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SELECTION OF FOOD PACKAGING MATERIAL, MIGRATION AND ITS EFFECTS ON FOOD QUALITY

Abstract: *Food packaging is one of the stages of food production that enables foods to reach consumers safely. By selecting the appropriate packaging material and technologies for different food products shelf life of food is increased and food quality and freshness can be preserved. While basic function of food packaging is to protect food from contaminants, if food packaging material is not selected properly food may be contaminated by chemicals. Because food may be kept in packaging for long time packages are evaluated as the main contamination source of chemicals. Migration, under specific conditions, can be described as mass transfer of chemicals from food packaging to food during storage and usage. These materials passing from packaging to food can cause taste and flavor loss and significant health problems. Substances migrating to food give a bad odor to food and thus reduce consumer choice. Also because migrating substances creates remains on food they adversely affect food safety and quality. It is a mandatory requirement for consumers to determine impact of packaging in contact with food on food safety as the last chain in food safety food. Today, new packaging materials are produced with different packaging technologies. Each newly produced packaging material must be evaluated in terms of food safety. Consumers may not use the packing material as intended always this situation may lead to different exposures. While querying the packaging of foodstuffs we buy as consumers, it is necessary to take into account that packaging materials in contact with food should not give its ingredients to food. Food quality affects human health and human health changes the quality of life. It is necessary to be aware of the possibility of chemical migration in food production, distribution, sales and consumption stages and it must be minimized. Migration and food safety in food packaging and its effect on quality will be addressed in this study.*
Keywords: *Packaging, migration, food safety, food quality*

1. INTRODUCTION

All industrial products manufactured by industry are forwarded to consumers after packaged in one way or another. Basic function of packaging therefore is to preserve and protect the product contained within packaging [1]. Packaging protects, maintains, presents, promotes and displays product during transport, storage and use economically and sensitive to environment throughout the entire life span of products [2]. Food packaging is in contact with the food depending on conditions such as packaging material and food properties, packaging and storage temperatures, ultraviolet light exposure and storage time of the product. During migration from the packaging material to food, migration to food from packaging material

may also occur. This interaction is one of the important factors that affect quality, appearance and shelf life of food. This interaction affects the permeability of the packaging and leads acceleration of reactions such as oxidation and flavor transition. Such interactions may increase the risk of migration [3]. Migration has become a major factor in regulations regarding the safety and quality of packaged food [4]. The migration of ingredients from packaging material into food is undesirable. However, a certain transfer is unavoidable, because most foodstuffs are packed prior to their purchase by the consumer. The term "migration" is used to describe the process of mass transfer from a food packaging material to its contents. During this process, a packaging material comes in contact with food, and though its mechanical or diffusion properties are not altered, it may adversely affect the organoleptic properties of the packaged food [5]. Diffusion is caused by concentration gradients, i.e. mass transfer of components from regions of high concentration to regions of low concentration will take place within the food and within the packaging material [6]. Besides keeping foods safe from contamination and retaining the nutritional properties and sensory characteristics of foods, packaging provides additional features that are important to consumers.

2. FOOD SAFETY AND PACKAGING

Food safety is defined as compliance with necessary requirements during production, processing, storage, transport and distribution of food and taking essential measurements to ensure healthy food production [7]. In parallel to developing economy fast food consumption and accordingly fast food production is increasing ([8,9]). Ensuring the safety of materials in contact with food from field to table as the final link of food safety chain, determination of its effect on food quality and safety and identification of health risks resulting from these materials are compulsory for the protection of consumer rights [10]. Lately, food packaging has gained a widespread importance in food safety due to the possibility of migration of chemicals from food contact materials. The term 'migration' usually describes a diffusion process, which may be strongly influenced by an interaction of the packaging material with the food [11].

3. MIGRATION - MIGRATION TYPES- FACTORS AFFECTING MIGRATION

As a result of migration occurring between food and food packages; required characteristics of packaging materials may change, loss of quality can occur in food ingredients or food material can be degraded. Therefore, migration is very important in food packaging and selection of appropriate packaging materials for foods and storage conditions should be considered [12].

