ATA-GIDA DERGİSİ
ATA-FOOD JOURNAL
e-ISSN: 2822-2776
DergiPark AKADEMİK ev sahipliğinde https://dergipark.org.tr/tr/pub/atafoodj

ATATÜRK ÜNİVERSİTESİ YAYINLARI
ATATURK UNIVERSITY PUBLICATIONS

Review/Derleme

New packaging methods used in the dairy industry

Süt Endüstrisinde Kullanılan Yeni Ambalajlama Yöntemleri

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OPEN ACCESS

Citation
Terzioğlu, M.E., Bakırcı, İ. (2022). New packaging methods used in the dairy industry. *ATA-Food Journal*, 1(2), 0011.

Received/Geliş: 22.05.2022
Accepted/Kabul: 26.07.2022
Published/Yayın: 31.07.2022

Abstract In recent years, with developing technology, a set of innovations is being observed in packaging of foods, consumer health is protected by keeping the quality and safety of milk and dairy products that are prone to be spoilt on the top level by using new packaging methods, the shelf life of products is extended, and economic losses are minimized. In the modified atmosphere packaging (MAP) technique used in the packaging of milk and dairy products, by changing the gas composition inside the package, the freshness of the product and microbial safety are protected. In smart packaging, by using indicators, sensors and radio frequency identification (RFID) tags, monitorability of milk and dairy products throughout storage is provided, and economic losses are reduced. With the help of the active absorbing-conserving systems and active secreting-distributing systems they have, active packages prevent unwanted microbial developments, oxidations and color changes, and their effectiveness is increased by supporting them with antimicrobial substances and antioxidants. Edible films and coatings that are obtained from natural sources and can be consumed with foods are applied on milk and dairy products with different methods such as submersion, spraying, pouring and painting, they prevent chemical and microbiological degradations by keeping the humidity and oxygen amount in the package on the desired levels, and they do not pose a risk for the environment. This review study provides information on the MAP technique, smart packaging, active packaging and edible films and coatings that are used in the dairy industry.

Keywords: Dairy industry, Modified atmosphere packaging (MAP), Smart packaging, Active packaging, Edible films and coatings

Özet Son yıllarda gelişen teknolojiyle birlikte gıdaların ambalajlanmasında birtakım yenilikler görülmekte, yeni ambalajlama yöntemlerinin kullanılmasıyla bozulmaya yatkın gıdalar arasında yer alan süt ve süt ürünlerinin kalitesi ve güvenliği en üst seviyede tutularak tüketici sağlığı korunmakta, ürünlerin raf ömrü uzamakta ve ekonomik kayıplar en aza indirilmektedir. Süt ve süt ürünlerinin ambalajlanmasında kullanılan modifiye atmosfer paketleme (MAP) tekniğinde ambalaj içerisindeki gaz kompozisyonu değiştirilerek ürün tazeliği ve mikrobiyal güvenlik korunmaktadır. Akıllı ambalajlamada indikatörler, sensörler ve radyo frekanslı tanıma sistemi (RFID) etiketleri kullanılarak süt ve süt ürünlerinin depolama süresince izlenebilirliği sağlanmakta ve ekonomik kayıplar azaltılmaktadır. Aktif ambalajlar içermiş oldukları aktif emici-tutucu sistemler ve aktif salıcı-yayıcı sistemler vasıtasıyla istenmeyen mikrobiyal gelişimlere, oksidasyona ve renk değişimlerine engel olmakta, antimikrobiyal maddeler ve antioksidanlarla desteklenerek etkinliği arttırılmaktadır. Doğal kaynaklardan elde edilen ve gıdalarla birlikte tüketilebilen yenilebilir film ve kaplamalar süt ve süt ürünlerine daldırma, püskürtme, dökme ve boyama gibi farklı yöntemlerle uygulanmakta, ambalaj içerisindeki nem ve oksijen miktarını istenilen seviyeye çekerek kimyasal ve mikrobiyolojik bozulmaları engellemekte ve çevre için risk oluşturmamaktadır. Bu derleme çalışmasında süt endüstrisinde kullanılan MAP tekniği, akıllı ambalajlama, aktif ambalajlama, yenilebilir film ve kaplamalar hakkında bilgi verilmektedir.

