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REVIEW ARTICLE

An overview of paper and paper based food packaging materials: health safety and environmental concerns

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Abstract Pulp and paper industry is one of the major sector in every country of the globe contributing not only to Gross Domestic Product but surprisingly to environmental pollution and health hazards also. Paper and paperboard based material is the one of the earliest and largest used packaging form for food products like milk and milk based products, beverages, dry powders, confectionary, bakery products etc. owing to its eco-friendly hallmark. Various toxic chemicals like printing inks, phthalates, surfactants, bleaching agents, hydrocarbons etc. are incorporated in the paper during its development process which leaches into the food chain during paper production, food consumption and recycling through water discharges. Recycling is considered the best option for replenishing the loss to environment but paper can be recycled maximum six to seven times and paper industry waste is very diverse in nature and composition. Various paper disposal methods like incineration, landfilling, pyrolysis and composting are available but their process optimization becomes a barrier. This review article aims at discussing in detail the use of paper and paper based packaging materials for food applications and painting a wide picture of various health and environmental issues related to the usage of paper and paper based packaging material in food industry. A brief comparison of the environmental aspects of paper production, recycling and its disposal options (incineration and land filling) had also been discussed.

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Introduction

Food processing industry selects the packaging material according to food product requirement considering factors like heat sealability, process ability, printability, strength, barrier properties (water, oil and gas barrier), cost-effectiveness, sustainability and legal requirements. Various materials like paper, plastic, glass, aluminium, wood or combination of any of these are used for food packaging depending on their pros and cons. Paper and paperboards encompasses 31% of the global packaging market segment and are most widely used in food packaging for containment and protection of the food products, convenience during storage or consumption and communication of the relevant information to consumers including its marketing aspects (Jones and Comfort 2017). Approximately, 47% of total paper and paperboard produced in the year 2000, was used for packaging applications (James et al. 2002). Paper have environmental friendly tag attached to it which makes it the first choice for food industries (Khwaldia et al. 2010) and predominantly used at primary (i.e. in direct contact with food products) and secondary (i.e. for transportation and storage of primary packages) levels. In particular, paper and paperboard is used for ice-cream cups, microwave popcorn bags, baking paper, milk cartons, fast food containers such as pizza, beverage cups etc.

Plain paper is insufficient for food products because of poor barrier properties, low heat sealability and strength. So, it is impregnated with some additive or laminated with aluminium or plastic to improve its functional properties. An educated person if asked about the food toxic

substances will mention pesticides and other environmental pollutants but to everyone's surprise it is the broad and complex category of food migrants from the packaging material (Grob et al. 2006). Various paper components and additives may migrate into food products and cause severe health hazards in humans depending on the level of migration and consumption (Exposure is expressed as product of migration and food consumption) (Poças et al. 2010). However, the migrants into food are too diverse and their toxicity level also varies which makes the issue more complex (Biedermann-Brem et al. 2016). Printing inks and its components are the major migrants into food which can lead to kidney failure, endocrine disruption and lung cancer (Muncke 2011) but finding an alternative of printing ink is still the leading question.

Inspite of environmental friendly component attached to the usage of paper, still there are environmental concerns associated with paper production and its recyclability. Tons of waste, varying in composition and types is generated from the paper industry at various stages of production, post-usage level, disposal and recyclability. According to United States Environmental Protection Agency (USEPA), corrugated paperboard boxes represented the largest single category of recycled product with 1.9 million tons landfilled in 2015 and overall paper and paperboard packaging containers recycling rate was 78.2% in United States of America. The recovery of waste paper in India is 25–27% as against 70–80% in developed nation. Overlooking this fact further 12% goods and services tax (GST) had been imposed on waste paper in India (Mukundan 2018). Looking at the strict legislations, landfilling and open dumping of waste is not the favorable choice, leading to incineration as the best disposal option for the paper production and recycling industries because of energy recovery involved in it. Pyrolysis, composting, gasification and reuse as building material are alternative disposal options but these process need to be optimized at various steps. Additives used during paper production also interferes during the recycling of the waste paper but recycling is necessary as it reduces pressure on virgin timber for the fresh stock of wood pulp.

Method of paper preparation

The word 'paper' was derived from the plant *papyrus*, which was used by Egyptians to produce the world's first crude writing material. Tsai-Lun of China in 105 AD used the bamboo and mulberry barks for the development of first authentic papermaking process (Smook 2002). However, paper had also been manufactured from cottonseed hair, flax, leaves, sunflower stalk and agricultural waste (Rudi et al. 2016). The raw material used for paper development severely effects its quality because of variation in fibre length and pulp composition. Most of the paper in today's world is prepared from wood pulp of coniferous trees (spruce and pines) found in north temperate zones of North America and Europe. Cellulose, hemi-cellulose and lignin are three main components of wood cell wall. Cellulose possess fibre-forming properties owing to the presence of the straight, long and parallel fibres. Hemicelluloses are responsible for the hydration of pulp and development of bonding during beating process. Lignin is natural binding constituent of wood cells with no fibre forming ability.

Figure 1 shows the various stages of paper preparation process. Pulping is the process of separating wood fibres using mechanical, chemical, thermal treatments or any of these in combination. Lignin is dissolved to produce individual fibres during pulping which can be reformed to paper sheet during paper making process. The solution or the fibres obtained after the pulping treatment is known as pulp. Bleaching treatment is applied to improve the whiteness of chemical and mechanical pulp. Chromophoric groups of lignin are responsible for color of the pulp which are removed during bleaching using chlorine, chlorine dioxide or hydrogen peroxide.

