Packaging of dairy products: an overview

SeungRan Yoo
World Institute of Kimchi, Gwangju 61755, Korea

Abstract

Dairy products, including milk, cheese, cream, yogurt, and butter, constitute excellent sources of essential nutrients such as calcium, proteins, and vitamin D; therefore, nutritionists recommend a constant daily dietary intake of dairy products. Packaging is an important feature that ensures high-quality products are delivered to consumers; different packaging materials and forms are required depending on the products. Packaging forms include pouches for butter, cheese, and milk powder; cartons for liquid, frozen, and coagulated milk; packets for pasteurized liquid milk; bottles for milkshakes and other liquid products; and cups for frozen and coagulated products. The increase in mobile lifestyles among consumers will lead to smaller households and greater preference for convenience, which will promote individual and smaller packaging for dairy products. This article reviews the development of packaging materials and forms, packaging requirements, and future considerations for the packaging of dairy products.

Keywords: packaging, dairy product, milk, cheese, yogurt, butter

1. Introduction

The current global usage of dairy product packaging consists of 27% plastic bottles, 43% cartons, 23% plastic pouches, and 7% glass bottles and other types of packaging. The choice of packaging material is dependent on the type of dairy product. The main materials currently in use are glass; coated paperboard cartons; and plastics, including high-density polyethylene (HDPE), polycarbonate (PC), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC), and polyethylene terephthalate (PET).

PS constitutes a significant share of the dairy packaging market, because it exhibits rigidity, excellent printing characteristics, surface gloss, and the ability to be colored, opaque, or transparent (Soroka 2002). The major application of PS in the dairy industry is the production of containers for yogurt, cream, cottage cheese, and ice-cream (Tawfik & Huyghebaert 1998).

PP is a low-cost material exhibiting rigidity, tensile strength, excellent moisture barrier properties, and a higher softening point, which is beneficial for hot-filling. PP is the major component of most injection-molded, thin-walled containers such as those used for butter, margarine, and yogurt (Soroka 2002).

Cartons, which consist of paperboard coated with plastics such as PE, have been used traditionally and are still highly prevalent in dairy markets. The paperboard component of cartons provides rigidity, mechanical strength, and a barrier against light, while the plastic coating ensures waterproofing. HDPE is the second most commonly used plastic in the packaging industry. The demand for HDPE equaled 17% of the world's consumption of polymers, a total of 157.4 million metric tons (Liu 2014). In addition, HDPE is widely used for dairy products, especially milk, since it is highly cost effective, durable, versatile for design, and lightweight. The translucent containers produced from the original resin are beneficial for preventing UV irradiation; pigments and/or UV protection additives can be added to HDPE resins to enhance the quality of the products (Dairy foods 2001).

Currently, both clear and pigmented PET with or without UV blocker additives are used (Cladman et al. 1998; Papachristou et al. 2006). PET is one of the main materials used for milk and other dairy products in a number of countries because of its advantageous properties. Over 40% of the pasteurized milk in Italy, approximately 30% in Greece, and 50% in Croatia are packaged in transparent PET bottles (Sidel et al. 2008). PET has also been used for other dairy products, for example, the PET stretch blow-molded containers manufactured by Nestle UK (Connolly 2008).

The transparency of PET is greatly attractive to consumers who want to be able to see the fresh dairy content inside the container. Clarity equivalent to glass provides an image of fresh premium quality and is reminiscentoftheglassmilkbottlesusedinthepast.Inaddition, thesuperioroxygen-barrierpropertyofPETpreventsoxidatio nandthelossofflavoranditsexcellentmechanicalpropertiespr ovidesturdinessandtensilestrength(Cladmanetal.1998; Papachristou et al. 2006). In addition, the reduced weight of PET bottles (28 g) is competitive with the 32 g HDPE bottle widely used for dairy products (Mohan 2003), since it reduces costs and packaging weight. The addition of pigments or UV blocker additives to PET decreases the adverse effects of light. In addition, the easy opening and re-closing without leakage is a convenient feature of PET bottles suitable for the modern way of life. PET bottles are non-reactive and free of any plasticizer or added stabilizers; therefore, there are no concerns regarding reactions between PET and the dairy products and the transmission of plasticizers and stabilizers into food (PETRA 2006). Based on these characteristics, the use of PET is predicted to become increasingly popular in the dairy industry.