Anahtar Kelimeler: Süt endüstrisi, Modifiye atmosfer paketleme (MAP), Akıllı ambalajlama, Aktif ambalajlama, Yenilebilir film ve kaplamalar

1. INTRODUCTION

Longer preservation of various biomolecules in the composition of foods (e.g., proteins, volatile oils and vitamins) under unfavorable conditions and prevention of physical, chemical and microbiological deteriorations that lead to food-based diseases and reduction of the shelf lives of products are among the most important goals of the food industry (Candan and Bağdatlı, 2018; Stockwell, 2022). Packaging material that has an effective role in determination of the shelf life and quality of fresh and processed foods is defined as covers and coatings that provide protection from external effects such as heat, light, oxygen, moisture and impact in the process during transportation, storage and until consumption and prevent physical, chemical and biological contaminations (Özçandır and Yetim, 2010; Üçüncü, 2011; Yeşiladalı and Karbancıoğlu Güler, 2016). The prevalence of the convenience food sector in relation to the changing living conditions and the increase in consumer expectations in parallel with the desire to high-quality and safe products have led the food industry towards the use of more natural and practical packaging materials. In the good preservation process, which is shown as an area that is highly open to innovations and has been popular in the world with developments, while selecting suitable packaging material, firstly the properties and preservation conditions of foods are considered, and in this process, usually paper, metal, glass and plastic materials are used (Temiz and Yeşilsu, 2006; Özçandır and Yetim, 2010; Candan and Bağdatlı, 2018).

Packaging milk and dairy products usually involves the use of polyethylene terephthalate (PET) and polycarbonate (PC) bottles, low-density polyethylene (LDPE) bags and carton boxes (Karaman et al., 2015). In addition to causing foods to interact with chemical substances, various petroleum-derived synthetic polymers that are frequently used as packaging material also create a great risk for nature as they are not biodegradable (Delikanlı and Özcan, 2014; Öksüztepe and Beyazgül, 2015; Candan and Bağdatlı, 2018). In line with developments in technology in recent years, as alternatives to classical preservation methods such as cooking, freezing, salting, drying and fermentation, new packaging methods (Figure 1) where freshness is preserved, shelf life is extended, and food safety and quality are achieved have been developed (Karagöz and Candoğan, 2007), and by addition of various components to conventional packages whose main duty is to protect and provide integrity or by usage of functional polymers in packaging, packaging systems that are reliable and monitorable in the food chain which control the contents of the package and react have become prominent (Özçandır and Yetim, 2010; Yeşiladalı and Karbancıoğlu Güler, 2016).

2. MODIFIED ATMOSPHERE PACKAGING (MAP)

In the modified atmosphere packaging (MAP) technique, as a result of changing the gas environment in the package in a controlled manner by adding or removing oxygen, carbon dioxide and nitrogen gasses by desired amounts based on the respiratory rate of foods and package permeability, enzymatic, biochemical and microbiological degradations are prevented, high-quality products are obtained, shelf life is extended, economic losses are reduced, and practical and odor-free packaging opportunities are provided (Karagöz and Demirdöven, 2017; Patel et al., 2018; Lee and Wang, 2022). The MAP technique provides the gas composition of food packaging with a structure different to that of air (20.96% (v/v) oxygen, 0.03% (v/v) carbon dioxide and 78.08% (v/v) nitrogen) (Lavieri and Williams, 2014). Although the MAP technique has been previously used in packaging different foods such as pastries, meat, fish, fruits and vegetables, it is a new method in packaging milk and dairy products. With preference of the MAP technique, in addition to formation of modified atmospheric conditions inside the packaging, preservation of milk and dairy products is achieved without using preservatives or using minimal amounts of preservatives, and this situation is appreciated by consumers (Çelikkol, 2011; Ščetar et al., 2019).