3.1 Factors affecting the migration

There are many parameters that affect the rate and speed of migration from materials in contact with food to food. These parameters can be summarized as follows ([13-15]) direct or indirect contact of packaging material with food. Features of the materials in contact with food (thickness, permeability, etc. for plastics); chemical properties (vapor pressure, polarity, molecular size and structure, etc.) of migrant. Initial concentration of migrant in the packaging material. Contact time and temperature. Components in contact with the packaging material (food or stimulants). Generally small molecules migrate faster than larger ones. Since migration takes place through physicochemical processes it increases significantly with increasing temperature. Migration depends on time. A food packaging compatible at the beginning of shelf- life may be incompatible at the end of shelf-life (e.g., durable products). For example, liquid or solid, aqueous or oily, moisture / fat content, granular, particle surface area. While water-based foods tend to attract pole immigrants, fatty foods will tend to attract nonpolar immigrants. Food with a high surface area based on its volume (for example high surface area - pasta) is typically more sensitive to transport. Different surface has different permeability potential against migrants. It is believed that metal and glass absolutely prevents migration. However, migration into the metal containers into food should be considered in addition to reducing coating [16]. Another factor to be considered in linking packaging usage, food consumption and migration data are the ratio of surface area of the packaging to volume of food product. Mass transfer of the chemical is a surface area phenomena and the concentration achieved in the food or food stimulant depends

on its volume or mass. Therefore, the size and format of the packages are also very important [17].

3.2. Types of migration

Migration can occur in a number of different ways:

Contact migration – involves the direct transfer of substances from the food contact surface of the packaging into the food. Examples might include the transfer of substances from a cardboard pizza box to the underside of a pizza, or transfer of substances from a plastic tub, tray, pouch or wrapping into food.

Gas phase migration – involves the transfer of volatile substances through the airspace between food and packaging and into the food by the process of diffusion. A good example might be the diffusion of mineral oil from recycled paper-board, into solid dry foodstuffs. Note that in this case, mineral oil can potentially migrate from the cartons, through an airspace, through a plastic inner pouch (subject to its barrier properties) and through a second airspace into the food.

Penetration migration involves the transfer of substances from the non food contact (often printed or coated) surface of the product's packaging, through the substrate and onto the food contact side of the packaging. Once on the food contact surface, the migrating substances can be transferred to the food by either contact or gas phase migration.

Set-off migration – involves the transfer of substances from printing inks, coatings or varnishes from the printed, non food contact side of the packaging to the food contact side, as a result of the stacking of printed items e.g. carton flats, or when winding a printed film into a reel. Note that set-off migration may be either visible or invisible. Once on the food contact surface, substances arising through set-off can be transferred to the food by either contact or gas phase migration.

Condensation / distillation migration – involves the transfer of substances into food during heating processes such as sterilisation or boiling of e.g. pouched food, or oven / microwave cooking of food in cartons or trays. It involves the evaporation of volatile components from the packaging and by steam distillation in the case of moist / aqueous food [16].

4. MIGRATION IN PLASTIC BASED PACKAGING MATERIALS

There are more than 30 types of plastic materials including widely used polyethylene, polypropylene, polycarbonate and polyvinyl chloride and chemicals known to migrate to food among these materials raise concern about health [18]. Additives, such as plasticizers, antioxidants, light stabilizers, thermal stabilizers, lubricants, antistatic agents, and slip additives, usually abound in various types of plastics. Migrating solvents, such as adipic acid, toluene, butanone-2, ethyl acetate, and hexane are also of concern as well as pigments, such as molybdate orange ([19-21]) For apparently inert materials such as stainless steel, ceramic or glass, chemicals lining the inner surface and in direct contact with the food could lead to contamination and migration may still occur from closures or sealants containing plasticizers. Chemical migration is more likely to occur for materials such as plastics, elastomers, paper and board [22]. Decomposition products from additives or monomers will also migrate into the food under proper conditions. The presence of the residues of these chemicals may lead to contamination. Diphenylthiurea is used in the manufacturing of PVC film, benzene, dioxins ([23, 24]) processing agents (hydrogen peroxide [25] and other volatiles and stands for some of the most representative residues [26].