Beating treatment increase the surface area of the fibres thus increasing their water holding capacity and creating additional bonding opportunities for fibres. Refining process is similar to beating process and used for improving the physical properties of the finished sheet. After pulping and beating, stock (fibrous material) preparation stage

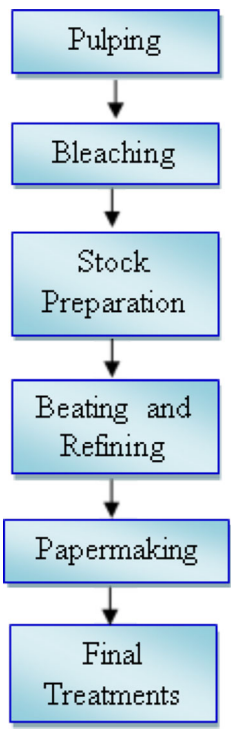

Fig. 1 Flow diagram for paper preparation process

involves the mechanical treatment of pulp for its conversion into a sheet on paper machine. Paper making process involves the use of mainly three different methods: Fourdrinier machine, cylinder machine and twin wire formers. During the paper forming process the fibrous material (containing approximately 99% water) is passed through rollers or wire mesh to remove water and form the paper web.

Final treatments include calendering, supercalendering, sizing, laminating, impregnating or saturating the developed paper as per the requirement of the industry or the product to be packed (Khwaldia et al. 2010). Calendering involves the application of pressure to reorient the surface fibre and smoothens the surface of paper. After calendaring treatment paper is said to be machine finished. Supercalendering is almost similar to calendering but it involves the addition of moisture and more pressure then calendering. Sizing is the process of coating paper with starch, casein, alum, etc. to improve its appearance, barrier properties and strength (Robertson 2013).

Classification of paper

Paper can be classified into the following categories based on numerous parameters.

Based on the grade: Firstly processed paper from raw wood pulp is called as *virgin paper* or *virgin grade paper*. *Recycled paper* is the paper obtained after reprocessing of virgin paper, recycled waste paper itself or their combination.

Based on the smoothness and treatment given to pulp and paper, it is broadly divided into two categories: Papers used for printing, labelling, writing, books etc. are made of bleached pulp and called as *fine paper*, and paper used in packaging of food materials which is made of unbleached pulp are called as *coarse paper*.

According to Food Safety and Standard Authority of India (FSSAI), only virgin grade packaging material should be used for direct food contact (FSSR 2011). Paper for food packaging can be classified into two broad categories (1) based on pulp or paper treatment (2) based on shape and combination of various materials. Wood pulp treatment effects the paper properties and its use significantly. The next section discusses about the various types of paper based on pulp and paper treatment and their use in food packaging.

Kraft paper

German chemist Carl F. Dahl introduced sodium sulfate for pulping resulting in production of stronger paper and was known as Kraft (sulfate) paper after the German word 'Kraft' which means strength. Kraft paper is prepared from the unbleached pulp and it is usually rolled on a core with inside diameter 70–75 mm and in length corresponding to the width of the paper. Kraft paper possess coarse structure and very high strength. Kraft paper is made on a Fourdrinier machine and then machine-glazed on a Yankee dryer or machine-finished on a calender. Calendering treatment is avoided if roughness is required, as stacking of kraft paper bags on pallet with rough surface in contact prevents sliding (Robertson 2013). It is available in three grades namely: Grade 1, Grade 2 and Grade 3.

Grade 1 It is referred as *virgin kraft* by paper industry and made from 100% unbleached sulphate pulp, or from a mixture of wood and bamboo pulp.

Grade 2 Bagasse, rice/wheat straw, grass, jute or a mixture of these with sulphate pulp is used for the preparation of Grade 2 kraft paper or *semi-virgin kraft* paper and also stated as *agricultural residue kraft*.

Grade 3 It may be made from 100% waste paper or a mixture of waste paper and agricultural waste. It is normally referred as *non-virgin kraft* paper by paper trade and industry (IS:SP-7 NBC 2016).

Kraft paper is used for the packaging of flour, sugar, dried fruits and vegetables. Charta Global, a US based firm, had announced the addition of Enza Kraft to its full line of specialty papers. It is machine glazed paper with gloss on one side and bit coarse on one side. The food grade version is United States Food and Drug Administration (USFDA) compliant and certified for food consumables which include sandwich wrapper, biscuit bag, chewing gum wrapper, frozen and non-frozen confection wrapper, salt, pepper, sugar packets and tea pouches (www.chartaglobal.com).

Maxwell and Esse (1989) patented a dual food compartment package containing corn kernels to be popped by microwave energy in one compartment and additives such as flavoring component in second compartment. The dual package consisted of metallized film for conversion of microwave energy to heat energy, sandwiched between the layers of kraft paper and glassine paper indicating the use of paper in microwaveable containers for food.

