Ciencia Latina Revista Científica Multidisciplinar, Ciudad de México, México.
ISSN 2707-2207 / ISSN 2707-2215 (en línea), mayo-junio 2026,
Volumen 10, Número 3.

https://doi.org/10.37811/cl_rcm.v10i3

PACKAGING SYSTEMS FOR THE IMPORT AND EXPORT OF FOOD PRODUCTS: TECHNICAL REQUIREMENTS, CUSTOMS REGULATIONS IN MEXICO, AND INTERNATIONAL STANDARDS FOR FOOD PRESERVATION: A REVIEW

SISTEMAS DE EMPAQUE PARA LA IMPORTACIÓN Y EXPORTACIÓN DE PRODUCTOS ALIMENTICIOS: REQUISITOS TÉCNICOS, REGULACIÓN ADUANERA MEXICANA Y ESTÁNDARES INTERNACIONALES PARA LA CONSERVACIÓN DE ALIMENTOS: A REVIEW

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DOI: https://doi.org/10.37811/cl_rcm.v10i3.24126

Packaging Systems for the Import and Export of Food Products: Technical Requirements, Customs Regulations in Mexico, and International Standards for Food Preservation: A Review

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ABTRACT

Food packages used to be considered just containers for transporting food products, but in recent years, they have evolved into multifunctional technologies that support safety, preservation, traceability, regulatory compliance, and international commercialization. This review analyzes packaging systems for the import and export of food products, with emphasis on Mexican customs procedures, technical requirements, regulatory frameworks, and international standards for food preservation. Analyze how active, intelligent, smart, and sustainable packaging systems contribute to shelf-life extension, quality maintenance, fungus and bacteria control, freshness monitoring, and environmental performance. In the Mexican context, where packaging functions through labeling, lot identification, sanitary information, origin declaration, and compliance with Mexican Official Standards, these were particularly established. Products such as beer, tequila, berries and avocado are discussed as representative cases of Mexico's export activity, while imported commodities and animal-based products are considered in relation to bulk handling, sanitary control, and traceability requirements. The review highlights that packaging in international trade must integrate product specifications, preservation needs, sanitary verification, material performance, product-specific preservation needs, customs documentation, NOM compliance, and sustainability considerations.

***Keywords*:** food packaging; active packaging; intelligent packaging; Mexican regulation

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Sistemas de Empaque para la Importación y Exportación de Productos Alimenticios: Requisitos Técnicos, Regulación Aduanera Mexicana y Estándares Internacionales para la Conservación de Alimentos: A Review

RESUME

Los empaques de alimentos solían considerarse únicamente como contenedores para transportar productos alimenticios; sin embargo, en los últimos años han evolucionado hacia tecnologías multifuncionales que apoyan la seguridad, la conservación, la trazabilidad, el cumplimiento regulatorio y la comercialización internacional. Esta revisión analiza los sistemas de empaque para la importación y exportación de productos alimenticios, con énfasis en los procedimientos aduaneros mexicanos, los requisitos técnicos, los marcos regulatorios y los estándares internacionales de conservación de alimentos. Se analiza cómo los sistemas de empaque activos, inteligentes, smart y sostenibles contribuyen a prolongar la vida útil, a mantener la calidad, a controlar hongos y bacterias y a monitorear la frescura y el desempeño ambiental. En el contexto mexicano, se destaca particularmente la función del empaque, que incluye el etiquetado, la identificación de lotes, la información sanitaria, la declaración de origen y el cumplimiento de las Normas Oficiales Mexicanas. Productos como la cerveza, el tequila, las berries y el aguacate se presentan como casos representativos de la actividad exportadora de México, mientras que las mercancías importadas y los productos de origen animal se consideran en relación con el manejo a granel, el control sanitario y los requisitos de trazabilidad. La revisión resalta que el empaque en el comercio internacional debe integrar especificaciones del producto, necesidades de conservación, verificación sanitaria, desempeño de los materiales, necesidades de conservación específicas del producto, documentación aduanera, cumplimiento de NOM y consideraciones de sostenibilidad.