5. MIGRATION IN PAPER BASED PACKAGING MATERIALS

Migration from paper and board packaging materials has not been as extensively studied as migration from plastic materials. However, it has been demonstrated that migration from paper and board packaging occurs [27-34] Most of the migrants detected originate from the printing inks or adhesives used in the manufacture of the finished packaging. The risks of contamination of food from printing ink components in packaging materials are associated with two mechanisms: transfer through the packaging material and set-off phenomena. The latter means that printing ink components are transferred from the printed to the non-printed surface by direct contact during the material's manufacture, storage or use. The use of recycled materials such as fibers from recovered paper may also result in direct contact

between ink components and food, or at least the route through the material might be shorter [35]. Paper and cardboard materials are used for many different purposes especially like packaging of hot drinks and food in restaurants described as fast food, in tea bags, filter papers, oven/bakery products and dry foods. In addition they are used for packaging of foods such as flour, sugar and pasta and in transport of vegetables, fruit and eggs frequently. Due to chemical substances arising from their natural structures and compounds added during production and in case they are used again paper and cardboard materials contain a large number of toxic organic molecules. Compared to other materials such as glass, metals and plastics in contact with food, paper / cardboard materials may keep especially volatile compounds that cause bad smells due to their porous structure [36]. Some chemical components in packaging such as printing inks (e.g. photo initiators such as benzophenone) may transfer to food contact surfaces via the 'set-off' process. This is a direct transfer from the external surface of the packaging to the food contact surface during stacking and storage of packaging. The chemicals may then migrate into food. Transfer can also occur via evaporation and then leach into food via the gaseous phase [37, 38]. Furthermore, chemicals such as ink components and recycled fibers may persist in recycled packaging materials and ultimately migrate into food [39, 40]. Antioxidants are added to a variety of polymer resins to slow the onset of oxidative degradation of plastics from exposure to UV light [5, 41]. Polymer degrades due to the action of highly reactive free radicals generated by heat, radiation, and mechanical shear that is often enhanced by the presence of metallic impurities. In food packaging, oxidation increases at high temperatures, including contact with hot foods or exposure to infrared heating, retort processing, and, potentially, MW heating [42].

6. METAL BASED PACKAGING AND MIGRATION

Metal lids used in glass jars may also be a source of potential contaminants: semicarbazide in baby food jars, resulting from degradation of azodicarbonamide used as blowing agent, and epoxidised soybean oil (ESBO) a plasticizer used in the plastisol gasket [43]. EFSA recommended the decrease of the legal specific migration limit (SML) for ESBO, for infants food packaging applications, from 60 to 30 mg/kg of food or food simulant [15]. Tin-coated metal cans act as a barrier against gas, water vapor and flavor like glass. It is opaque and lightproof and recycling is possible. When steel and aluminum are used, it is required to make lacquering to prevent food interaction because these materials are not inert as glass [44]. The migration from metal boxes arises from metals they contain and initial components or derivatives of polymers used in lacquering [45]. Migrants from can coatings, namely phenolic resins, often contain only small amounts of monomers, oligomers and additives, but a large amount of other unknown or undescribed components.Tin-plate is most used for food cans and aluminum for beverage cans. Most cans are internally coated with a polymeric layer, and thus the layer of food contact is not the metal but the lacquer. The substances of concern in can systems are therefore not only the metals involved, but also components migrating from the coatings, such as starting substances and their potential derivatives [46]. Chemicals in the structure aluminum containers and / or added during their production can migrate to foods and can reach the size to be harmful for human health. Sources of Al transition are contact environment during production and before submitted to consumption, packaging, kitchen materials, cutting and cooking tools and many materials. Although contact time with the manufacturing and packaging apparatus is less; foods can stay for long periods in their packaging during shelf life [47, 48]. There are studies are carried out to limit overall and specific migration values in some countries for packaging group. However there is no common legislation in EU and in our country with regard to materials like metal, silicon, paper and so. This poses a risk to human health [48, 49]. For the case of the beverage cans made from tinplate, the control of the migration of iron acquires an even greater importance; because extremely small levels of iron migrated to the drink (0.5 ppm) can already compromise the flavor of the drink [50].