Bleached paper

Johan Richter, an engineer and industrialist from Norway invented the continuous process for continuous bleaching of paper pulp. Bleaching is the chemical process done using chemical agents such as chlorine, chlorine dioxide, hydrogen peroxide, ozone etc., mainly to improve the whiteness and brightness of the paper. Kappa number is an index for bleaching ability of wood pulp or indicator of residual lignin. Lower kappa number indicates the use of less amount of chemical for bleaching of the pulp (Correia et al. 2014). Bleaching reduces the strength of paper

making it soft, expensive and white, and used when focus is on appearance rather than its strength. The appearance of bleached paper for food applications can also be augmented by clay coatings (Robertson 2013). However, the bleaching have adverse environmental effects leading to release of harmful chemicals into waterways. However, an eco-friendly approach had been developed for bio-bleaching of paper pulp using ligninolytic enzymes including xylanase, laccase and manganese peroxidase (Saleem et al. 2018). Bleached kraft paper is used for flour, sugar, and fruits and vegetables.

Wrapping tissue paper or tissues

According to IS 8460 (1999) specifications, wrapping tissue paper is of two types namely: Type A—ordinary tissue and Type B—neutral (non-tarnish) tissue. The grammage of wrapping tissue paper shall not exceed 25 g/m^2 with a permissible tolerance of ± 1.5 g/m^2 (IS:SP-7 NBC 2016). Food grade tissue paper is mainly used as bakery product liner, sandwich wrap and box liner. The tissues are widely used for tea and coffee bags which is derived from Manila hemp owing to its porosity, light weight and long fibres (Macarthur and Hemmings 2017). Wrapping tissue paper should not be confused with absorbent tissues used for absorption application as they are prepared using other type of pulp. Ornamental design for tissue paper with embossing pattern had recently been patented by Barran and McCormick (2018).

Greaseproof paper

Greaseproof paper is translucent and hydrated to give oil and grease resistance. The production of greaseproof paper involves prolonged beating of the pulp which breaks down the cellulose fibres enhancing their water absorbtion capacity and finally leading to their superficial gelatinization and stickiness. This phenomenon of hydration leads to the formation of paper web with interstitial gaps and its performance depends on filling of these interstitial gaps. Lesser the number of interconnecting pores between the fibers, the passage of liquid through greaseproof paper becomes difficult. Water hyacinth (*Eichhornia crassipes*) consist of very long fibres and considerable amount of hemicellulose allowing its utilization for the preparation of greaseproof paper. Goswami and Saikia (1994) tried water hyacinth pulp and bamboo pulp in various ratios of 75:25, 80:20 and 90:10, which possessed satisfactory greaseproof properties. Research work had also been conducted for the development of greaseproof paper from banana (*Musa paradisica L.*) pulp fibre. Gums and pentosans inside the sheaths of *Musa Paradisica* imparted greaseproof properties (Goswami et al. 2008). Kjellgren et al. (2006) impregnated chitosan coating of 5 g/m^2 on grease proof paper using metered size press technique resulting to negligible carbondioxide and nitrogen permeability. Plastisol coatings of starch-PVOH on greaseproof paper decreased its water vapor transmission rate (WVTR) significantly (Jansson and Järnström 2006).

According to Bureau of Indian Standards (IS: 6622-1972), the greaseproof paper shall be evenly machine finished with uniform thickness and free from any offensive odour, visible cuts and holes. The paper should have a burst factor of minimum 20 and tear factor in any direction should be 30. Oil transudation time (measure of grease or oil resistance) should be minimum 1200 s and minimum grammage of 35 g/m^2 (IS:SP-7 NBC 2016). Greaseproof paper as the name suggests is impermeable to fats and oils but for a certain interval of time, still they are predominantly used for packing butter and other fat containing food products (Marsh and Bugusu 2007). Greaseproof paper can also find its application as an embodiment or inner liner of the microwave double bag food container with outer layer comprising of paper and integral microwaveable heating element (Hartman et al. 1991).

Glassine paper

Glassine paper is upgraded version of greaseproof paper in which extreme hydration had been performed to develop a dense sheet with high density, transparency, smooth and glassy surface. These set of properties are produced by supercalendering the greaseproof paper where it is wetted by water and pressed in a series of steam-heated rollers. This results in such intimate inter fiber hydrogen bonding that the refractive index of the glassine paper approaches 1.02 times of amorphous cellulose, indicating that very few pores or other fiber/air interfaces exist for light scattering or liquid penetration (Yam 2009). The opacity of the paper can be increased by addition of titanium dioxide and it is also affected by the level of pulp hydration and grammage of the paper. Toughness of the glassine paper can be upgraded by addition of plasticizers (Zhu et al. 2014).

Moisture proofed glassine paper was claimed to be developed using a copolymer coating of vinyl halide and maleate ester. Lamination of glassine paper with amorphous or resin wax tends to make it less pliable causing a ripping sound when two sheets are separated. Amorphous wax (83%), polymerized resin (12%), heavy viscous liquid polybutene (3%) and butyl rubber (2%) was suggested for satisfactory lamination of glassine paper. This lamination process also improved the moisture vapour barrier property as compared with amorphous and resin wax lamination (Fisher and Borden 1952). Surprisingly, glassine paper had been used as a water permeable layer in the development of

contact dehydrating sheets for drying of product containing protein such as fish and meat (Numamoto and Kasai 1983).