The dairy product packaging industry is conservative; consequently, only moderate change is expected in the future. Single serving packages are gaining in popularity because of the move towards individual and smaller packages promoted by mobile lifestyles and the increasing number (32% between 2000 and 2005) of smaller households (Sidel et al. 2008; Duncan 1998). Aseptic and modified-atmosphere packaging technologies will satisfy some of the future trends in the dairy industry. Therefore, the packaging materials and processes used by these technologies require further investigation.

The interest in biodegradable packaging materials is increasing because of environmental issues. PP and PS are widely used for dairy product packaging. Unfortunately, these materials are not recycled in most places; therefore, HDPE and PET could provide good alternatives to replace PP and PS although several technical challenges remain.

Aluminum cans could constitute a possible packaging option providing a longer shelf life (up to a few months). The Dairy Farmers of America (DFA) and The Coca-Cola Company have developed canned chocolate milk that was test marketed in Florida in 2003. The cans are filled with milk, pressurized with liquid nitrogen gas, and sealed with aluminum. Previous studies have shown that a longer shelf life may reduce the return of expired products and that canned milk can be stored at room temperature.

2. Milk Packaging

Milk is one of mankind's oldest and most basic foodstuffs. Initially, local dairies sold milk transported in copper tubs that was ladled into containers left on customers' doorsteps (Jenkins & Harrington 1991). Glass packaging materials in the form of 0.9-liter bottles were subsequently introduced and used almost exclusively until the 1950s. Glass provides advantages such as transparency, good preserving qualities, 100% recyclability, and the ability to be designed for refilling. However, its relative fragility and higher weight, which incurs higher transport costs, are disadvantageous. The decline in home delivery to <30% and the increase in supermarket shopping reduced the use of glass milk bottles to 40% by 1965; the use of glass packaging materials for liquid milk has since been nearly eliminated in North America (Sacharow & Griffin 1981).

In the late 1940s, wax-coated paperboard was introduced in the U.S., and it attracted consumers because it was lightweight. However, the product exhibited occasional leakage due to poor seals, as well as a waxy flavor (caused by wax particles in the milk) and an unattractive cloudy external appearance. The low-density polyethylene-coated paperboard introduced in the 1960s solved these problems, and it has been widely used since (Jenkins & Harrington 1991).

Blow-molded HDPE jugs were adopted by dairies to replace the fragile and heavy glass packaging materials, however, this proved unsuccessful because of the high manufacturing cost. Improvements in molding technology resulted in low-cost, durable, and lightweight HDPE bottles preferred by consumers over the coated paperboard. These translucent containers prevent oxidative flavors from developing in milk and protect light-labile vitamins and minerals from UV damage. Pigments can be added to the HDPE resin for further protection against destructive elements in the environment (Dairy foods 2001). HDPE materials are predominantly used for one-gallon-sized bottles since they can withstand the weight of the milk. However, paperboard cartons are still commonly used for half gallon and smaller sized milk containers (Jenkins & Harrington 1991).

The development of milk packaging in Canada was similar to that in the U.S. by the 1960s. Plastic pouches were introduced at that time and are still prevalent. According to a previous report, approximately 50% of the milk sold in North America is packaged in HDPE jugs, 33% in gable top cartons, and 50% of the remainder in plastic pouches (Jenkins & Harrington 1991).

3. Cheese Packaging

Little is known regarding the origins of cheese making. Traditionally, surplus milk produced by the household goat or cow was converted into cheese and butter. Cheese is a major dairy product in modern life because of its nutritional value and sensory characteristics; the global cheese production is greater than the combined yearly production of coffee beans, tea leaves, cocoa beans, and tobacco. The first cheese factory in the U.S. was built in Oneida County, New York in 1851 (Hedrick et al. 1981); The U.S. has since been the largest cheese manufacturer, accounting for 30% of world production, followed by Germany and France (Wikipedia 2008).