Palabras clave: empaque de alimentos; empaque activo; empaque inteligente: normas mexicanas

Artículo recibido 25 marzo 2026
Aceptado para publicación: 25 abril 2026

INTRODUCTION

Food packaging is a critical component of modern food systems, as it protects products from physical, chemical, biological, and environmental deterioration during processing, storage, transportation, commercialization, and consumption. Packaging was considered a passive barrier that contained the product and protected it from external factors such as light, oxygen, moisture, microorganisms, and mechanical damage (Abdullah et al., 2017; Baddigam et al., 2025; Khadtare et al., 2017; Liang et al., 2020). However, the need for packaging systems that protect the product during transportation, and for food packaging that protects it during export under optimal conditions, ensuring the product's quality and the conservation of all its nutrients, led us to seek food packages capable of keeping the product safe. In import and export operations, packaging must preserve product quality, support shelf-life stability, facilitate logistics, communicate mandatory information, and comply with national and international regulatory requirements (García et al., 2014; Kumari et al., 2017; Ojha et al., 2018; Pankaj, 2018).

The increasing complexity of global food trade has heightened the need for packaging systems that maintain product safety and quality under variable environmental and logistical conditions. Long-distance transportation requires controlling temperature fluctuation, extended storage, humidity changes, vibration, handling, and customs inspections, which can compromise the integrity of food products, particularly fresh produce, meat, dairy products, seafood, beverages, and processed foods. In the last 15 years, active packaging has gained important relevance; researchers have focused on active, intelligent, smart, biodegradable, and bio-based packaging technologies (Hu et al., 2022; Misra et al., 2019; Roh et al., 2020). Active packaging systems interact with the food or its surrounding atmosphere by releasing or absorbing compounds that control oxidation, microbial growth, moisture, gases, or undesirable odors. Intelligent packaging systems, in contrast, monitor and communicate information about freshness, temperature history, oxygen levels, pH changes, microbial activity, or package integrity. Smart packaging integrates both functions by responding to changes in the food microenvironment and providing preservation or monitoring capabilities based on the product’s condition (Andrade et al., 2025; Chan et al., 2025a).

For products imported into or exported from Mexico, packaging must support product identification, labeling, traceability, customs classification, sanitary verification, and consumer protection. Mexican authorities, such as Servicio de Administración Tributaria (SAT), Comisión Federal para la Protección contra Riesgos Sanitarios (COFEPRIS), Servicio Nacional de Sanidad, Inocuidad y Calidad Agroalimentaria (SENASICA), Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT), Servicio de Información Agroalimentaria y Pesquera (SIAP), Consejo Regulador del Tequila (CRT) and international regulation authorities United States Department of Agriculture (USDA), International Trade Administration (ITA), participate in the control of food and agricultural products depending on their nature, origin, destination, and intended use. Mexican Official Standards, particularly NOM-051-SCFI/SSA1-2010 for prepackaged foods and non-alcoholic beverages, establish mandatory labeling requirements related to product identity, ingredients, nutritional information, net content, lot number, expiration date, country of origin, and responsible company information. In the case of beer and tequila, standards such as NOM-142-SSA1/SCFI-2014, NOM-199-SCFI-2017, and NOM-006-SCFI-2012 are especially relevant due to the regulation of sanitary specifications, commercial information, denomination, authenticity, and labeling practices(De Anda-Rodríguez et al., 2025; Morales et al., 2025; Suárez-Sánchez et al., 2025).

Mexico exports a wide variety of food and beverage products, including avocado, berries, tomatoes, beer, and tequila, while also importing grains, animal-based products, and processed foods. Each product requires specific packaging specifications to conserve minerals, vitamins, quality, and extend its shelf life until it reaches the customer. Fresh produce requires ventilation, cushioning, temperature control, humidity management, and phytosanitary traceability. Bulk commodities require containment systems that reduce moisture, pests, mycotoxin risks, and contamination during transport and storage. Alcoholic beverages require packaging systems that protect against flavor or odor changes, maintain commercial identity, ensure authenticity, and provide regulatory information. These examples demonstrate that packaging must be evaluated not only as a material or container, but as a technical, logistical, legal, and commercial system (De Anda-Rodríguez et al., 2025; de Lima et al., 2023; Morales et al., 2025; Suárez-Sánchez et al., 2025).

Despite the growing scientific literature on active and sustainable packaging, fewer studies integrate technical packaging requirements with customs procedures, Mexican regulatory obligations, and international standards for food preservation. This creates a gap in understanding how packaging innovation can be practically applied in import and export contexts. Therefore, this review aims to analyze food packaging systems from an integrated perspective, considering preservation technologies, Mexican customs and regulatory requirements, representative export and import products, and international food safety standards. By connecting scientific packaging developments with regulatory and trade requirements, this review provides a framework for understanding packaging as a strategic component of food preservation, compliance, traceability, and market access.