Glassine paper finds its use as a liner for baked goods, biscuits and cooking fats. It is mainly used as release liner in meat and baked goods as it facilitates the separation of individual pieces of food products. Glassine paper and kraft paper had been listed in approved packaging materials for the irradiation exposure of up to 10 kGy gamma irradiation for sterilization of either food packed or the packaging material itself in FDA document 21CFR 179.45, subpart C (Haji-Saeid et al. 2007).

Vegetable parchment paper

Vegetable parchment paper production process was developed in nineteenth century, firstly used for wrapping butter followed till today and physically similar to *vellum*, which is made from animal skin. Various species of flax (*Linum vistatissimum* L.,) had been used for making fine parchment paper in Northern America (Berglund 2002). The development process includes transition of chemical pulp having a web of non-uniform, high quality fibres through a concentrated sulfuric acid solution. The acid treatment results in partial solubilization and swelling of cellulosic fibres, filling the interstitial spaces between the fibers and excessive hydrogen bonding. Acid treatment is followed by washing in water, passage through conventional paper dryers. These treatments unites the paper network creating a paper having appreciably excellent wet strength, free of off-flavours and oil resistant (Yam 2009). The stronger and durable parchment paper with uniform transparency had been claimed to be produced by treating it with glycerine and water solution in 1:4 ratio (Pauley et al. 2005). Parchment paper is non-heat sealable having more wet strength with poor barrier to gases unless coated. Parchment paper with great shock-absorbing capability can be produced by wet creping, resulting in extensibility and natural tensile toughness. Special finishing processes provide qualities ranging from rough to smooth, brittle to soft and sticky to releasable. Glazed imitation parchment (GIP) paper is made from strong sulfite pulp, which is heavily sized and glazed to give the necessary degree of protection.

Vegetable parchment paper is extensively used as a layer between slices of pastry or meat because its grease resistance and wet strength properties makes it easily removable from food contact surface. Labels and inserts for products with high oil or grease content are often made from parchment paper. High fat containing cheeses coated with food grade mold inhibitors can also be wrapped with vegetable parchment paper (Ribeiro et al. 2016).

Waxed paper

Waxed paper as the name suggests is any suitable paper as base material on which wax had been coated to improve its barrier property against liquid and gases. The extent of barrier to liquid and gases is directly proportional to the amount of wax. Fibers act as path for moisture movement into paper which is inhibited by wax application. Wax layer not only acts as an adhesive but also provide heat sealability. Wet-waxed, dry-waxed and wax-laminated are the different grades based on the thickness of wax coating. When the wax is augmented on the base paper surface during the beating process of paper making, the coating is least thin leading to lower protection. *Wet waxed* paper is obtained by rapid chilling of the applied wax web leading to the formation of a continuous layer of wax on both sides and high degree of glossiness. Contrarily, paper with discontinuous layer of wax are obtained by use of heated rollers and called as *dry-waxed*. Wax usually cracks at lower temperature and also due to folding of paper thus hampering the barrier properties which is overcome by use of resins or plastic polymers (Mir et al. 2017). Bread, biscuits, dairy products (UHT milk and cream), sandwich, cakes, sunflower oil and breakfast cereals are most commonly packed using waxed paper. Waxed paper containers are extensively used for distribution and consumption of fruit juices and milk.

Sulfite paper

Sulfite paper is light weight and weaker as compared to kraft paper. It is often glazed to improve its appearance, wet strength and grease resistance. Plastic and aluminium foil can be laminated on it for better performance. Small bags or bindings for packaging confectionary and bakery products are of sulfite paper (Raheem 2013).

Paperboard

The major difference between paper and paperboard is of grammage with paperboard having a grammage of more than 250 gsm (gram per meter square) (Robertson 2013). Paper board are generally having multiple layers with more thickness than paper. Boards can be manufactured in a single Fourdrinier wire, a single cylinder former or on a series of formers of the same type or their combination (Smook 2002). The 3D forming technique could be used for advanced designs of paperboard packaging material overcoming the failure of deep drawing method (Hauptmann and Majschak 2011).

Newspapers and other inexpensive low grade waste papers can be used in the internal structure of paperboards, thus creating an inexpensive alternative use of paper.

However, for food grade applications only virgin grade paper can be used thus eliminating multi-ply boards containing newspaper and other recycled paper from food contact applications. Multi-ply boards consists of two or more plies compacted into a single paper-board which is further used for making rigid boxes, milk and juice cartons. Ventilated box design of paperboard is used for the transportation and storage of fruits and vegetables (Fadiji et al. 2016).

The various types of paperboard materials are as follows:

Linerboard consist of 100% virgin pulp, top layer prepared using Fourdrinier machine and a second lower layer of low quality as compared to top layer.

Foodboard made from 100% bleached virgin pulp for food packaging, available as single or various layer of plies.

Folding boxboard Multiple plies with outer layers of virgin chemical pulp and inner layers of mechanical pulp, used for making folding boxes.

Chipboard multiply board made from 100% recycled paper and often contains impurities like inks of original paper, thus hindering its usage from direct food contact surfaces. Chipboard is one of the inexpensive paperboard whose appearance and strength can be improved by using white board as a liner and mainly used in cartons of tea and cereals as outer layers.

Baseboard mainly used as a base layer which is coated with some additive.

Whiteboard Bleaching treatment is given to improve the whiteness and mainly used as inner layer of food cartons. The heat sealability can be achieved by coating with wax or laminating with a thin layer of polyethylene.