Different packaging materials are used depending on the type of cheese. Plasticized PVC, PET, PVDC-coated cellophane, or PP/PE laminated films are used as individual wrapping film for sliced cheese; aluminum foil coated with lacquer or other heat-sealing materials is used for portion-type cheese packaging; and PVDC copolymers are used for tube packaging (Ono 1990).

The various types of cheese produced can be categorized into two types: natural cheese and processed cheese. Several common packaging requirements must be fulfilled in order to extend the shelf-life of cheeses. First, the oxygen in the package must be eliminated, as it can promote the growth of molds such as *Penicillium*, the most common spoilage organism, as well as rancidity and deterioration. Exposure to oxygen can be prevented by hermetically sealing under vacuum or in inert gases/carbon dioxide because spoilage organisms are usually aerobic (Paine 1983).

Second, water loss through evaporation should be avoided to ensure qualities such as texture and weight. Cheese products contain a high volume of water; therefore, water adsorption through the packaging is less important than water loss (Robertson 2006).

Cheese film wrapping requires mechanical strength, absence of toxic effects, moisture control, and oxygen and carbon dioxide permeability (Paine 1983).

4. Yogurt Packaging

Yogurt is a popular dairy product originally packaged in glass bottles and milk cartons when first introduced. Cup-type packages comprised of a lid and container are predominantly used in markets. Plastics and paperboards with plastic coating are commonly used for the container since they possess properties of good printability, lower cost, and easy disposal. Plastic-coated aluminum foil or paperboard and their composites are used for the lids since they are easy to open and enable the prevention of post contamination by heat sealing (Ono 1990).

5. Butter Packaging

Butter is thought to have originated in early civilizations such as Sumer in Mesopotamia and the Aryans of India (Sacharow & Griffin 1980). There are various butter compositions depending on manufacturer; however, usually butter contains a maximum of 16% moisture, 1% protein, 0.4% lactose, 0.15% milk, and different levels of salt. Because of the nature of the emulsion, it is susceptible to oxidation, leading to a fishy flavor. Therefore, in order to prevent or delay oxidation, the proper choice of packaging materials and forms is necessary. Parchment paper, aluminum foil wrapper laminated with vegetable parchment, and greaseproof paper are commonly used butter packaging materials (Robinson 2006; Paine 1983).

6. Cream Packaging

Because cream contains a high content of butter fat, it is susceptible to spoilage. Therefore, cream packaging should be designed to protect it from spoilage. In addition, water loss should be avoided to ensure its quality. As waxed paper cartons with press-in lids of the same material exhibited a deformation problem due to the absorbance of moisture during refrigeration, plastic tubs made of high-impact PS are currently being used for cream packaging. Rectangular gable-topped waxed or polyethylene-coated paperboard packages are also commonly used (Sacharow & Griffin 1980; Paine 1983).

7. Safety issues regarding packaging of dairy products

Migration is defined as the mass transfer of compounds from the plastic material(s) that make up the containers into the packaged foods. Food safety issues arise when harmful migrated compounds are consumed. In recent years, there have been increasing concerns regarding the migration of several dairy product packaging materials.

PS is produced by the polymerization of styrene monomers. Although styrene monomers have been established as safe, their migration into food can cause adverse effects on human health, such as eye, nose, throat, and skin irritation, when consumed (Ehret-Henry et al. 1994). Toxic effects on the liver, inhibition of the central nervous system, an increase in the frequency of chromosomal aberrations, and neurological impairments have also been observed (Tawfik & Huyghebaert 1998; Varner et al. 1983). Several studies have examined the potential carcinogenic effect of migrated styrene in food including dairy products (Tang et al. 2000). Tawfik & Huyghebaert (1998) reported that a higher fat content in food increases the level of migration because of the hydrophobic nature of styrene; this is a significantly important factor in dairy products that contain a relatively high fat content, such as cream. Based on these findings, O'Neill et al. (1994) examined the migration of residual styrene from PS cups into milk containing 1.5, 3.5, or 10% fat. Ehret-Henry et al. (1994) reported that extended contact time increased migration. Although styrene is present in many foodstuffs including fruit and meat (Biedermann et al. 1995; Bosset & Gauch 1993; Steele et al. 1994), most of the styrene content in food is the result of migration of residual styrene in PS packaging; the level of migration in dairy products should be continuously monitored because of concerns over human health (Tang et al. 2000; Ehret-Henry et al. 1994).

