototype packaging for beeswax frames produced by Nektar "The Soul of Flowers," considering criteria of physical protection, food safety, sustainability, and commercial functionality. It also sought to generate an innovative proposal that contributes to improving the storage, transport, and presentation of the product within the beekeeping market.

MATERIALS AND METHODS

This research was conducted using a descriptive and applied approach, focused on the design and preliminary validation of a prototype packaging for beeswax frames produced by the company Nektar "El alma de las flores" (The Soul of Flowers). The work was carried out between June and December 2025, through a collaboration between the Instituto Tecnológico Superior de Escárcega (Higher Technological Institute of Escárcega) and the participating beekeeping company. The research integrated documentary research, technical analysis of the product, structural design of the packaging, and functional evaluation of the prototype. In the first stage, a diagnosis of the physical and functional characteristics of the beeswax frames was performed to identify the main problems associated with their handling, storage, and marketing. To this end, direct observations were made within the company's facilities, considering variables related to dimensions, weight, structural fragility, thermal sensitivity, and susceptibility to physical damage during transport. The current storage conditions of the product and the type of packaging previously used by the company were also analyzed, identifying limitations related to wax deformation, partial fractures, and deficiencies in the commercial presentation. Subsequently, a specialized literature review was conducted on food packaging technologies, food safety, biodegradable materials, and regulations applicable to bee products. For this stage, scientific articles, specialized books, and official standards related to food packaging, labeling, and honey production were consulted. Among the references considered were the guidelines established in the Mexican Official Standard NOM-003-SAG/GAN-2017 for honey production and NOM-145-SCFI-2001 regarding the commercial labeling of bee products. Based on the information obtained during the diagnostic and literature review, the structural design of the packaging prototype was developed. The design considered criteria of mechanical resistance, ergonomics, sustainability, and food safety. Elements were also incorporated to reduce damage caused by vibrations, sudden movements, and temperature changes during storage and distribution. The prototype included modular internal dividers designed to maintain the stability of the wax-honey frames and prevent direct contact with the outer walls of the packaging. For material selection, various food-grade options were evaluated, taking into account physical properties such as strength, flexibility, thermal insulation, commercial availability, and cost. Priority was given to the use of recyclable and biodegradable materials to reduce the environmental impact associated with

conventional packaging. The final material selection considered both the packaging's functionality and its technical and economic viability for the company. Once the structural design was defined, a physical prototype was created using basic cutting, assembly, and material adaptation processes. Subsequently, the prototype underwent preliminary functional testing to evaluate its performance during product handling and storage. These tests consisted of basic transport and handling simulations, observing the packaging's structural stability, the level of protection provided to the wax-honey frames, and its ease of handling by operational personnel. Finally, a practical validation of the prototype was conducted with the support of the technical and administrative staff of Nektar "The Soul of Flowers," who provided feedback on the packaging's functionality, practicality, and commercial presentation. The feedback obtained allowed us to identify strengths and opportunities for improvement in the proposed design, consolidating a viable alternative for the conservation and marketing of bee products.

RESULTS AND DISCUSSION

The development of the prototype resulted in a functional package capable of improving the physical protection of beeswax frames during storage and distribution. The structural design incorporated internal separators and partial suspension mechanisms that reduced the impact of vibrations and sudden movements. The selected materials proved suitable for food contact and exhibited favorable resistance and sustainability characteristics. Several studies indicate that the use of biodegradable materials in food packaging significantly reduces environmental impact and improves consumer perception of the product (Siracusa et al., 2008; Verghese et al., 2015). The prototype showed significant advantages over the packaging previously used by the company, primarily in terms of mechanical protection and commercial presentation. The developed structure facilitated product storage and transport, reducing damage associated with wax fractures and deformation. The incorporation of an ergonomic design improved handling and distribution. According to Robertson (2016), functional packaging should facilitate both logistics and consumer interaction with the product. Furthermore, the new design increased the product's added value through a more attractive and professional presentation. The visual aspect of the packaging is a determining factor in the consumer's purchasing decision, particularly for artisanal and natural foods (Silayoi & Speece, 2007). From a food safety perspective, the prototype helps reduce the risk of physical and environmental contamination during product handling. The selection of food-grade materials and the partial isolation of the product help preserve its original characteristics.

The interaction between the educational institution and the company allowed for the integration of technical knowledge and practical experience in the project's development. This type of collaboration strengthens technological innovation and knowledge transfer processes in the agribusiness sector. Finally, the prototype design represents an innovation strategy aimed at strengthening Nektar's competitiveness through the development of sustainable and functional solutions for marketing bee products.

CONCLUSIONS

The development of a prototype packaging solution for wax-honey frames yielded an innovative and functional alternative aimed at improving the preservation, protection, and marketing of this bee product. The results showed that incorporating criteria for mechanical resistance, ergonomics, food safety, and sustainability significantly reduces physical damage during storage and transport, thus preserving the product's natural characteristics and quality. Furthermore, the proposed structural design proved to be a viable option for optimizing the logistical management of wax-honey frames, facilitating handling, storage, and distribution within the supply chain. The inclusion of internal separators and food-grade materials improved product stability and reduced the risk of contamination or wax deformation caused by vibrations, temperature changes, and improper handling. From a commercial perspective, the prototype represents a value-added strategy for Nektar "The Soul of Flowers," as the packaging not only provides protection but also enhances the product's visual presentation and improves consumer perception. In this regard, the proposed design can contribute to positioning the company in more competitive markets, where innovation, functionality, and sustainability are key factors in purchasing decisions. Similarly, the use of recyclable and biodegradable materials reflects the importance of integrating sustainable practices within the agri-food sector, responding to current trends in responsible consumption and reducing the environmental impact associated with conventional packaging. This demonstrates that the development of sustainable packaging technologies can represent an opportunity to strengthen the competitiveness and environmental responsibility of beekeeping companies.

Finally, the collaboration between the Higher Technological Institute of Escárcega and the company Nektar made it possible to link academic knowledge with the real needs of the production sector, fostering the generation of practical and applicable solutions. The project constitutes an important foundation for future research related to the design of specialized packaging for bee products, as well as for the development of technological innovation strategies aimed at strengthening the agro-industrial sector.

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