Solidboard Sulfate pulp is mainly used for solid board on account of its strength and durability. Solid board can be used for packaging of milk, fruit juice and soft drinks when laminated with several layers of polyethylene to improve its barrier properties and heat sealability (Smook 2002).

Newspaper as food packaging material

Newspapers are used for providing cushioning effects to fruits and vegetables, covering the food products to prevent their exposure to environmental pollutants and even to wrap freshly made roti/chappati (Biedermann and Grob 2010). The use of newspaper based packaging material for wrapping, packing and serving food is most common practice in India. It is one of the food safety hazards, especially in the context of street foods. When it comes to eating street food, we often spend a lot of time worrying about its safety and ignore the way it is packed in Paschke et al. (2015). Odds are that the food we buy from street vendors are mostly wrapped in a newspaper.

Various types of paper and their use in food packaging had been discussed in detail in previous section. Figure 2 shows paper and paper based material of varying shape and sizes used for food packaging application. The paper material discussed are constructed in various shapes or combined in multiple layers with plastics to improve their use and properties which will be discussed hereafter.

Paper bags

The premiere use of paper bags had been reported in 1630 for 'grocery carry use'. Paper bags are available in different forms and used mainly for 'carry out' and 'carry home' applications in daily use at point of sale (Kirwan 2005). Various types of paper like grease resistant, kraft paper, recycled kraft, coated papers, wax impregnated, laminated etc. are being used for manufacturing paper bags. Paper bags are available in different forms such as flat and satchel, self-opening satchel (SOS) bags, strip window bags etc. Recently, research studies had been conducted for the use of lignocellulosic micro/nano fibres from sawdust with recycled cardboard for the production of paper bags (Tarrés et al. 2017).

Composite cans

A composite can is a linearly drawn rigid structure and spirally or convolute bound with one or both end openable or permanently fixed. Initially, it was available only in round shape but to influence consumers with package design various unique shapes like oval and rectangular are available in the mega stores (Romaine 2005). Paper especially kraft type is the major layer in composite cans with polypropylene, high density polyethylene (HDPE) and aluminium as layer for enhancement of its properties. Food applications include containers for refrigerated dough, snacks (*Pringles*®, *Planters*), frozen fruits, dried fruits, nuts, chips, powdered foods, dried meats, chips, salt/spices, cookies/crackers, solid/liquid shortening, refrigerated dough (*Pillsbury*®) and confectionary products. Composite cans made up of aluminium foil, paperboard and polymer are predominantly used as replacement of metal cans for milk powder packaging (Karaman et al. 2015).

Fibre drums

Fibre drums are large sized cylindrical containers having paperboard based side walls and end components made up of metal, plywood or paperboard itself. They are mainly

Fig. 2 Paper and paperboard based packaging materials used for food packaging application, **a** biscuits packed in paper based boxes, **b** egg crates, an example of moulded pulp packaging material, **c** paperboard based rigid box containing traditional Indian dairy sweet *Burfi*, **d** ice-cream cone, **e** vegetable parchment paper containing butter, **f** corrugated fibre board, **g** composite cans containing crackers, **h** fibre drum

used for bulk dispensing of food products due to their high strength and protection they offer to the food products during transportation. It is used for carriage of dry powders, pastes and semi-liquid food products (Foulds 2017).

Multiwall paper sacks

Multiwall paper sacks are light weight and biodegradable concentric tubes of 2–6 layers of paper with various types of end closures like open mouth, pasted, flat, sewn and gusseted. They are used for bulk packaging of flour, potatoes, dried milk, coarse flakes, grain, sugar etc. weighing 5–50 kg. Approximately 704 million units of paper sacks were utilized for food products by European end-users in 2001 (Martins and Cleto 2016).

Rigid boxes

Rigid boxes are made of paper and paperboard with thickness varying between 1000 and 2500 microns, grammage 400–1600 g/m^2 and gelatin glues as adhesives. Rigid boxes are based on lift-off-lid mechanism and ready to fill when procured from the manufacturers. It is available in various shapes like square, rectangular, round, elliptical etc., and designs like shell and slide (drawer), bookstyle, fliptop, tray and lift off lid. Rigid boxes are mainly used for packaging of chocolate confectionary and other bakery products (Geldenhuys 2016). However, Indian food industry is most extensively using it for packaging of traditional Indian dairy products like burfi, peda, milkcake, gulabjamun, kalakand etc.

Folding cartons

Cartons are the boxes made from sheets of paperboard (thickness varying between 300 and 1200 μ) and available in various shapes and sizes as per market requirement. Majorly folding cartons are used as secondary packaging in wholesale market during transportation of multipacks of food items. Folding cartons are cut in desired shapes, delivered in collapsible states and erected at the point of packaging (Obolewicz 2009). The folding cartons are also used at tertiary level of packaging i.e. for containing secondary containers of bakery and confectionary products. Reconfigurable robotics system had been developed for the automatic folding of the cartons looking at their increasing usage in food and beverage industry (Yao et al. 2011).