PVC is a commonly used versatile polymer; PVC films have been widely used for wrapping various foods such as cheese because of their flexibility, transparency, and relatively high permeability to oxygen and water. Processed cheese is often wrapped in PVC film and sold at retail supermarkets (Robertson 2006). However, PVC is naturally hard and brittle and therefore, it is often combined with plasticizers to increase flexibility, extensibility, and workability by imparting rubber-like properties through a decrease in the glass transition temperature (Wang 2000; Oriol-Hemmerlin & Pham 2000; Giam & Wong 1987; Goulas et al. 2007; Goulas et al. 2008). PVC films produced by the addition of plasticizers have excellent shrink, good optical characteristics, mechanical strength, and excellent grease and oil barrier properties (Soroka 2002). However, plasticizers possess high mobility because of their relatively low molecular weight and large initial concentration, and therefore, can readily migrate into food. This in turn results in the contamination of packaged foods, particularly those products with a high fat content because of the lipophilic nature of the plasticizers, and subsequent safety issues upon consumption (Petersen & Breindahl 1998; Goulas et al. 2007; Goulas et al. 2008).

Most PVC films are combined with di-(2-ethylhexyl) adipate (DEHA); the level of plasticizer used for PVC is very high, often over 20% of the polymer weight (Goulas et al. 2000). Concerns over the use of DEHA have been increasing since the U.S. national toxicology program published in the early 1980s that DEHA has a carcinogenic effect at high doses in mice. Adverse effects of DEHA on human health, including hepatic peroxisome proliferation and infertility, have also been reported (Bergman & Albanus 1987; Lake et al. 1997; EC 1999; Dalgaard et al. 2003)

Many studies have examined migration using various cheeses wrapped in plasticized PVC film; high levels of DEHA, exceeding the 3 mg/dm^2 legal specific migration limit set by the EU (EC 1994; EC 2002), have been detected in many cases. Goulas et al. (2000) reported DEHA levels of 18.9 mg/dm^2 for Kefalotyri cheese, 12.2 mg/dm^2 for Eda mcheese, and 7.3 mg/dm^2 for Feta cheese packaged in PVC film. Petersen et al. (1995) reported that the amount of DEHA migrated from PVC film containing 13.4–15.4% w/w DEHA was 45 mg/kg cheese after 2 hours of storage and 150 mg/kg after 10 days of storage. A subsequent study specified that these values should be divided by 6 in order to express migration relative to surface area (mg/dm^2), resulting in values of approximately 12 mg/dm^2. Petersenetal. (1995; 1997) and Rauter (2000) found similar high levels of DEHA migration.

In order to reduce the migration of DEHA from PVC cling film into foods, particularly cheeses, Castle et al. (1988) suggested the use of thinner films and partial substitution of DEHA by polymeric additives. Goulas et al. (2007) demonstrated a correlation between the use of alternative flexible films such as PVDC/PVC and lower plasticizer content.

8. Conclusions

The main functions of dairy food packaging are to maintain product hygiene, protect nutrients and flavor, reduce food spoilage and waste, increase food availability, enable efficient food distribution, and communicate product information (National food 2008). In order to ensure these functions, packaging materials and forms should be carefully chosen and designed.

Acknowledgments

This research was supported by the High Value-added Food Technology Development Program (114008-03) of the Ministry of Agriculture, Food and Rural Affairs and a research grant (KE1602-3-1) from the World Institute of Kimchi, Republic of Korea.

References

1. Bergman, K., Albanus, L. (1987). Di-(2-ethylhexyl)

adipate: absorption, autoradiographic distribution and elimination in mice and rats. Food and Chemical Toxicology 25 (4), 309-316.