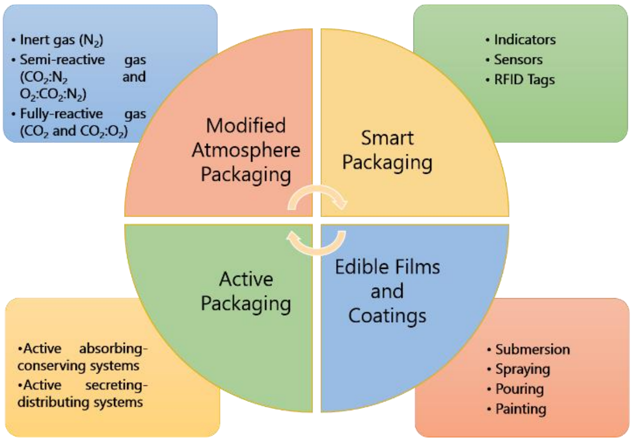

Figure 1. The mechanism of the new packaging methods in food packaging

Mainly oxygen, carbon dioxide and nitrogen gasses are used in the MAP technique. Although the use of trace gasses such as chlorine, ethane, carbon monoxide, sulfur dioxide, nitric oxides and nitrous has been considered, these are not preferred due to legal restrictions, consumer reactions and costs (Karagöz and Demirdöven, 2017). The aim in the MAP technique is to prevent microbiological and enzymatic deteriorations by reducing the oxygen concentration and increasing the carbon dioxide and nitrogen concentration in the package and increase the durability of foods. On the other hand, the requirement of different gas concentrations for different foods in the MAP technique increases the cost (Çelikkol, 2011). Oxygen, which is needed by aerobic microorganisms for their development, is a colorless, odorless and highly reactive gas. Oxygen that has low solubility in water leads to fat and pigment oxidations in addition to browning reactions in food. As it triggers spoiling of food, it is needed to reduce the oxygen levels in the top void of milk and dairy product packages. Usage of carbon dioxide, which can be dissolved in water and fat and reduces the growth rate of microorganisms by extending their lag phase, in packaging prevents bacteria and mold development in especially pot cheeses and fluid dairy products (bacteriostatic and fungistatic effect), affects enzyme activities and extends shelf life by 200-400%. Although nitrogen gas which is used in the MAP technique as filler material, does not dissolve in water or fat and is a tasteless inert gas does not have a direct antimicrobial effect, by replacing oxygen inside the package, it prevents development of aerobic microorganisms, oxidation and crushing of the package (Gün et al., 2009; Çelikkol, 2011; Karagöz and Demirdöven, 2017; Ščetar et al., 2019).

Papaioannou et al. (2007) and Dermiki et al. (2008) in different curd cheeses, Del Nobile et al. (2009) and Mancuso et al. (2014) in ricotta cheese, Brown et al. (2018) in fresh cheese and Solomakos et al. (2019) in graviera agraphon cheese demonstrated that the MAP technique takes microbial development under control. Mastromatteo et al. (2014) reported that, as a result of combining the MAP technique with active packaging, the shelf life of mozzarella cheese was extended.

3. SMART PACKAGING

Smart packages, which are defined as materials that are capable of monitoring environment and food conditions, inform consumers, retailers and producers about the physical, chemical, microbiological and enzymatic changes inside the package during transportation and storage (Çelik and Tümer, 2016; Karagöz and Demirdöven, 2017; Konuk Takma and Şahin Nadeem, 2019). In smart packaging systems, by using indicators, sensors and radio frequency identification (RFID) tags with monitoring, sensing and indication properties, advantages such as real-time data collection, rapid response and appropriate decision-making are provided (Kocaman and Sarımehmetoğlu, 2010; Üçüncü, 2011). Smart packages achieve food safety by making the cold chain inspection themselves, spoil-related losses are reduced, and consumers are provided with opportunities of fresh food (Çelik and Tümer, 2016). Smart packages, which provide information with the help of devices placed inside and outside the package, do not change the status of the package or the food (Ščetar et al., 2019 Oladzadabbasabadi et al., 2022). Usage of smart packaging, which had not had a legal regulation until 2004 in Europe, is highly prevalent in the United States and Japan. In Turkey, regarding the use, marketing and safety of smart packages, the Turkish Food Codex Directive on Substances and Materials Contacting Food (05.04.2018/30382) was created (Öksüztepe and Beyazgül, 2015; Anonymous, 2018).