. **Food packaging systems and technical requirements**

Food packaging is not just a physical container but also an active system that helps preserve quality and maintain safety throughout shelf life and during transportation. Recent developments in active packaging use natural compounds, such as essential oils, plant extracts, and phenolic compounds, due to their antimicrobial and antioxidant properties. These compounds can help reduce fungal and bacterial growth, such as *Alternaria sp., Fusarium oxysporum*, and *Solanum lycopersicum L*, among others, limit oxidation, and maintain the sensory characteristics of food products during storage and transportation. However, essential oils are often volatile, sensitive to oxidation, and may have strong aromas that affect the product's taste or smell. Technologies such as encapsulation, nanoemulsions, Pickering emulsions, electrospinning, intelligent packaging, and gelation are used to control their release and improve their stability inside the packaging system (Buendía−Moreno et al., 2020; Calo et al., 2015; Göksen et al., 2021; Radünz et al., 2021; Sharma et al., 2021). .

Another important aspect is the use of intelligent packaging technologies that enable the package to monitor changes in the product or its environment. Sensors, indicators, RFID systems, freshness indicators, oxygen scavengers, and antimicrobial agents can provide information on temperature changes, microbial activity, oxygen exposure, or product deterioration (Ma et al., 2026; Rojas-Graü et al., 2009). This is especially relevant for exported foods, because long-distance transportation can expose products to variations in temperature, humidity, and handling conditions.

Intelligent packaging aims to maintain its quality throughout the supply chain. This shows why packaging and storage conditions are directly related to flavor stability and final product acceptance (Teng et al., 2019).

In addition to preservation and monitoring, packaging can also be linked to sustainable processing and circular economy strategies. Bio-based polymers such as chitosan, starch, and polylactic acid can be combined with natural active compounds to create biodegradable or more environmentally friendly packaging materials (Lumdubwong, 2019; Pelissari et al., 2009; Sifuentes-Nieves et al., 2021; Zhu, 2017). These systems can also promote the valorization of agro-industrial by-products by transforming residues into useful packaging components. For fresh products such as avocados, which Mexico exports in large volumes, packaging must protect the fruit during transportation, maintain freshness, and comply with phytosanitary and quality requirements. Complementary preservation technologies, such as supercritical carbon dioxide, may also support packaging strategies by reducing microbial risks while preserving nutritional and sensory quality (Marović et al., 2024; Ojha et al., 2018)

Active package (AP) systems release different substances, flavors, essential oils, antioxidants, and carbon dioxide. This is because the matrix form during the elaboration process contains different substances that can be used in this package. Different polymers such as pectin, protein, sodium alginate, starch is a renewable polysaccharide with a low cost and biodegradable, chitosan, which is biodegradable and presents antimicrobial properties, polylactic acid (PLA), which stands out for its mechanical strength, renewability, transparency non-toxicity (Asrafali et al., 2026; Cejudo et al., 2021; Chan et al., 2025a, 2025b).

Intelligent packaging monitors changes in a product and can inform customers of changes in properties, such as pathogens, leaks, oxygen levels, pH levels, time, and temperature, the product presents or experiences during the time from when the procedures are performed to when they buy it. Freshness indicators detect chemical changes that occur during microbial growth; on the other hand, Time Temperature indicators indicate the changes the product has undergone during transportation or storage, ensuring it arrives at your home fresh and in perfect condition. Although active packaging has become a growing trend in recent years, all types have their advantages and disadvantages, as environmental conditions can change (Cui et al., 2025; Khalil et al., 2024).

Mexican Customs and Regulatory Requirements

A food package not only protects food products from damage (post-harvest and/or during storage), light, oxygen, temperature, or contamination, but also communicates mandatory information such as sanitary verification, commercialization, traceability, and protects the consumer. Since Mexico Exports and imports different kinds of food, such as avocados, beer, and pork, among others, it's important to view food packaging not only as a barrier to protect food from external contaminants, but also as a primary tool for providing information to consumers (*COFEPRIS*, 2024).

