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IMPACT OF MIGRATION OF SUBSTANCES FROM PACKAGING MATERIALS ON THE HALAL STATUS OF FOOD

Natalija Atanasova-Pancevska[1] & Aleksandra Markovska[2*]

[1]Department of Microbiology and Microbial Biotechnology, Institute of Biology, Faculty of Natural Sciences and Mathematics, "Ss. Cyril and Methodius" University, Arhimedova 3, 1000 Skopje, Republic of North Macedonia
[2]Quality Consulting, Februarski pohod 26 1/2, 1000 Skopje, Republic of North Macedonia

[*]*Corresponding author: Aleksandra Markovska*
E-mail address: markovska@fc.com.mk

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ABSTRACT

Packaging plays an important role in the containment, protection, and preservation of products throughout the supply chain activities. For a halal-certified product, the packaging is expected to protect and preserve its halal integrity until the product reaches the consumer. However, cases of migration of nonhalal substances originating from the packaging materials were reported. The issue has called for halal certification of the packaging material especially the ones which are in direct contact with the halal product. Such interaction between food and packaging materials is considered to be an interchange among food, packaging, and the environment and can impact food quality, safety, and/or halal status of food. The main goal of food packaging is to protect food from external environmental factors, but food–packaging interactions also can compromise the quality and/or safety of foods and halal status of the food.
However, the mass transfer of additives from packaging to the foods is undesirable and can alter the food's flavor. Other undesired phenomena include removal of some desirable flavors from the food to the packaging and the uptake or release of moisture by permeation. An interesting possibility is that food quality and safety could be enhanced via such package-to-food interactions.

Keywords: *Halal, Migration, Packaging material, Halal Certification, Islamic Dietary Laws*

Introduction

Halal food is closely related to halal certification. Foods with Halal certification are called Halal foods. The relationship between halal certification and food can be easily found in the literature. Halal certification ensures that a food is permitted or "allowed" for Muslims. Certification also provides distributors with the opportunity to establish operational and product differentiation strategies that focus on other attributes besides pricing, such as: providing convenience, variety, consistency, quality, and security.The construction of what is included within the halal parameters of the two main sources of sharia, the Quran and the Sunnah, and the issuance of fatwas by national religious authorities, depend on the process of halal certification

Halal, meaning permissible in Arabic, refers to products and practices that are compliant with Islamic principles. The concept of Halal Control

Points (HCPs) is crucial in certifying various industries to ensure their products are Halal and meet the dietary requirements of Muslims. This research focuses on identifying and understanding HCPs in the food industry,

Migration

The most common food packaging materials are different types of plastic polymers, including bio-based and biodegradable plastics, paper and board, metal, glass, and various multilayer materials. The packaging materials are used in combination with each other and with other materials, such as printing inks, adhesives, and coatings. Besides its many useful properties, food packaging is a well-known source of chemicals that can be transferred from the packaging into food and beverages. This process is called chemical migration, and it leads to low levels of chemical mixtures regularly becoming part of everybody’s diet.

Packaging material used in food industry

In the food industry, when it comes to halal status, the greatest focus is placed on the food, the choice of ingredients, the method of preparation, but very little emphasis is placed on the packaging material and the possibility of changing the halal status of the food according to the material in which it is packaged food.

Materials and methods

Research Objects

The research consists in determining the composition of primary packaging materials and the power of migration of haram ingredients in food

Primary packaging- Glass

Glass has been around for centuries, used for everything from jewelry to coffee tables and windows to fine art. It is common to see a variety of glass bottle shapes in grocery stores, as glass bottles are deemed food-safe containers for a number of products, including condiments, pickles, and sodas. As glass does not change the taste of the foods it contains, it’s the ideal choice for foods and beverages. Glass is virtually inert and impermeable, making it the most stable of all packaging materials and it is generally heat-resistant and, most importantly, recyclable. Its versatility continues to make it a widely-used product in every facet of life.

To begin the glass bottle making process, the silica sand must be mixed with several other materials. Soda ash (sodium carbonate) is added in a smaller percentage to decrease the melting point of the sand. This allows the sand to melt faster in the furnace, saving energy along the way. Adding only soda ash to the sand would eventually result in the production of a bottle capable of dissolving in water. To avoid such a result, limestone (calcium carbonate) must be added. The resulting glass type is then referred to as soda-lime glass, which accounts for approximately 90% of the world’s glass production.