Corrugated fibreboard (CFB)

The raw material for CFB is mainly kraft paper however agave bagasse, by-products from the tequila industry had also been used for the fibreboard production (Iñiguez-Covarrubias et al. 2001). Corrugated fibreboard usually

consists of two or more layers of flat kraft paper (liner) and layers of corrugated material (flute) is sandwiched between the flat layers to provide cushioning effect and abrasion resistance. Fluted material is developed using corrugator which involves passage of flat kraft paper between two serrated rollers, followed by application of adhesive to the tips of corrugations and liner is stuck to the corrugated material using pressure (Kirwan 2005). If it is having only one liner, it is single wall; if lined on both sides than three ply or double faced and so on. According to Bureau of Indian Standards (IS 2771(1) 1990), A (Broad), B (Narrow), C (Medium) and E (Micro) flute types had been defined. A type of flutes is used when cushioning properties are of prime importance, B type is stronger than A and C, C is compromise of properties between A and B and E is easiest to fold with best printability (IS:SP-7 NBC 2016). Food packaging singly utilizes thirty-two percent of total corrugated board in European countries and forty percent if beverage packaging segment is also included (Kirwan 2005). It is used in direct food contact surface mainly for fruits and vegetables, where all grades of waste paper can be used as internal layers but the specified requirement on the level of pentachlorophenol (PCP), phthalate and benzophenone had to be fulfilled.

Compartment based CFB cartons are typically used for multipacks of yoghurt cups of polystyrene. Meat, fish, pizza, burgers, fast food, bread, poultry and French fries can be packed in fibreboards (Begley et al. 2005). Fruits and vegetables can also be packed for supply to markets on daily basis.

Paperboard based liquid packaging

The earliest attempts of the paperboard based liquid food packaging dates back to 1915 where John Wormer of Ohio patented a 'paper bottle' which he referred to as Pure-Pak®. It was a folded carton which was used for packaging of milk in those days and followed till date for domestic sale plus exports. Later, various advances were made in paperboard based liquid packaging and today it is extensively used for packaging of milk, cream, juices, wine products, mineral water, cooking oil, soups, freeze dried vegetables under prestigious brands and in varying shapes like gable-top, pyramid, brick, pouch and wedge (Kirwan 2005). The product packed in paperboard containers under sterilized surrounding conditions possess longer shelf-life due to sterilization treatment given to both product and packaging material. Tetra Pak® is most promising brand for paperboard packaging material and its milk pouches consists of six layers including polyethylene and paper, with paper contributing approximately 70% of total packaging material used in a single pouch (Lokahita et al. 2017). Tetra Pak® sold 180 billion packs globally in 2017 and adding billion packages a year (https://www.tetrapak.com/) which indicates the prevalence of paperboard based liquid packaging.

Moulded pulp packaging

As the name suggests, moulded pulp packaging is made from water and fiber mixture which is moulded in varying attractive shape by pressing and drying of the pulp solution. The raw material consists of 96% water and 4% fiber with some waterproofing agents such as wax and resins. Some of the premier examples of moulded pulp packaging in food industry is egg trays, fruits and vegetables trays used mainly to provide cushioning effect to the product and preserve their delicate structure during transportation. Clam-shell style containers of moulded pulp packaging is used for closed packaging of eggs and bottles (Didone et al. 2017). Pulp moulded material containing up to 80% wheat straw possessed better tensile properties and biodegradability than expanded polystyrene (EPS), which is non-characteristic of EPS (Curling et al. 2017).

Paper labels and adhesives

Labels are used in food industry mainly for identification of the food commodities, declarations regarding nutritional information, health claims, bar code, manufacturer's information, instructions for use, expiry date and quantity of the product. Letterpress printing, lithography, flexography, gravure and stamping process are extensively used for printing of information and pictures on paper labels. Paper labels are attached to food packets or containers in forms of wet glue paper labels, gummed paper labels and self-adhesive labels. Innovative labels had been used in food industry which indicates the tampering of the product thus safeguarding the food (Kirwan 2005).

Adhesives are most commonly used in packaging industry for sealing of folding cartons, laminating paper to paperboard and labelling of food containers. Until 1940s, naturally derived materials such as paste, glue etc. were used as packaging adhesives. Presently, starch and casein based adhesives, natural rubber latex, polyvinyl alcohol emulsion, petroleum wax in combination with polymers and tackifying resin are used as adhesives. Glued-on, self-adhesive (pressure sensitive), in-mold and sleeve labels are most commonly used for any type of food container including bottles and metal cans (Robertson 2013).

Paper is considered as innocent packaging material in terms of its adverse environmental impact and human health concerns. However, the situation is totally different as the wastewater from paper and pulp industry, migrants from packaging material into food and several issues related with its disposal method depicts the clear picture.

The adverse health and environmental impact of paper industry are discussed henceforth.

Health effects and safety issues of packaging migrants

During the preparation of paper and paperboard from pulp or recycled materials various types of additives are added to gain better properties in the final product. Various processes like pulping, bleaching, digestion and final treatments (sizing, converting and calendering) involves the use of numerous chemical additives which may interact with food materials hence, causing adverse health implications in the humans. The migration of all the substances from the packaging material into food is referred to as *overall migration* while migration of a particular substance is referred to as *specific migration*. According to European Union 2002/72 guidelines the maximum limit of overall migration from packaging material to food is 60 mg/kg. However, for smaller containers less than 500 ml, plastic films and non-fillable materials the limit is 10 mg/dm^2. The chemical additives are low molecular weight volatile and non-volatile, either added directly to the pulp or applied as coating during final treatments (Bradley et al. 2013; Trier et al. 2011). These chemical additives can be broadly categorized as processing aids, assisting during the preparation process and functional additives, enhancing the properties of the finished material. Some of the major additive migrants from paper and paperboard are mineral oils, dyes (organic, inorganic and synthetic), phthalates, adipates and polyfluorinated substances (Fierens et al. 2012). Recycling of the paper and paperboard does not eliminate these additives, however mineral oil presence above threshold level had been reported by Biedermann and Grob (2010).