Mexico's regulatory framework for food packaging is overseen by multiple authorities, including SAT, COFEPRIS, and SENASICA. There are specific Mexican official standards (NOMs) that are applied to ensure that food products meet high-quality and specification requirements for export or import by Mexican customs and regulatory authorities. On the other hand, COFEPRIS regulates food safety and packaging materials that come into direct contact with food, enforcing migration limits and material safety standards. SENASICA oversees phytosanitary measures to prevent the transmission of pests and diseases, particularly for agricultural imports and exports. Exporters often struggle to align packaging designs with the correct combined requirements, especially when packaging developed for other markets is reused without adaptation for the country to which the product is sent.

Mexican official standard NOM-051-SCFI/SSA-2010 establishes commercial and sanitary labeling specifications for prepackaged foods and non-alcoholic beverages. This NOM requires that products provide information such as ingredients, nutritional content, lot identification, quantity, expiration or best-before date, company, and other mandatory declarations. The NOM establishes that once the product reaches the consumer, the information on the package must be clear in Spanish, as the entire food package serves as the main vehicle for transmitting regulatory information to consumers and authorities Norma Oficial Mexicana, 2020).

The implementation of warning labels on food packages for products that exceed specific nutritional standards (calories, sugars, sodium, saturated fats, or trans fats) made NOM-051 more relevant for labeling specifications. Warning levels must be displayed on the package's main panel; some may think these warnings affect the package's visual design. The Mexican market must consider not only branding and consumer appeal, but also the required space, format, and visibility for mandatory regulatory

elements. A label design must be prepared by exporters before shipment because non-compliant products may face delays, relabeling requirements, or restrictions on commercialization (Batista et al., 2026, Bauner & Lavoie, 2026).

The information included in the package (product name, lot number, country of origin, etc.) must be consistent with key documents such as certificates, tariff classifications, and sanitary permits. This information helps authorities verify the product's identity and condition of the product. If the package presents errors, it can become a custom and regulatory risk. USDA's FAIRS report on Mexico emphasizes that food and agricultural products may be subject to oversight by several Mexican government agencies and recommends working with experienced importers and customs brokers to avoid compliance issues. Authorities need the package and label to match the documents used in international trade.

There are NOMs frequently used by Mexicans customs and regulatory authorities, as shown in Table 1, for the import and export of food products, especially those related to packaging, labeling, safety, and transport.

Table 1. The Mexican official Standard frequently used by Mexicans customs and regulatory authorities

Norma Mexicana	Description
NOM-051-SCFI/SSA1-2010	It specifies the information that must appear on packaging, including product name, ingredient list, nutritional declaration, allergen warnings, net content, country of origin, lot number, expiration date, and importer or manufacturer information.
NOM-050-SCFI-2004	Establishes general commercial information requirements applicable to all products marketed in Mexico, including food products
NOM-251-SSA1-2009	Defines hygienic practices for the processing, packaging, storage, and transportation of food products. It establishes requirements for sanitary facilities, personnel hygiene, pest control, cleaning procedures, and the proper handling of packaging materials.
NOM-120-SSA1-1994	Provides guidelines for hygienic practices in food preparation and handling, particularly in establishments where food is processed or prepared for consumption
NOM-130-SSA1-1995	Establishes sanitary specifications for packaged food products, including microbiological limits and safety requirements throughout the product's shelf life. It applies to industrialized foods and is commonly used by COFEPRIS
NOM-002-SCFI-2011	regulates tolerances for net content declarations on packaged products. It ensures that the quantity declared on the label accurately reflects the amount of product contained within the package, within legally defined tolerance limits
NOM-008-SCFI-2002	establishes the use of the International System of Units (SI) for all measurements used in commercial transactions in Mexico

Food Packaging is subject to sanitary controls; Mexican authorities, such as SENASICA, COFEPRIS, and SEMARNAT, may regulate imported food and agricultural products. Packaging must help preserve the food's sanitary condition during transportation, storage, border inspection, and distribution. This is especially important for perishable foods, such as fresh produce, meat, seafood, and dairy products, as well as products that require temperature control or sanitary certificates. On the other hand, packaging supports traceability and risk management by providing information such as lot numbers, expiration dates, barcodes, and QR codes, enabling products to be tracked through the supply chain and identified in the event of food safety incidents, recalls, labeling errors, or quality complaints.

Active, intelligent, and smart packaging technologies can complement Mexican regulatory requirements by providing additional information on freshness, temperature, gas consumption, or package integrity. Thus, modern packaging systems can strengthen both food preservation and regulatory compliance in import and export operations.