Food-Safe Glass Bottles

In the United States, the Food and Drug Administration (FDA) oversees food safety regulations. The FDA is responsible for determining which materials are considered food safe, including the processes used in glass bottle manufacturing and the creation of food-safe glass bottles and jars. As part of the FDA process for qualifying packaging options for food safety, the agency considers the glass and plastic containers used in food packaging to be indirect food additives. This means the containers used to hold food and beverages make contact with the products as part of the production process. The plastic and glass used in packaging isn’t a direct additive to the products but nonetheless must be validates as safe for food applications.

The FDA has previously advised that soda lime glass bottles and jars are not "food additives". Soda-Lime glass is classified as Type I, Type II, and Type III which are all considered to be food safe, or in the terms of the FDA, GRAS (generally regarded as safe). For this reason, soda- lime bottles are very often chosen as the packaging of choice for most food and beverage products.

Type I Borosilicate Glass
A Type I glass container contains silica, boric oxide, sodium oxide, and aluminum oxide. It is suitable for packing alkali materials and acids and is considered food-grade safe.

Type II Treated Soda Lime Glass
Type II glass container is suitable for liquids and acids. It is similar in composition to Type III glass and is easier to mold than Type I glass and is food-grade safe.

Type III Soda Lime Glass
Type III glass is untreated soda lime glass offering average chemical resistance. It is made up of silica and various oxides, including sodium, calcium, aluminum, magnesium, and potassium. Type III is the most common glass type in use and is compatible with most items such as: food, beverages, and common chemicals - and, it is food-grade safe.

Migration from packaging material to food

The migration phenomenon in packaged foods may happen in two directions simultaneously, i.e., from packaging material to the food product and vice versa (Mousavi et al., 1998). In the former case, the molecularly diffused low-molecular weight substances such as additives and oligomers from the packaging films are transferred into the foods (Helmroth et al., 2020).

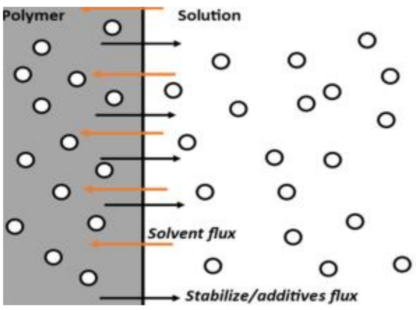

Figure 1. The polymer packaging and food interface suggesting chemical migration.

In the latter scenario, the mass transfer of food color, aroma, flavor, and nutrients happens from the food product to the packaging and results in a strong impact on the organoleptic properties of foods (Lee et al., 2008).

Types of food packaging migrating compounds From printing inks

The packaging, besides providing containment for the foods, also delivers information about the brand and composition and provides nutritional labelling for the foods. High-performance plastic packaging materials are very effective for shelf stability of the product until expiry. Generally, the single layer of material used in packaging the food products also has printed inks to disseminate the product description to consumers. A food stored in such packaging could increase the probability of transfer of printing dyes or inks to the food and thus may pose a quality and safety challenge. Printable ultraviolet (UV)-curable inks and varnishes are commonly used in packaging and normally comprise three components: a monomer, an initiator, and a pigment. For application, the ink is exposed to a UV source where the photoinitiator is converted into a free radical that ultimately reacts with the added monomers and starts polymerization (Castle et al., 1997, Robertson, 2006, Samonsek and Puype, 2013). During polymerization, the developed polymers bind the base polymeric packaging irreversibly and entrap the pigments resulting in a fast and good-quality printed surface. Some other printing inks are composed of pigmented resins and an organic carrier or polar solvent. This type of ink requires adequate drying if solvent removal is necessary, and print quality is highly dependent on numerous factors. In the case of UV-cured inks, the unbalanced formulation of the monomers and photoinitiators and incorrect functioning of the UV source may result in excessive residuals of monomers or photoinitiators. Thus, a potential migration of these substances into a food matrix would alter the organoleptic properties of food and compromise the safety of the food. Additionally, the interaction of the migrating species with the food would initiate taints and possibly result in loss of quality and nutritional value (Johns et al., 2000, Boon, 2008, Bradley et al., 2013).

Migration of benzophenone, a frequently used odorless photoinitiator, has been reported to generate alkyl benzoates, which contribute to undesirable flavors. Studies have reported the presence of printing inks in snacks and confectionary products well above the minimal detectable limits. Similarly, plasticizers, commonly used in packaging materials and in printing inks to provide functions such as flexibility, wrinkle resistance, and adhesion, are capable of contaminating foods by migrating from the packaging films. The presence of phthalates and other compounds such as tris(2-ethylhexyl) trimellitate, sulphonamides, and N-ethyl-toluene and N-methyl-toluene has been detected in printing inks. However, the chance of mass transfer of printing ink is relatively lower than that of the plasticizers used in the fabrication of packaging materials during direct contact with foods (Rasff, 2005, Boon, 2008, Bradley et al., 2013).