7. MIGRATION AND HEALTH EFFECTS

Protection of food packaging / materials in contact food during storing or handling food and prevention of migration of any unwanted non-food components to food are main tasks of food

packaging. In the compositions of materials in contact with food according to feature given to food: they can be monomer, starting materials, catalyst, solvent and additives (antioxidants, antistatics, plasticizers, heat stabilizers, dyes and pigments ..) and they may be also known and unknown mixtures of these substances, impurities, reactions and decomposition products. Every day, toxic effects of chemicals used in non-food materials in contact with food emerge and mostly affected groups are especially babies and children consumer groups. In addition, specific migrant can sometimes transform into toxic metabolites migrant shape and can also be difficult to identify. Consumers don't use packaging materials always as offered and this causes different exposures [51]. Diffusing agents can affect the organoleptic properties of the food and health of humans negatively [52]. Many plasticizers and additives are described as Endocrine Disrupting. They adversely affect the human reproductive system and are carcinogenic. Some of these chemicals are phthalate esters, alkyl phenols (APs) and 2,2-bis (4- hydroxyphenyl) propane known as bisphenol A, its derivatives and di (2-ethylhexyl) adipate (DEHA). Repeated exposures to even very low concentrations of these components create serious toxic effects [53]. Therefore, as much as intake food packaging material should also be safe [54]. Due to the increasing awareness of consumers in terms of health matters, the importance of the migration of substances from food packaging materials to foods attracted the interest of the scientific and legislative communities ([55], [56]). The employment of novel food packaging materials has increased the number of occurring hazards due to the migration from packaging material to the packaged food. Furthermore, the list of hazardous monomers, oligomers, and additives continues to augment in order to ensure that the consumer safety is in current agreement with the HACCP, which is continuously gaining ground [5]. Melamine (2,4,6-triamino-1,3,5-triazine, CAS number 108-78-1) may contaminate foods as it is commonly used as a raw material or additive in the manufacture of melamine-formaldehyde resins, plastic food packaging materials and containers [57]. Information regarding the migration of melamine from food packaging materials and containers into foods is very limited. A Denmark group observed that migration of melamine was found in seven of ten tested melamine samples from the Danish market, including bowl, jug, mug, ladle, cups and plates [58]. Framework Directive 89/109/EEC (CEC 1989) provides 2 basic principles on which the legislation is based. These include "inertness" of the food-contact materials and articles, and "safety." The principle of inertness is that any material, article, or its components should be inert enough not to pose any health hazards, unacceptable changes in food composition or deterioration of food qualities [42]. The use of high volume of PS food packaging [5] may pose health concern as residual styrene can migrated from PS. Epoxy resins of BPA, also known as bisphenol A diglyceride ether (BADGE), have cytotoxic effects in living tissues, and have been shown to increase the rate of cell division [56]. According to Commission Regulation (EU) No 10/2011, the vinyl chloride monomers in PVC plastic can pose acute toxicity in the human body. The isocyanates used in polyurethane polymers and adhesives carry a low risk of oral toxicity, but a high risk of toxicity from dermal or inhalation exposure. BADGE is a monomer and the main component of epoxy resins for internal can linings. Unreacted BPA in the plastic lining of the cans or containers can migrate into foods during heating and storage. BADGE is added to the polymers to serve as an antioxidant, but may contain unreacted BPA. It is not harmful to humans, as long as the amount of substances is below the specified limit [42]. Monomers and oligomers both tend to migrate from packaging materials into foods [56]. Serious health risks may arise when the amount of unreacted monomers or low-molecular-weight substances in food reaches to a specified limit and thus absorbed by the human body (EU 10/2011). The restriction has also been applied to the SML for some metals and primary aromatic amines migrating from plastic packages into food (EU 10/2011). DEHA (di-(ethylhexyl) adipate), a plasticizer in PVC, can migrate from packaging into fatty foods, and exposure is restricted to keep the total daily intake (TDI) below 0.3 mg/kg body weight ([59], [60]). Gao and others [61] measured the migration of 8 antioxidants: BHA, BHT, Cyanox 2246, Irganox 1035, Irganox 1010, Irganox 1330, Irganox 1076, Irgafos 168, and its degradation product DBP at 40 °C in a 10-d storage study BHA, DBP, BHT, Cyanox 2246, Irganox 1035 migrated into aqueous simulants; Irganox 1010, Irganox 1330, and BHT were detected in oil. Beldì and others [62] studied the effect of fat content and storage

