Migration study of food packaging material

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Abstract

Consumers expect safety and quality from packing materials in addition to contamination protection and prevention. The extensive use of additives in the synthesis of food packaging materials increases the likelihood of migration into food ingredients. These migrants include monomers and oligomers, antioxidants, pollutants, pigments, and solvents, among others. The migration rate is influenced by factors such as packaging material contact time with food products, food composition, and storage temperature. The scientific community has taken notice of the health difficulties caused by the migration phenomena. As a result, its identification, quantification, and negative impacts on the human body must be addressed.

Keywords: Food safety, Food packaging, Legislation, Migration

I. Introduction

Food packaging's primary functions are to protect food goods from outside contaminants and damage, to keep food contained, and to provide consumers with ingredient and nutritional information. The most widely used plastic materials are polyethylene, polyvinyl chloride, polyvinylidene chloride, polystyrene, polyethylene terephthalate, and polyamide. The food packaging section is always evolving to meet specific requirements of the consumer. Nowdays, consumers are not only expecting safety and quality from food packaging materials but also, they are concerned about the migration issues occurred from the packaging materials. Migration, defined as the mass transference of constituents from the packaging material to the foodstuff, is one of the most important processes that occur as a result of food packaging. This diffusion process has a considerable consequence on the properties of the packaging material. The migration itself does not stand for a health problem, but is mainly a legal problem in most countries with legislation on acceptable materials, limits on substances, and restrictions for certain applications. Because consumers are becoming more health-conscious, the importance of substances migrating from food packaging materials to foods has intrigued the scientific and legislative communities. The term migration usually refers to a diffusion process that is influenced significantly by the interaction of food components with the packaging material. In this chapter the migration mechanism, potential migrants, the migration evaluation and the regulatory controls are discussed.

II. Migration mechanism

The migration of additives from packages into food mainly occurs through diffusion, adsorption, desorption and evaporation of migrant. Different factors affect the rate of migration. When direct contact with food is used, the migration extent is considerably increased. The ingredients from packaging material migrate into food, which is undesirable. However, because most foodstuffs are packed before being purchased by the consumer, sometransfer is unavoidable. Dissolution in the food that interacts with the migrated stabilizers on the polymer surface causes contamination. A packaging material gets in touch with food during this process, and even if its mechanical or diffusion properties remain unchanged, it may harm the packaged food's organoleptic properties. During the processing and fabrication of polymeric packaging components, a variety of additives get develop. Plasticizers, antioxidants, thermal stabilizers, lubricants, and slip additives are the common additives in most plastics. Some of the solvents that migrate with pigments are molybdate orange including adipic acid, toluene, butanone-2, ethyl acetate, and hexane [1]. A certain factors influence migration parameters, the most important of these elements are: The type of contact- the extent of migration depends on direct or indirect contact of food packaging material and packaged food. The nature of the food- foods with a high-fat content have significantly higher rates of migration [2]. The amount of a migrating substance is inversely proportional to the contact time squared [3]**.** The temperature of contact appears to have a direct influence on boththe frequency and volume of migration. Temperature increase cause faster migration and the establishment of equilibrium [2]**.** The thickness of the package has a sizable effect on migration rates; higher migration rates are associated with thinner packages [4], whereas there is no connection between migration and the amount of recycled ingredients [5]**.** The migrant's characteristics typically get influence the migration route. Highly volatile materials show a high rate and increased migration, as demonstrated by [6]**.** Furthermore, high molecular weight ingredients (>1,200 Daltons) exhibit lower migration levels when compared to low molecular weight materials.

III. Migration compounds from food packaging materials

A. Plasticisers

A plasticiser is a chemical that, when added to a plastic, can increase its flexibility and ease processing of the material. Plasticizers are key additives in many plastics and are therefore important constituents of a variety of products like food packaging, bottled water containers, toys, cosmetics and medical materials. The most common plasticizer chemical structures, polar or nonpolar, are, for example: phthalates, phosphates, carboxylic acid esters, epoxidized fatty acid esters, polymeric polyesters, modified polymers; liquid rubbers, and plastics, Nitrile Butadiene Rubber (NBR), chlorinated PE, EVA, etc.; paraffinic, aromatic, or naphthenic petroleum oils. Plasticizers get released into the environment during the synthesis and preparation of plastic products, as well as during consumer usage [3].

B. Solvents

Inks are employed as solvent-based dissolutions or dispersions during the printing of plastic packages, which can then evaporate or be removed by penetration, distillation, and contact, usually in specific types of oven [3]**.** Organic compounds with low molecular weight that include ketones, esters, alcohols, and hydrocarbons are the most widely used solvents, and they can migrate into food by directly contacting it or through the open space in the package's interior.