2. Biedermann, M., Grob, K.,Morchio, G. (1995). On the origin of benzene, toluene, ethylbenzene and xylene in extra virgin olive oil. Z ebensm Unters Forsch. 200: 266-272.
3. Bosset, J.O, Gauch, R. (1993). Comparison of the volatile flavour compounds of six European 'AOC' cheeses by using a new dynamic headspace GC-MS method. International Dairy Journal 3: 359-377.
4. Canned milk boasts long shelf life. (2003). Web-page: http://aluminum.org/ANTemplate.cfm?IssueDate=01/01/2003&Template=/ContentManagement/ContentDisplay.cfm&ContentID=7177
5. Castle, L., Mercer, A.J., Gilbert, J. (1988). Migration from plasticized films into food. 4. Use of polymeric plasticizers and lower levels of DEHA plasticizers in PVC films to reduce migration into foods. Food Additives and Contaminants, 5, 277-282.
6. Cladman W., Scheffer, S., Goodrich, N., Griffiths. M. W. (1998). Shelf-life of milk packaged in plastic containers with and without treatment to reduce light transmission. International Dairy Journal. 8, 629-636.
7. Connolly, K. Got milk…packaging? Food processing. Itasca, IL. http://www.foodprocessing.com/articles/2007/287.html
8. Dairy foods. (2001). Packaging opportunities for fluid milk. CNET Networks, Inc. Web-page: http://findarticles.com/p/articles/mi_m3301/is_2_103/ai_83151743.
9. Dalgaard, M., Hass, U., Vinggaard, A.M., Jarfelt, K., Lam, H.R., Sorensen, I.K., Sommer, H.M. and Ladefoged, O. (2003). Di-(2-ethylhexyl) adipate (DEHA) induced toxicity but not antiandrogenic effects in pre-and postnatally exposed Wistar rats. Reproductive Toxicology 17, 163-170.
10. Duncan, E.S. (1998). ADSA Foundation scholar award. Dairy products: the next generation. Altering the image of dairy products through technology. Journal of Dairy Science 81: 877-883.
11. EC, (1994). Synoptic Document no. 7. Draft of provisional list of monomers and additives used in the manufacture of plastics and coatings intended to come into contact with foodstuffs. CS/PM/2356, Brussels.
12. EC, (1999). Opinion on the toxicological characteristics and risks of certain citrates and adipates used as a substitute for phthalates as plasticizers in certain soft PVC products. Scientific Committee on Toxicity, Ecotoxicity and the Environment (CSTEE), Brussels.
13. EC, (2002). Commission Directive 2002/72/EC of 6 August 2002, relating to plastic materials and articles intended to come into contact with foodstuffs. Official Journal of the European Union, L 39 46, 1-42.
14. Ehret-henry, J., Ducruet, V., Luciani, A., Feigenbaum, A., (1994). Styrene and ethylbenzene migration from polystyrene into dairy products by dynamic purge-and-trap gas chromatography. Journal of food science 59 (5): 990-993
15. Giam, C.S., Wong, M.K. (1987). Plasticizers in food. Journal of Food Protection 50 (9), 769-782.
16. Goulas, A., Salpea E., Michael G., Kontominas, M. (2008). M. Di(2-ethylhexyl) adipate migration from PVC-cling film into packaged sea bream (Sparus aurata) and rainbow trout (Oncorhynchus mykiss) fillets: kinetic study and control of compliance with EU specifications. European Food Resesrach and Technology 226:915-923