temperature on the migration of Irganox 1076 from LDPE to several foods (cheese sauce, chicken, chocolate, margarine, mayonnaise, milk, orange juice, soft cheese, pork, salmon, and wheat flour) and food simulants (distilled water, 3% acetic acid, ethanol 10%, rectified olive oil, isooctane, and 95% ethanol). They found that migration increased as the fat content of the food and storage temperature increased, with the highest level of migration (1413 μg/dm2) for chocolate (32.1% fat) at 40 °C after 30 d of storage. Linssen and others [63] found that migration of antioxidants (Irganox 1076 and Irgafos 168) increased with increasing concentration (40% to 100%) of ethanol in food simulants, with the highest percentage of migration in 100% ethanolic simulants. Important applications of PS include cups, packaging trays for yogurt and cheese, and so on. Several studies report the migration of styrene into food ([64-68]) and estimate the daily styrene exposure of 18.2 to 55.2 μg for individuals, with an annual exposure of 6.7 to 20.2 mg. This level of exposure causes irritation of the human organs and skin, as well as neurological disorders [5]. Lickly and others [64]studied the migration of styrene from different food-contact PS foam materials (meat trays, egg cartoons, cups, plates, and hinged carry-out containers) to the oil (mixture of canola, sunflower, and other vegetable oil) and 8% ethanol at 70 °F (21 °C) for 10 d, 120 (49 °C), and 150 °F (65.5 °C) for 1, 4, and 10 d. Migration increased from 1 to 10 d and found to be proportional to the square root of the increase in time at a specific temperature for all articles except for drink cups. Migration of chemical compounds from packaging polymers into foods should be evaluated to ensure that the amount of migrating components meet compliance standards set by regulatory agencies ([14,68], [69]) As temperature increases, the diffusion of monomers, oligomers, and other compounds increases, and it can result in higher diffusion or rates of migration from packaging materials. The diffusion coefficient of packaging material components increases 6- to 7-fold when packages are exposed to extreme temperature fluctuations (for example, from freezer temperatures to cooking temperature) [70]. Microwave food packaging has become a tremendous element in the food manufacturing process. The purpose of any food packaging regulations concerned with the safety of the food is to control and limit the migration of substances from the packaging into the food. Monomers from plastic microwave packaging, chemical compounds like additives or catalysts may filter (leach) from food containers and can cause bad smell, taste and even cause health risks and harmful effects. Generally, when food is heated in a microwave oven with plastic packing it has been shown that there may be massive migration. And also food with high water content may migrate to oil and liquid foods [71]. Migrant transfer routes can be more complicated when the foods are heated in the packaging than when they are only stored at room temperature, because of possible transient contact with splashed food. The photoinitiator benzophenone has been studied as an indicator migrant. Migration to foods microwaved in a paperboard packaging was up to 1 mg/kg 74. It was concluded that the mechanism of migration depended on the design of the packaging, occurring by direct food contact, transient contact with splashed food, or by gas-phase diffusion through an air gap. In a later study, it was shown that migration into foods heated in trays with cartonboard splashguards was some 10 times higher when there was direct contact between the food and the lid than in a situation where there was no direct contact [72]. Chemical compounds that are incorporated within polymeric packaging materials to improve functionality, may interact with food components during processing or storage and migrate into the food. Once these compounds reach a specified limit, food quality and safety may be jeopardized. Possible chemical migrants include plasticizers, antioxidants, thermal stabilizers, slip compounds, and monomers [42].The risk of adverse health effects to consumers from any chemical present in food depends on the characteristics of the chemical and the exposure resulting from consuming foods containing the chemical. Various international bodies have looked at the risks posed by packaging chemicals migrating into food and this has resulted in the implementation of risk management measures for several thousand chemicals. The risk assessment approaches are typically tiered, with increasing information required on the toxicology of the chemical as the migration level of the chemical increases (see SD4). Migration levels of packaging chemicals in food are typically too low to result in acute adverse health effects. A major aim of risk management is, therefore, to protect consumers from potential adverse effects

arising from repeated dietary exposure to packaging chemicals over a long period (chronic exposure) [73].

7. CONCLUSION

Migration is an important factor affecting the quality and shelf life of food and it also affects the human health. In order to protect the quality and safety of food it is necessary to be careful about properties of selected packaging materials. Conditions that could lead to migration must be known and migration capabilities of the new technology packaging material must be determined.

More research should be conducted about chemicals that cause migration and effects on human health.

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