From adhesives

Adhesives are the compounds that are used to seal the packaging and they can also migrate to the foods during packaging or storage. The adhesives commonly used in the packaging industry are hot-melt, cold-seal, pressure-sensitive polyurethanes and acrylics that are water- or solvent- based or solvent-free. The selection of adhesives must be based on the type of packaging and characteristics of the food product. For example, the use of a hot-melt adhesive is inappropriate for wrapping bars of milk chocolate. Also, special requirements apply in cases where aromatic volatiles are directly incorporated in cold seals to augment the food-product perception at the time of opening (Athenstädt et al., 2012, Sella et al., 2013). From a previous survey by adhesive manufacturers, a listing of more than 360 substances was compiled to indicate potential chemical migrants from adhesives into foods.A subsequent study focused on the chemical composition and level of migration of polyurethane-based adhesives. The migrating residuals (e.g., polyether, polyols, and cyclic reaction products derived from polyester polyols) were identified at concentrations of 10–100 μgdm−2 (Sella et al., 2013, Hoppe et al., 2016). The migrants from the inks of a printed packaging surface also can easily transfer to the layer of adhesives, especially when the packaging is stacked, and thus could ultimately migrate to the food matrix during the process of packaging. However, in the case of multilayer packaging systems such as laminates, the chances of potential contact migration of migrants are increased significantly. The multilayer laminates are complex packaging materials that are manufactured by layering of different polymeric with non-polymeric materials (e.g., metals) to achieve particular packaging characteristics. The existence of diverse components along with adhesives could greatly increase the likelihood of health problems while also making the identification and detection processes more difficult and complex.

Plastic packaging

Plasticizers

Most plasticizers are the esters of phthalic (phthalates) and adipic acids. Dioctyl phthalate, di-2-ethylhexyl phthalate and di-2-ethylhexyl adipate are systematically applied during the preparation of packaging material. The phthalates are cast off in sealing gaskets and cap-sealing resins for bottled food, polyvinylchloride (PVC) films, and some plastic packaging. Phthalates once used as plasticizers in polymeric packaging films are characterized by low molecular weight, thus facilitating the package-to-food migration.

Thermal stabilizers

Thermal stabilizers are commonly incorporated in plastic materials, including PVC and polystyrene (PS). Generally, epoxidized seed and vegetable oils (e.g., soybean oil–esterified soybean oil) is commonly used in a wide range of food-contact plastic-polymer films as heat stabilizers, lubricants, and plasticizers (Lau and Wong, 2000). From studies of the impact of the degree of purity on toxicity, it was found that residual ethylene oxide is highly toxic.

Slip additives

Fatty acid-based amides are extensively used as additives in plastic packaging manufactured from polyolefins, PS, and PVC. Slip additives, which are directly incorporated into the plastic formulations, cause the emergence of surface bloom. These compounds are used to impart specific characteristics to the products. For example, they provide lubricating properties to the packaging materials to avoid sticking or conglomeration and also to reduce static charges (Cooper and Tice, 1995, Arvanitoyannis and Bosnea, 2004).

Light stabilizers

These chemicals are used in plastic packaging materials (polyolefins) to enhance endurance for long-term applications. Light stabilizers are used in many applications to improve long-term weathering properties of plastic polymers such as polyolefins.

Antioxidants

When polymers are exposed to UV light and air, they could be degraded significantly owing to the oxidation reactions. Antioxidants can be applied to decrease the degree of oxidation and enhance stabilization of the polymers. Tinuvin P, Tinuvin 776 DF, Tinuvin 326, Tinuvin 234, Irganox168, Irganox 1010, Irganox 1330, and Irganox P-EPQ are the commonly used chemical antioxidants in plastic packaging materialsAlso, vitamins such as A, C, and E and derivatives such as tocopherols, tocotrienols, and carotenoids can be added. Similarly, some metal ions (e.g., selenium) are crucial for the activity of antioxidant enzymes, and other phytochemicals, such as CoQ10, glutathione, and lipoic acid, are also considered good in controlling the oxidation of packaging materials.