Mexico's Food Exports to Other Countries, and Its Packaging Innovations

Mexico exports and imports various products, including avocados, beer, tequila, and berries. The functions of packaging in Mexico´s food trade are to preserve, serve as a logistics tool, and serve as a regulatory communication mechanism. Fruits and vegetables exported to other countries should be packaged to preserve quality during long-distance transportation while also supporting phytosanitary inspection, lot identification, and traceability. There are packages that protect products against light, oxygen, leakage, and tampering, and that also communicate the origin, batch information, and commercial identity, as in the case of beer and tequila (SIAP 2025).

On the other hand, imported products such as corn require bulk containment systems that control moisture, pests, and contamination during transport and storage. Imported animal-based products and processed foods require an even more direct link between packaging and regulation. This is due to batch numbers on the package, expiration dates, certificates, imported information, and Spanish-language labels, as required by Mexican sanitary and customs documentation.

Avocado

Avocado is Mexico's fourth-largest export after beer, tequila, and berries. Avocado is a fruit that originates from the subtropical and tropical regions of Mexico and Central America (Fuenmayor et al.,

2025). Avocado is known for its exceptional nutritional profile and well-established health benefits, it has a high content of soluble and insoluble fiber, beneficial fats, and a range of essential minerals (such as magnesium, potassium, copper, phosphorus, and zinc) and vitamins (including vitamin E, vitamin C, vitamin K, and vitamin B) and also contains a wealth of bioactive compounds such as carotenoids, phenols, phytoestrogens, acetogenins, and tannins. This comprehensive nutrient profile contributes to numerous overall positive effects on human health through the action of antioxidants, anti-inflammatory agents, cardioprotective substances, and antimicrobial agents with potential anti-cancer properties (Fuenmayor et al., 2025; Marović et al., 2024).

The primary market for Mexican avocado exporters is the United States. Data from November 2023 show that Mexican export production to the USA accounted for 89.3% of the total volume, valued at $3.098 billion (Secretaria de Economia., 2024). The export success of Mexican avocados is linked to their quality and creamy texture, which are ideal for slicing, dicing, and mashing—traits consumers typically prefer in fresh fruit. Other commercial formats include pulp, prepared salsa, chunks, and halves (Nguema, 2025, SIAP, 2024).

However, due to its perishable nature, refrigerated storage (4 ◦C) and air transport are typically required for international trade, which increases energy consumption and logistical complexity, ultimately contributing to a higher carbon footprint. Different authors have searched for package options and treatments to preserve the quality of the avocado during the exportation process.

Fuenmayor et al., 2025, presented a detailed analysis of the quality decay patterns of Hass avocado combining a passively modified atmosphere packaging (MAP) system with cinnamaldehyde-based active packaging (CA), and demonstrates the potential of MAP-CA systems as an efficient solution for preservation as fresh produce that could be easily adopted by current supply chains, especially for international trade, MAP-CA system with the higher CA concentration extended shelf life of avocado by at least 12 days (~50 %) compared to MAP alone.

Díaz-Saenz et al., 2026 developed and characterized edible films and coatings produced from purple corn flour (MMH) and ethanolic propolis extract (EEP) and evaluated their effectiveness in extending the shelf life of Fuerte avocado. The author obtained that coated avocados reached a shelf life of 30

days at ambient temperature, compared to 15 days for uncoated fruit, and 72 days under refrigerated storage, compared to 50 days for the control.

On the other hand, Hernandez-Torres et al., 2021, reported that polylactic acid (PLA) films, added with essential oils of oregano or mint and modified with cold plasma, are an alternative for the production of an active, biodegradable packaging capable of inhibiting *Botriodiplodia theobromae*, *Colletotrichum sp*., and *Alternaria sp*. to extend the shelf life of avocados.

Berries

Blackberries, blueberries, raspberries, loganberries, and strawberries are all classified as berries. They have a short shelf life, are small, sweet yet tangy, juicy, and come in shades of red and purple. Due to their antioxidant properties, which slow aging and the onset of degenerative diseases in humans, berries are highly valued and have, in recent years, been classified within the new category of functional foods known as superfruits, a factor that has driven the rapid growth of their production, marketing, and consumption worldwide. According to Harvard University, berries are one of the five foods that help improve cognitive function (Espinosa, 2021; Mari et al., 2025).