Migration studies had been conducted by several researchers regarding the migration of mineral hydrocarbon wax from waxed paper onto food surface. Migration of the wax increased at higher temperatures. Bread samples outer layer contained up to 50 mg/kg. Toffee products contained 110–1300 mg/kg and wrapped sweets contained 12–1300 mg/kg level of mineral hydrocarbon on product surface (Castle et al. 1993; Castle et al. 1994). Polyfluorinated surfactants (PFS) are most widely used for imparting oil and water resistance to paper and paperboard. PFS with molecular weight of more than 3600 g mol^{-1} and their oxidation products are toxic and cause endrocine disruption. Microwavable popcorn, burger box, rye bread mix, coffee, noodles, chocolate cake and curry chicken with jasmine rice contained in paper bag or cardboard boxes were found to contain PFS, which is of serious concern (Trier et al. 2011). Bisphenol A and its emerging structural analogue Bisphenol S is used as color developer on thermal receipt paper, commonly found attached to food packets and food cartons in mega retail food stores (Pivnenko et al. 2018). Bisphenol A causes endocrine disruption and had been proposed to be banned from its usage in thermal paper from 2020.

Recycling of paper is promoted in preview of sustainability and environmental concerns. However, recycled paper and paperboard based food containers had been considered as the major culprit for migration of mineral oil into food products. Hydrocarbons containing up to 20 carbon atoms (n-C_{20}) migrate into food products within few weeks and hydrocarbons with 20–28 carbon atom (n-$C_{20–28}$) at a decreasing rate. The major source of mineral oil had been attributed to inks with printed recycled board containing 300–1000 mg/kg mineral oil ($<$ n-C_{28}). However, the upper limit for daily intake of $<$ n-C_{28} had been fixed at level of 0.01 mg/kg body weight by JECFA (Joint FAO/WHO Expert Committee on Food Additives) (Biedermann and Grob 2010). The migration level of organic pollutants from recycled paperboard was dependent on volatility of migrant and composition of recycled paper. Migration level was found directly correlated with fat content in food (Triantafyllou et al. 2007). A study conducted by Gartner et al. (2009) showed that infant foods packed in recycled paperboard boxes with coated paper liners were contaminated with diisobutyl phthalate and di-n-butyl phthalate. A few samples contained diisobutyl phthalate at levels exceeding European Commission's limits for food contaminants indicating the inefficiency of paper as a barrier against migration of phthalates.

The ink used in newspaper had been reported to cause lung cancer among workers exposed to ink mist during rotary letter press technology of newspaper printing as per a study conducted in Manchester, England. The carcinogenicity of newspaper ink had been co-related to the solvent extracts of carbon black, which contains polyaromatic hydrocarbons such as benzo(a)pyrene. Benzo(a)pyrene particles get adsorbed on the surface of the carbon black particles (Leon et al. 1994). Naphthylamine, benzidine, benzophenone and 4-aminobiphenyl found in newspaper and other recycled paper are the major risk factor for bladder cancer with risk being proportional to exposure levels. Benzophenone had been reported as the major endocrine disrupting chemicals in infants and pregnant women (Muncke 2011). Approximately 20 printing ink compounds were found in three hundred and fifty samples of food items (cheese, cherry pie, tea, walnuts, chocolates, pancakes etc.) packed in paper and paperboard. Benzophenone (37 samples) and benzoylbenzoate (26 samples) were found to occur in highest number of United Kingdom market food samples (Bradley et al. 2013). High fat chocolate packed in direct contact with carton board at room temperature contained 7.3 mg/kg of benzozphenone

(Anderson and Castle 2003). Migration of benzophenone derivatives was found to be highest in cakes followed by bread and rice (Rodríguez-Bernaldo de Quirós et al. 2009).

Environmental concerns and approaches: paper production and recycling

The pulp and paper industry is world's third largest consumer of water and fifth largest consumer of energy for their manufacturing process. The Indian paper industry with approximately 13 million tons of paper production accounts for about 3% of global paper production. The domestic paper consumption in India during 2014–2015 was 13.9 million tons and may increase to 20 million tons by 2020 (Mukundan 2018). From pulping to paper making process, large amount of fresh water and energy are consumed and consequently generates high amounts of waste and pollution. The major environmental impact of paper development and recycling is energy consumption of paper systems, waste and wastewater generation, toxic emissions, resource consumption (biotic and abiotic), global warming, ozone depleting potential etc. During the paper production process various types of waste are generated, which affects both the economics of paper mills as well as raises the environmental concerns. The waste generated from the paper industry can be divided into two broad categories: (1) pulp mill wastes (2) paper mill wastes.