C. Monomers and Oligomers

Polystyrene Monomer Styrene is one of the most widely used monomers in polymers that come into contact with food. Polystyrene is commonly found in yoghurt, cream, cottage cheese, ice cream, and fruit juice containers, as well as meat trays, biscuit trays, egg carton [7]. According to [8], styrene monomer can be reduced to styrene oxide, which has a high mutagenicity and can be further metabolised to produce hippuric acid. The most prevalent harmful effects of styrene exposure include skin, eye, and respiratory tract irritation, as well as central nervous system depression. According to [9], styrene monomer levels in food packaging typically vary from 100 to 3,000 ppm. PET (Polyethylene Terephthalate Oligomer) is widely employed in the production of various types of fabrication of dishes for microwave and conventional thermal processing because of its high temperature resistance (up to 220°C). However, studies have revealed that PET contains trace amounts of low molecular weight oligomers ranging from dimers to pentamers. The principal volatile chemical present in PET is acetaldehyde, which is high significance because of its impact on smell quality, particularly in cola-type beverages.

D. Contaminants

Other chemicals that could contaminate food include those produced by the breakdown of additives or monomers [10]. Benzene and other volatile benzene and alkyl-benzene could be produced during high temperature applications from a variety of food contact plastics. It has been reported, for example, that benzene can diffuse into food from contaminated PET, PVC, and PS packaging. Because benzene has a low molecular weight, it can pass through the packaging substance and into the food. Because benzene is a potentially carcinogenic component, it must be measured in plastic food packaging [11,12].

IV. Migration Testing

The migrating compounds from packaging materials to foods can be quantitatively determined by exposing the packaging material in contact with food for specific time and temperature [11]. These migrants are quantified in terms of specific migration limit (SML) and overall migration limit (OML). The term overall migration limit (OML) refers to the most permissible quantity of non-volatile chemicals that may be released from a product or item into food-simulants. SML means the maximum permitted amount of a given substance released from a packaging material into food or food simulants. Plastic materials and articles shall not release the following substances in quantities exceeding the specific migration limits given under Table 1.

Table 1: Requirements for specific migration limit for plastic materials to be in contact with food products

S.No.	Contaminant	Maximum migration limit (mg/kg)
1	Barium	1.0
2	Cobalt	0.05
3	Copper	5.0
4	Iron	48.0
5	Lithium	0.6
6	Manganese	0.6
7	Zinc	25.0

(Source: Food Safety and Standards (Packaging) Regulations, 2017)

V. Food Simulants

The food simulant is a chemical with characteristics similar to the different food categories (watery, acidic, alcoholic, milk, oil and fat and dry foods). The determination of migration in simulants is to be carried out using the simulants laid down as under Table 2.

Table 2 List of simulants for migration testing

Simulant A	Distilled water aqueous foods with a pH higher than 4.5
Simulant B	3% acetic acid used for acidic aqueous foods (pH below 4.5) such as vinegar
Simulant C	15% ethanol for the production of alcoholic products
Simulant D	Rectified olive oil, sunflower oil for the production of fatty foods

(Source: IS 9845:1988)

VI. Quantification of Overall Migration Limit (OML)

Take the required volume of preheated simulant at the specified temperature in a 1000 ml capacity cylindrical jar. Later immerse the test film (10cm×10cm) completely in the simulant. Place the cylindrical jar covered with a glass plate, and submerge the jar with the specimen in a simulant at the required temperature and time. Upon completion of the test period remove, the sample using a glass rod and wash with a small amount of fresh simulant before being combined with the extractants. By evaporating within a hot plate over low heat, the extracted simulant concentrated to 50-60 ml. The concentrate is then transferred to a clean-tared stainless-steel dish and wash three times with a small amount of fresh simulant before being dried in an oven at 100± 5°C. After cooling in a desiccator for 30 minutes, the concentrate 0.1 mg closest to the weight until a constant weight of residue get into cylindrical jar. The extractive is calculated in mg/dm^2. Blank shall also perform in the absence of a sample. The determination of overall migration shall done by **IS 9845:1998** method as given in equation (1)

$$\text{Amount of extract (Ex)}\ \frac{mg}{dm^2} = \frac{M}{A} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where
M = residue amount in mg,
A = total exposed surface area in cm^2 for each replicate

VII. Legislation

According to IS 9845 and CEC (Commission of the European Communities) all packaging materials made of plastic must pass with no detectable color migration at the prescribed overall migration level of 60 mg/kg or 10 mg/dm^2.

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