Solvents

Various solvents are used in the preparation of solutions or in dispersions of the printing inks used in plastic packaging. The solvents are mainly low-molecular-weight organic compounds such as ethers, esters, alcohols, and ketones. These solvents are mostly evaporated from printed plastic packaging but may also disperse by distillation, penetration, or direct contact. However, some residue of the base solvent may remain entrapped in the packaging materials and later get transferred to the food upon direct contact or after release into the packaging headspace. The amount of solvent transferring to the food from packaging material is highly dependent on the concentration and distribution of the solvent. Therefore, potential migration of residual solvent may pose a risk of changing the food organoleptic properties.

Monomers and oligomers

Many monomers and oligomeric building blocks connect to produce polymers by various chemical reactions. Styrene is among monomers that are widely applied to produce PS, which is used in packaging that is in direct contact with foods. PS is used mostly as containment for a range of dairy products (ice cream, cottage cheese, yogurt), fruit juice and other drinks, poultry and other meat, bakery products, and fresh produce . Leibman (1975) reported that a styrene monomer may degrade into its respective oxide, which is characterized as a severe mutagenic and if metabolized in body can produce hippuric acid that could be excreted from the body in urine. Styrene exposure could result in organ toxicity and irritation of the skin, eyes, and lungs with simultaneous suppression of the activity of the central nervous system.

Isocyanates

Isocyanates are commonly used to produce polyurethanes and are used in some adhesives for the preparation of food packaging. Also, aromatic amines, especially primary amines, are a subcategory of this class of compounds, and Miltz et al. (1997) reported their migration into foods from materials such as rubber, epoxy polymers, aromatic polyurethanes, and azo dyes. The toxic effects of isocyanates on human health have been extensively reviewed in other studies (Lau and Wong, 2000). The maximum level of isocyanates residues must be < 1.0 mg kg^{-1} in the final packaging material. However, only 12 isocyanates are approved for use in food packaging.

Vinyl chloride

Under normal temperature and pressure conditions, vinyl chloride is a colorless gas. It is compressed into liquid under high pressure and has been used in the preparation of polyvinyl chloride-based packaging material. Vinyl chloride can leach from PVC bottles and food packaging and may modify the food organoleptic properties and also may result in toxicity. Because it is highly toxic, maximum allowed levels in food packaging have been in place since the 1970s. Many organizations, including the U.S. Food and Drug Administration, have established limitations regarding the maximum vinyl chloride content in food-packaging films and bottles.

Polyethylene terephthalate oligomer

Polyethylene terephthalate (PET) oligomers are used mainly in manufacturing of trays and bottles for packaging of various types of food (including fresh produce) and drink (including mineral water, juice, beer, carbonated beverages, and milk). It is a thermoplastic polyester produced by a condensation reaction (esterification) of ethylene glycol in the presence of terephthalic acid or its derivative as dimethyl terephthalate. PET is easy to mold for producing trays and dishes of various desired shapes, and due to its temperature resistance (∼220 °C), these containers can be used in heating or reheating of food. However, PET reportedly contains small amounts of low-molecular-weight oligomers (some dimers to pentamers). Additionally, the main volatile substance found in PET is acetaldehyde, which is of high significance owing to its effects on food odors, especially in cola-type beverages.

Metal packaging

Tin

Tin-based cans are used in containing foods and various carbonated and noncarbonated drinks. Tin traces transfer into the foods contained in tin cans with or without any lacquering. Foods with higher concentrations of tin (e.g., ∼500 mg kg^{-1}) reportedly can cause severe gastrointestinal ailments. According to clinical trials, found that the threshold for an acute effect from tin starts after consuming a dose >730 mg kg^{-1}. A thin layer of tin can help protect corrosion of metal cans. Although usually no lacquering is done for tin, especially when oxygen scavenging is desired, a lacquer coating is otherwise preferable because an uncoated can may lead to various interactions between the tin and the food matrix (Oldring, 2007).

Lead

Despite its toxicity and although it is known to be a common contaminant in foods, lead is commonly used in metal food and beverage containers. Lead toxicity could damage the central nervous system and has negative impacts on various body organs in humans. Infants are especially prone to lead toxicity because of the greater retention of lead in their brains and bones. Even a subacute consumption of lead could result in mental retardation, convulsions, and encephalopathy in children (Skrzydlewska et al., 2003, Robertson, 2006).