In November 2025, exports of fresh raspberries, blackberries, and loganberries reached $141 million, while imports stood at $0. This results in a trade balance of $141 million. In 2024, the states with the highest exports of fresh raspberries, blackberries, strawberries, and loganberries were Jalisco (US $1,698M), Michoacan (US $222M), Baja California (US $22.4M), Guanajuato (US $16.4M) and Sonora (US $10.6M) (Secretaria de Economia., 2024)

Due to the short shelf life of berries, authors have studied how modified atmosphere packaging (MAP) can extend their shelf life by controlling temperature and the package atmosphere gases. Islam & Mitcham, 2024, analyzed raspberries and how storage atmosphere in elevated in CO_2 and reduced O_2 atmospheres can delay senescence in fruit by reducing softening, respiration and ethylene production rates, and pathogen growth storage in elevated CO_2 and reduced O_2 atmospheres can delay senescence in fruit by reducing softening, respiration, and ethylene production rates, and pathogen growth. The authors reported that Raspberry fruits kept in a 15 kPa CO2 atmosphere, followed by 8 kPa CO2, had higher firmness, a brighter red color, and the least fungal decay or leakiness (Islam & Mitcham, 2024).

Although strawberries are considered rich in vitamins and minerals, to have nutraceutical values, organoleptic quality, antioxidant properties, and anti-inflammatory properties, strawberries have a short postharvest life attributed to their fast respiration rate, fragile texture, vulnerability to temperature, water loss, gray mold (*Botrytis cinerea*), soft rot (*Rhizopus stolonifera*) deterioration, and mechanical and vibration injuries. Researchers are continually working to enhance strawberry shelf life using various non-invasive packaging techniques, such as hypobaric treatment and UV-C irradiation combined with vacuum sealing, which have demonstrated significant potential for extending shelf life (Menéndez-Cañamares et al., 2024; Mulla et al., 2026).

Packaging of Mexican Beer and Tequila Exports: Quality Stability, Regulatory Identity, and Sustainability

Beer and tequila are the 2 products most exported in México, USDA FAS and The International Trade Administration (ITA) reported that in 2024, beer and tequila ranked above berries, avocado, bovine meat, and tomatoes among México's agricultural exports. In 2024, the Consejo Regulador del Tequila (CRT) reports that 400.3 million liters of tequila were exported, with 84% going to the United States in 2024 and 86% in 2025. In January 2025, the CRT reported that 73% of exported tequila corresponded to the 100% agave tequila category, while 27% corresponded to the tequila category (CRT, 2025)

In the case of beer and tequila, packaging must be understood as both a preservation system and a regulatory communication system. Mexican standards such as NOM-142-SSA1/SCFI-2014 and NOM-199-SCFI-2017 establish sanitary, commercial, denomination, and labeling requirements for alcoholic beverages, while NOM-006-SCFI-2012 is specific to tequila and includes packaging, commercialization, and information practices. Therefore, bottles, cans, closures, labels, seals, cartons, and pallets are not only logistics elements; they are part of the legal and quality infrastructure that allows these beverages to circulate in domestic and export markets. For beer, the general alcoholic beverage rules are especially important: NOM-142 and NOM 199, as shown in Table 2. For tequila, you need NOM-006 in addition to those general rules.

Table 2. Most relevant Mexican standard for tequila and Beer

NOM	Applies	Importance of packaging
NOM-142-SSA1/SCFI-2014	Alcohol Beverages	Establishes sanitary specifications and labeling for alcoholic beverages.
NOM-199-SCFI-2017	Alcohol Beverages	Establishes denomination, physicochemical specifications, commercial information, and test methods for alcoholic
NOM-006-SCFI-2012	Tequila Specifically,	Applies to agave supply, production, packaging, commercialization, and information
NOM-106-SCFI	Official Password/Nom Mark	Tequila labels must display the official NOM design and authorized producer registration

Beer

Beer is one of the world's most widely consumed alcoholic beverages, enjoyed by millions of people worldwide. Its popularity transcends cultures and societies, making it a significant and enduring part of our social fabric (Marrucci et al., 2024). Selecting a beer package is important due to all the external factors (oxygen, light, temperature, vibration, and time) can affect its composition and product quality. It's important to know which package it is better to preserve beer; some packages that are selected are glass bottles, aluminum cans, kegs, closures, cardboard carriers, and pallets.