From pulp mills

The waste from pulp mills consist of wood residues, lime mud, dregs, waste water and chemicals depending on the type of raw material and method utilized (Kamali et al. 2016). Rejects in the pulp mills consists of sand and undesirable wood residues generated during wood handling. These wood residues are generally having low moisture content and can be used in boiler. Lime mud, dregs and green liquor sludge generated during the chemical recovery cycle could be dried and landfilled. Wastewater and chemicals used in pulp mills could be treated and converted into sludge. Kraft pulp mill sludge (pulp residues and ash generated during pulping and paper making) had been converted to ethanol, acetone and butanol by saccharification and fermentation process using cellulose enzymes (Spezyme CP) and recombinant *Escherichia coli* (ATCC-55124). Ethanol yield in the range of 75–81% had been reported depending on the concentration of carbohydrates (Guan et al. 2016). These suggested disposal methods of pulp industry waste could be helpful in reducing the adverse environmental effect.

From paper mills

Rejects found in the paper mills are of varied nature including fibres, staples, metals form ring binder, rubbers bands, sand, glass and sizing agents. Deinking process of paper generates waste consisting of fines, coatings, fillers, ink residues and deinking additives (Monte et al. 2009). During the various processing stages of the pulp and paper industry, water is required which later had to be treated in proper ways to make it fit for re-use or drainage (Krigstin and Sain 2006). The discharges of wastewater during the production of virgin paper are more polluted than from recycling process. During the bleaching process free chlorine usage had ceased but chlorine dioxide being used have adverse effect on ozone layer (Villanueva and Wenzel 2007).

Recycling of paper and paper wastes

Recycling of paper refers to the reutilization of recovered paper after proper processing in form of new paper or other paper based products (Ervasti et al. 2016). Recycling of paper reduces the carbon footprints and recycling a single newspaper can save 41,000 trees from being cut down. A virgin grade paper can be recycled maximum 6–7 times as during recycling fibre length keeps on getting reduced. The mass of recycled paper required during paper development increases in every recycling cycle due to decreasing fibre length. Recycled paper can never match the quality of virgin paper therefore a balance of virgin and recycled paper had to be maintained (Villanueva and Wenzel 2007). When recycling of waste paper is increased, raw materials i.e. wood, forest and biomass could be used for other purpose. A study by Wang et al. (2013) reported bioethanol production from waste paper including newspaper and cardboard to be more economically viable than petrol at pump prices (reference to UK petrol prices in year 2009). European community legislation in 1994 had set targets to increase recycling of paper and paperboard under the Directive on Packaging and Packaging Waste (94/62/EC) reflecting the importance of paper recycling (Elfithri et al. 2012). However, there had been debates among researchers and policy framers about the approaches for the recycling of the paper and paperboard based product.

Incineration and land filling are the major alternative approaches other than recycling for the paper and paperboard based packaging material. Incineration is most widely used disposal method in Europe for almost every type of sludge. Energy from paper and paperboard, in form of heat and electricity can be reutilized via incineration owing to high heat value of paper and paperboard. Landfilling could be a better option but groundwater contamination due to leaching and emission of methane leads to

global warming. However, the methane emissions is greatly reduced during other disposal options like composting and incineration (Virtanen and Nilsson 1993).

Energy consumption and waste generation (*paper production vs. recycling vs. incineration vs. landfilling*)

During the production of paper and paperboard huge amount of steam and electricity is involved which cannot be overlooked. Production of virgin paper utilizes the maximum energy followed by recycling and incineration considering the fact of energy recovery from incineration. Energy recovered from equivalent volume of paper by incineration was 2.6 gigajoules per tonne (GJ/T) as compared to 26.2 GJ/T of energy from paper fuel (Morris 1996). Landfill process can also generate energy by recovery of generated methane and indirectly contributing to global warming reduction. Recycling requires less energy because of no requirement of refining while virgin paper production require energy for harvesting of wood, pulping, refining and drying. Adverse environmental impact of recycling in terms of energy are less as compared to virgin paper production.

Waste generation comparative study shows lower waste generation during recycling as compared to incineration with latter process generating inorganic chemicals such as slag, ash and desulphurised gypsum. Waste generated during landfilling is approximately 10% lower as compared to incineration considering equivalent paper volume. During landfilling toxicity is generated from leaching of toxic components into soil. Recycling scenario is considered to be more environmentally friendly as incineration leads to generation of more toxic components. Waste water generated during virgin paper production have higher COD (Chemical Oxygen Demand) than waste water of incineration. Recycling versus Incineration elucidated that in most of the factors recycling is more favorable than incineration (Villanueva and Wenzel 2007).

Conclusion

Paper and paper based material usage in food packaging is increasing day by day in form of primary and secondary packaging, but its adverse health and environmental impact could not be overlooked. Recycled paper and paperboard does not fulfill the requirement for direct contact food packaging applications because processing and functional additives like mineral oil, phthalates etc. migrates from the recycled paper into food products. However, the use of recycled paper is necessary to maintain sustainability of natural resources. Strict legislation and better policies need to be developed for the migration limits of toxic chemicals into food, disposal techniques to be followed and usage of recycled paper for food packaging applications. Similar to plastics identification codes, paper identification code depending on the material used, additives incorporated, number of recycling treatment could be developed. Recycling and better disposal techniques can be alternatives for sustainability but waste reduction and usage minimization will be the best choice. Industries could be given incentives in terms of tax benefits for recycling and waste reduction. Research studies for the types and amount of migrants into various food products form varying types of paper and paper based packaging materials could be undertaken.

Compliance with ethical standards

Conflict of interest Authors declare that there have been no conflict of interest.

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