17. Goulas, A., Zygoura, P. Karatapanis, A. Georgantelis, D. and Kontominas, M. (2007). Migration of di(2-ethylhexyl) adipate and acetyltributyl citrate plasticizers from food-grade PVC film into sweetened sesame paste (halawa tehineh): Kinetic and penetration study. Food Chemical Toxicology 45: 585-591.
18. Goulas, A.E., Anifantaki, K.I., Kolioulis, D.G., Kontominas, M.G. (2000). Migration of di-(2-ethylhexylexyl) adipate plasticizer from food-grade polyvinyl chloride film into hard and soft cheese. J Dairy Sci 83 (17): 1712-1718.
19. Hedrick, T.I. Harmon, L.G. Chandan, R.C. and Seiberling, D. (1981). Dairy products industry in 2006. Journal of Dairy Science 64: 959-970.
20. Jenkins, W., Harrington, J. 1991. Dairy products. In; Packaging food with plastics. Technomic publishing company, Inc. Lancaster, Pennsylvania. P 145-171.
21. Lake, B.G., Price, R.J., Cunninghame, M.E., Walters, D.G. (1997). Comparison of the effects of di-(2-ethylhexyl) adipate on hepatic peroxisome proliferation and cell replication in the rat and mouse. Toxicology 123, 217–226.
22. Liu, X.H., Zhang, P., Peng, J.P., Huang, M.J. Hu, M.J., Li, H.B., Qian, J. (2014). Preparation and properties of fluorinated acrylate resin film with resisting fluid for dairy packaging. International polymer processing 29: 350-355.
23. Mohan, A. M. (2003). PET project fortified by blow/fill/cap. Packaging digest. 40 (6): 43-46.
24. Ono, K. Dairy products. (1990). Editor; Kadoya, T. In: Food packaging. Academic Press, Inc. San Diego, California p 349-356.
25. Oriol-Hemmerlin, C., Pham, Q.T. (2000). Poly 1,3-butylene adipate Reoplex as high molecular weight plasticizer for PVC-based cling films-microstructure and number-average molecular weight studied by 1H and 13C NMR. Polymer 41, 4401-4407.
26. Paine, F.A., Paine, H. Y. (1983). Dairy products, fats and oils, confectionery and fruit juices. A handbook of food packaging. Blackie & Son Ltd. London. P. 236-256
27. Papachristou, C., Badeka, A., Chouliara, I., Kondyli E., Kourtis L., Kontominas, M. (2006). Evaluation of polyethylene terephthalate as a packaging material for premium quality whole pasteurized milk in Greece Part II. Storage under fluorescent light. European Food Research Technology 224 (2): 237-247.
28. PET Resin Association (PETRA). (2006). PET-What is it and where does it come from? Web-page: http://www.petresin.org/qa_003.asp
29. Petersen, J., Breindahl, T. (1998). Specific migration of di-(2-ethylhexyl) adipate (DEHA) from plasticized PVC film: results from an enforcement campaign. Food additives and contamination 15 (5): 600-608.
30. Petersen, J. H., Lillemark, L, Lund, L. (1997). Migration from PVC cling films compared with their field of application. Food Additives and Contaminants, 14, 345–353.
31. Petersen, J. H., Naamansen, E. T., Nielsen, P. A. (1995). PVC cling film in contact with cheese: health aspects related to global migration and specific migration of DEHA. Food Additives and Contaminants 12: 245-253.
32. Rauter, W. (2000). Adipinsa¨ure-bis-2-ethylhexylester (DEHA) in PVCD ehnfolien verpacktem Ka¨se. Deutsche Lebensmittelrundschau, 9, 324-326.
33. Robertson. G.L. (2006). Packaging of dairy products. In: Food packaging; principles and practice. 2nd edition. Marcel Dekker, Inc. New York, New York. P.388-415.

34. Sacharow, G., Griffin, R. (1980). Milk and dairy products. In: Principles of food packaging. 2nd edition. The AVI publishing company, Inc., Westport, Connecticut. p 176-208.

35. Soroka, W. (2002). Plastic applications. In: Fundamentals of packaging technology. 3rd edition. Naperville: Instidutue of packaging professional. p. 261-292.

36. Steele, D.H., Thornburg, M.J., Stanley, J.S., Miller, R.R., Brooke, R., Cushman, J.R. Cruzan, G. (1994). Determination of styrene in selected foods. Journal of Agricultural Food Chemisty 42: 1661-1665.

37. Tang, W., Hemm, I., Eisenbrand G. (2000). Estimation of human exposure to styrene and ethylbenzene. Toxicology 114: 39-50.

38. Tawfik, M.S., Huyghebaert A. (1998). Polystyrene cups and containers: styrene migration. Food additives and contaminants 15 (5): 592-599.

39. Varner, S.L., Breder, C.V., Fazio, T. (1983). Determination of styrene migration from food-contact polymers into margarine, using azeotropic distillation and headspace gas chromatography. Journal of the association of official analytical chemists international, 66, 1067-1073.

40. Wang, F.C.Y. (2000). Polymer additive pyrolysis-gas chromatography. I. Plasticizers. Journal of Chromatography A 883, 199 – 210.