Aluminum

Al is used in preparation of laminate or multilayer food packaging or directly design cups and trays. It is used mostly in alloy form with other metals (such as Cu, Zn, Si, Mn, Mg, and Fe) to design food packaging. Small concentrations of Al are found in various plants and animals (Taylor, 1964). Unlike so many other vital elements that take part in the metabolism of animals, Al is not essential for the functionality of enzymes or any other metabolic process. High intake and increasing levels of Al in tissues have been associated with many disorders (such as dialysis encephalopathy, osteodystrophy, and microcytic anemia). Therefore, elements other than Al could be present in foods upon corrosion of the cans used to contain the food.

Chromium

Electrolytic Cr coating is widely used as a thin layer in tin-based cans to make them more stable against oxidative damage and to strengthen enamel adherence. Cr is characterized by relatively high toxicity and undesirable sensory properties. Also, in its hexavalent form (Cr(VI)), it could have a severe impact on living organisms owing to its having both carcinogenic and mutagenic properties (Skrzydlewska et al., 2003, Kim et al., 2008).

Paper packagng

Dioxins

These form a class comprising a large number of synthetic polychlorinated compounds that include but are not limited to polychlorinated dibenzofurans and dibenzo-dioxins. Dioxins are used in paper-based packaging for food applications. Dioxins are reported as highly toxic and mutagenic organic compounds. The isomer called 2,3,7,8-tetrachlorodibenzo-*para*-dioxin is the most toxic among all the dioxins.

Benzophenone

This organic compound is used in inks and lacquers as a photoinitiator and also is used as a wetting agent for dyes and pigments to improve their flowability. In general, 5%–10% of this compound is used once considered as photoinitiator in inks (Anderson and Castle, 2003). UV light is used to cure the printing inks for cardboard packaging thus online production process of finished packaging is relatively faster. However, because the benzophenones used in these inks may not get totally removed during this process, benzophenone could migrate to the inner sides of the cardboard components during stacking before forming the cardboard cartons or boxes. Also, the use of fiber recycled from cardboard may increase the probability of the presence and migration of benzophenones. The specific compound 4-methoxybenzophenone is also used but reportedly is carcinogenic and mutagenic.

Nitrosamines

Nitrosamines are commonly found in foods and beverages (Robertson, 2006). These amines are considered potential carcinogens and genotoxic. Nitrosamines are formed endogenously in the human body by reaction of amines with salivary nitrates or nitrites. Nitrosamines could also come from waxed cardboard and paper. These materials contain morpholine and N-nitrosomorpholine, which contaminate food after migration from a surface upon contact during storage and the processes involved in packaging.

Chlorophenols and chloroanisoles

Chlorophenols are organochlorides that have been industrially used for the production of biocides, fungicides, and herbicide intermediates . These compounds commonly transfer into food from packaging materials. Contamination of foods with these organochemicals results in the production of off-flavors and taints.

Additive derivatives and monomers

Other than the multiple above-mentioned types of possible food contamination, various derivatives of additives and monomers also could transfer to foods. In particular, direct contact between food and packaging material could result in migration of chemical substances and potentially contaminate the product. The environment also could contaminate the food if water and air quality are not properly monitored and thoroughly cleaned.

Benzene and other volatiles

For diverse food-contact plastics, organic components such as benzene or alkyl-benzene are typically produced at higher temperatures. For example, benzene is known to migrate into food from PET-, PVC-, and PS-based food packaging. Owing to its low molecular weight, it can easily diffuse through the package and contaminate foods. Therefore, the detection of benzene levels in plastic-based food packaging is necessary given its potential carcinogenicity.

Environmental contaminants

The surrounding environment could be a major source of food contamination if it is not hygienic. Numerous environmental contaminants, such as dust, microbes, insects, and naphthalene, can be transferred into foods and result in contamination.

This may occur through damaged or absorbent packaging material with subsequent migration to the foods. For example, concentration of naphthalene could rise significantly in the environment where naphthalene- based insect repellants are in use. Similarly, milk or milk-based drinks packaged in low-density polyethylene containers have shown increased concentration of naphthalene once stored in high-naphthalene environments.

Other contaminants

Besides the already-mentioned contaminants, there are various possible components that could migrate and contaminate foods. For instance, PVC-based food packaging contains the contaminant dioxin. Similarly, benzene, diphenyl thiourea (a heat-stabilizing agent), processing-aids additives, and diverse volatiles may migrate into packaged foods. Contamination of foods by diphenyl thiourea and its derivatives (e.g., aniline, diphenylurea, isothiocyanatobenzene) reportedly has been found in packaging materials (Lawson et al., 1996, Careri et al., 2002, Arvanitoyannis and Bosnea, 2004).