Fromuth et al. (2023) observed a strong correlation by package type for amber ale (AA) but not for India pale ale (IPA) over all time points. Mention that baseline differences in amino acids (glycine, tyrosine, and asparagine) and esters (isobutyl isobutyrate, 2-methylbutyl butyrate, and ethyl decanoate) were also observed in AA. Overall, the results demonstrate that beer metabolites and thus stability are significantly affected by package type. De Lima et al., 2023)studied larger beers in aluminum cans and glass bottles and identified 34 volatile compounds during the natural aging process. A 2024 life-cycle assessment compared beer consumption in PET kegs, glass bottles, and aluminum cans, showing that packaging choices are central to the environmental footprint of beer distribution (Marrucci et al., 2024) Furthermore, Brown glass bottles proved to be a more effective barrier against light than green glass bottles and Plastic bottles, and they contained lower amounts of phthalates than beers in plastic bottles and aluminum cans. Aluminum cans retained all organoleptic characteristics, with a slight increase in bitterness after 10 months of storage. However, beers stored in Aluminum cans had higher aluminum content than those stored in glass bottles. Beer packaging materials play a crucial role in beer quality.

Thus, glass bottles, aluminum cans, and polyethylene, due to their barrier characteristics and protection against external factors, generally outperform plastic bottles in preserving the integrity and quality of beer (Santos et al., 2024)

Beer is known for its aroma and taste, however some aroma compounds can change and affect the final sensory quality of the product. Diacetyl is a compound associated with buttery or creamy flavors, and in high concentrations, it is usually considered an undesirable flavor in beer. Dimethyl sulphide is another aroma compound that can give beer a cooked corn, cabbage, or vegetal smell when present at noticeable levels. (Goran et al., 2024) investigated the impact of pasteurization and storage in bottles on the aroma of pale large beer and concluded that after 6 months of storage in the bottle, the levels of diacetyl, dimethyl sulfide, and 2,3-pentanedione increased. This means that storage conditions and time can influence the development of specific aroma compounds in beer, potentially affecting its freshness, flavor stability, and overall quality.

Tequila

The tequila industry has grown into a globally recognized sector known for producing the iconic beverage distilled from the blue agave plant. Tequila, once primarily produced and consumed in Mexico, is now a widely commercialized and highly sought-after beverage worldwide. Recognizing the value of the “liquid gold” from the blue agave, the Mexican government took initiatives to protect tequila as early as the 1970s; tequila became the country’s first appellation of origin in 1974, and in 1978, it was internationally registered for protection under the Lisbon Agreement for Protection of Appellations of Origin and their International Registration. There are several categories or quality levels for tequila, based on the aging time in oak barrels and the proportion of agave used in its production, as shown in Table 3 (Lara-Topete et al., 2024; Morales et al., 2025; Suárez-Sánchez et al., 2025).

Table 3. Quality levels for tequila

Name	Description
Tequila Blanco	Silver or younger tequila, which is not aged after the distillation process
Tequila Reposado	Aged in oak barrels for a minimum period of 2 months and a maximum of 1 year
Tequila Añejo	Aged in oak barrels for a minimum period of 1 year and a maximum of 3 years
Tequila Extra Añejo	Aged for a minimum period of 3 years

Taken from (Morales et al., 2025)

Beer and tequila are strategic examples for analyzing packaging in Mexican food and beverage exports because they represent high-value products in which packaging performs technical, commercial, regulatory, and environmental functions. In beer, packaging directly influences quality stability because oxygen exposure, light transmission, temperature changes, and storage time can modify volatile compounds, flavor, aroma, and shelf life. Recent studies comparing aluminum cans and glass bottles demonstrate that package type can significantly affect beer stability and aroma evolution during aging. Therefore, beer export packaging must protect against oxidation, photodegradation, carbonation loss, breakage, and transport-related deterioration. In tequila, packaging has a different but equally important role (de Lima et al., 2023).

As a denomination-of-origin product regulated by NOM-006-SCFI-2012, tequila packaging must support authenticity, traceability, labeling, and commercial identity. Glass bottles, closures, seals, labels, cartons, and pallets protect the product during international transport while also communicating the tequila category, alcohol content, lot, authorized producer, and origin. Recent life-cycle studies also show that bottling and glass packaging contribute significantly to tequila's environmental footprint, creating opportunities for lighter bottles, recycled glass, improved palletization, and bio-based secondary packaging derived from agave residues. Together, beer and tequila show that beverage packaging for export is not only a container but also a preservation system, a regulatory document, a brand-protection tool, and a sustainability challenge

(Morales et al., 2025) reported that after obtaining an environmental overview of the industrial process of a 700 mL bottle of 100% *Reposado* tequila aged for 6 months in oak barrels, the results showed that a bottle aged for 6 months generates 2.27 kg of CO_2 eq, an impact comparable to other spirits. The author mentions that low level of glass recycling in Mexico, the use of fuel oil, and the lack of clean energies aggravate the impact and increase emissions, for what they obtained it’s clear that bottling is a major environmental hotspot in tequila production.