Conclusion

The migration of components from the packaging material can affect the taste of the food, the composition of the food, its safety and its halal status. For components that migrate from packaging materials that are relevant for food safety there is a clearly established regulation. Regarding the halal status of substances that can migrate, there is no clear picture. The construction of what is included within the halal parameters of the two main sources of sharia, the Quran and the Sunnah, and the issuance of fatwas by national religious authorities, depend on the process of halal certification. Also, there are components that may affect the halal status of food, but are not subject to food safety legislation. Regarding the methods for proving such ingredients, since there are no clear rules, there are no accredited methods available that would determine the presence or absence of a specific migrated substance.

Food is usually packaged in plastic, wood, glass or metal. Food safety standards allow the use of material that does not migrate or has minimal migration as primary packaging. Material that migrates very little or does not migrate is likely to contain ingredients of animal origin. In this way, he receives food that is safe for consumption, but the halal status of the food may be questioned. Also is very important to be noticed that chemical migration increases at higher temperatures. Heat (and microwave) foods in suitable inert containers.In general, migration levels increase over time. Limit migration by shortening the storage time of foods.Small packaging formats have a high surface-to-volume ratio enabling higher migration levels. Many chemicals migrate at higher levels in fatty and-or acidic foods than in aqueous foods. This shows that handling of food can have direct influence on migration and also on halal status of the food. With the introduction of halal standards, this risk can be reduced by checking the suppliers of packaging material and requiring them to be approved for use in food. But the question remains open about the possibility of migration of components that are not subject to food safety and can change the halal status of food. In the world of food safety, the effect of environmental pollution is always connected. With this challenge before them, scientists are discovering and working on new packaging materials that will be environmentally friendly. New materials may have an impact on the halal status of food, which leads to an increased need to control new materials that may migrate into food and their halal status. Additionally, for consideration, which is a challenge of the halal industry is of course the use of recycled packaging, about the composition of which very little is known.

However, whether recycling can be applied to keep the material in a closed cycle and produce new food packaging strongly depends on the material type. Properties such as stability, color, and smell can change during recycling. Additionally, the chemical safety can be compromised if the material allows carry over of contaminants or tends to degrade in the process. Trends emerging in the field of packaging materials will have an impact on determining the halal status of food.

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UTICAJ MIGRACIJE SUPSTANCI IZ MATERIJALA ZA PAKOVANJE NA HALAL STATUS HRANE

Natalija Atanasova-Pancevska[1] , Aleksandra Markovska[2]*

[1]Katedra za mikrobiologiju i mikrobnu biotehnologiju, Institut za biologiju, Prirodno-matematički fakultet, Uiverzitet „Sv. Ćirila i Metodija”, Arhimedova 3, 1000 Skopje, Sjeverna Makedonija
[2]Quality Consulting, Februarski pohod 26 1/2, 1000 Skopje, Sjeverna Makedonija

Autor za korespodenciju: Aleksandra Markovska
E-mail adresa: markovska@fc.com.mk

Stručni rad

SAŽETAK

Ambalaža igra važnu ulogu u zadržavanju, zaštiti i očuvanju proizvoda kroz aktivnosti lanca opskrbe. Za halal certificirani proizvod, od ambalaže se očekuje da štiti i čuva svoj halal integritet sve dok proizvod ne stigne do potrošača. Međutim, prijavljeni su slučajevi migracije nehalal supstanci koje potiču iz materijala za pakovanje. Problem je zahtijevao halal certifikaciju materijala za pakovanje, posebno onih koji su u direktnom kontaktu sa halal proizvodom. Takva interakcija između hrane i materijala za pakovanje smatra se razmjenom između hrane, ambalaže i okoliša i može utjecati na kvalitet hrane, sigurnost i/ili halal status hrane. Glavni cilj ambalaže hrane je zaštita hrane od vanjskih faktora okoline, ali interakcije između hrane i ambalaže također mogu ugroziti kvalitet i/ili sigurnost hrane i halal status hrane. Međutim, masovni prijenos aditiva iz ambalaže u hranu je nepoželjan i može promijeniti okus hrane. Druge neželjene pojave uključuju uklanjanje nekih poželjnih aroma iz hrane u ambalažu i upijanje ili oslobađanje vlage prodiranjem. Zanimljiva mogućnost je da bi se kvalitet i sigurnost hrane mogli poboljšati kroz takve interakcije između paketa i hrane.

Ključne riječi: *halal, migracija, materijal za pakovanje, halal certifikat, islamski zakon o ishrani*