(De Anda-Rodríguez et al., 2025) developed a bio-packaging for Tequila bottles using mycelium from Ganoderma lucidum. The fungus was isolated from Bosque de la Primavera (Jalisco, Mexico), where it was grown on agave bagasse and corn stover. These agricultural residues were dried, ground, and pasteurized to optimize their performance as growth media.

After several tests they conclude that the package showed physical and mechanical characterization, competitive performance regarding bulk density, water absorption, and high impact resistance. The package has a significantly lower environmental impact than expanded polystyrene. The material supports circular-economy principles throughout the Tequila production chain.

The main solid residue from tequila production is the agave bagasse, which is reported to be used as a sustainable alternative for developing tequila packaging materials. (Lara-Topete et al., 2024) reports that agave bagasse can be transformed into agave fibers (AF), additionally adding Polylactic Acid (PLA) base composites or low-density polyethylene (LDPE). The author mentions that production of PLA-AF displays a significantly higher environmental impact, but it remains a preferable option when compared to pure PLA and may further improve its sustainability through green chemistry principles, the author also mentions that LDPE was less environmentally impactful.

Scientific Relevance

The scientific relevance of this review lies in its integrated analysis of food packaging as a preservation, regulatory, and trade-support system. While most packaging studies focus on material development, antimicrobial activity, shelf-life extension, or sustainability, international food trade requires packaging to perform additional functions related to traceability, labeling, customs verification, sanitary control, and consumer information.

This review provides a broader framework for understanding packaging performance, in Beer, tequila, berries, and avocado, it also shows that packaging requirements vary according to product specifications, composition, logistics, and regulatory identity. By connecting active, intelligent, smart, and sustainable packaging technologies with Mexican regulatory requirements and selected export products, packaging requirements vary. Therefore, packaging innovation should not be evaluated solely by its technical properties, but also by its compliance with food safety standards, Mexican NOMs, customs documentation, and international market access requirements.

CONCLUSION

Food packaging plays a strategic role in the import and export of food products by connecting preservation, logistics, regulatory compliance, traceability, and commercialization. In international trade, packaging is not limited to containing or protecting the product; it must also preserve quality

during storage and transportation, communicate information, and support sanitary and customs verification. This is a relevant point for products that are exposed to long-distance transportation, temperature variation, handling operations, and extended distribution times before reaching the consumer.

Recent advances in active, intelligent, smart, and sustainable packaging demonstrate that packaging technologies can improve food preservation, reduce quality losses, and reduce food waste. Active packaging can help control oxidation, microbial growth, gas composition, moisture, and aroma deterioration, while intelligent packaging can monitor freshness, temperature, oxygen levels, and pH changes. These technologies are particularly relevant for perishable products such as avocados and berries, where shelf life, cold-chain control, and postharvest deterioration directly affect export quality. In contrast, beer and tequila demonstrate that packaging also plays a critical role in beverages, protecting sensory stability, authenticity, commercial identity, and product value.

In Mexico, food packaging must also be analyzed from a regulatory perspective. Mexican Official Standards related to labeling, hygiene, alcoholic beverages, and tequila identity show that packaging is part of the legal infrastructure required for market access. NOM-051-SCFI/SSA1-2010 is especially relevant for prepackaged foods and non-alcoholic beverages, while NOM-142-SSA1/SCFI-2014, NOM-199-SCFI-2017, and NOM-006-SCFI-2012 are important for alcoholic beverages such as beer and tequila.

Overall, this review highlights that food packaging should be integrated as a system rather than an isolated material. Future developments should focus on packaging solutions that combine technical performance, regulatory compatibility, traceability, and environmental responsibility. For Mexico, this includes improving sustainable packaging alternatives, strengthening cold-chain and intelligent monitoring systems, and designing packages that comply with both Mexican NOMs and international market requirements.

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