Table 1. Smart packaging systems

	Smart Packaging Systems	**Working Principle**	**Source**
INDICATORS	Temperature-Time Indicators	These are indicators that provide information on the temperature history of perishables such as milk and dairy products irreversibly by color changes as a result of chemical, electrochemical and enzymatic reactions. They are highly sensitive to biochemical, microbial and enzymatic degradations. They allow an effective cold chain inspection.	Karagöz and Demirdöven, 2017; Konuk Takma and Şahin Nadeem, 2019
	Freshness Indicators	These are indicators that indicate metabolites like carbon dioxide, sulfur dioxide, hydrogen sulfide, ammonia, ethanol, amines, organic acids, enzymes and toxins that emerge as a result of storing foods in unfavorable conditions and changing gas composition by color changes.	Çelik and Tümer, 2016
	Leak Indicators	These provide information on the integrity of the package and leaks by being added onto the package in the form of labels, tablets or prints. Irreversible color changes are observed as a result of chemical and enzymatic reactions. Leak indicators turn blue when the level of oxygen in the packaging exceeds 0.5% (v/v) and pink when the level drops below 0.1% (v/v).	Purma and Serdaroğlu, 2006; Kokangül and Fenercioğlu, 2012; Çelik and Tümer, 2016
	Pathogen Indicators	These are indicators that indicate contamination of *Listeria* spp., *Salmonella* spp., *Campylobacter* spp. and *Escherichia coli* O157:H7 in foods. In the case of contamination, the color of the barcode gets noticeably darker.	Öksüztepe and Beyazgül, 2015
SENSORS	Chemical Sensors	They are prevalently used in monitoring package integrity and food quality. They provide information on the chemical composition of the environment that is in the liquid or gas phase.	Dalmoro *et al.,* 2017
	Biosensors	Biosensors, which are known as devices that detect, record and transmit biochemical reactions in packaged foods, consist of energy converters that convert biochemical energy into electrical energy and bioreceptors (organic materials such as hormones, antigens, enzymes and nucleic acids).	Kocaman and Sarımehmetoğlu, 2010
	Nanosensors	They detect temperature, mass and color changes caused by microorganisms that cause food poisoning by producing toxins with the help of molecular recognition systems.	Karagöz and Demirdöven, 2017
	Gas Sensors	They provide information on bacterial reproduction based on changes in the concentrations of the metabolites of bacteria in the gas form (such as carbon dioxide production).	Dalmoro *et al.,* 2017
	Fluorescence-Based Gas Sensors	Gas forming inside the packaging is determined by polymer containers containing fluorescent and phosphorane dyes. As a result of the gas that penetrates the polymer by diffusion reaching the fluorescent dye, the package fluoresces.	Karagöz and Demirdöven, 2017
RFID Tags		The RFID system consisting of a reader with an antenna and a tag allows monitoring foods from afar. In addition to identification with radio waves, it keeps basic information such as barcode numbers, relative humidity and temperature information.	Karagöz and Demirdöven, 2017; Hepsağ and Varol, 2018

4. ACTIVE PACKAGING

In active packaging, in addition to protecting foods from physical effects, the sensory and composition properties of foods are preserved, and their shelf life is increased by slowing down or completely stopping chemical and microbiological degradation reactions as a result of changing the environment inside the packaging (Üçüncü, 2011; Lee and Wang, 2022). The use of active packages in packaging foods is highly prevalent in the United States and Asian countries rather than European countries (Prasad and Kochhar, 2014). As a result of using active substances (antimicrobial substances and antioxidants) in packaging instead of directly adding them into fresh and processed foods, their contact with food components is prevented, the activity of these substances is increased, and this way, their usage amount is reduced (Yildirim et al., 2018). Inside active packaging systems that are divided into two categories based on their working principle as active absorbing-conserving systems and active secreting-distributing systems, there are oxygen conserving or antioxidant-containing active systems, carbon dioxide conservers/releasers, humidity absorbers, ethylene absorbers, ethanol releasers, taste/smell absorbers and preservative secreters based on the characteristics of the foods to be preserved, and in packaging of milk and dairy products, oxygen conservers and antimicrobial substances are preferred more to prevent rancidity, color degradations and mold development on the surface (Karagöz and Demirdöven, 2017).

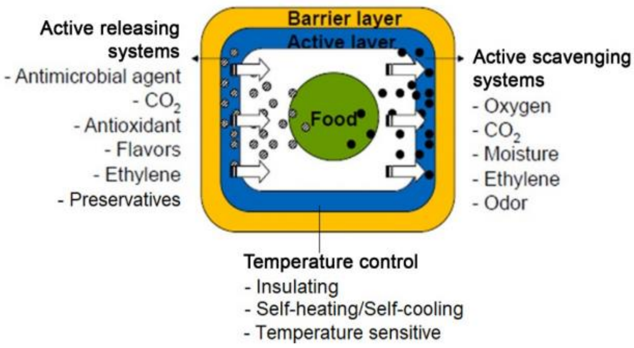

Figure 2. The active packaging system (Kuswandi and Jumina, 2020)

After packaging, the level of oxygen remaining in the package generally varies in the range of 0.5-5% (v/v) (Yildirim et al., 2018). In active packaging, by the help of oxygen scavenging systems (used in the form of film, pouch, bottle cap, card and label), the oxygen ratio inside the package is reduced under 0.01% (v/v), and unwanted color changes, microbial degradations, taste and nutrition losses that may occur in milk and dairy products are prevented (Çelik and Tümer, 2016; Yildirim et al., 2018). In oxygen scavenging systems, by utilizing ascorbic acid, unsaturated fatty acids, iron dust, enzymes and palladium catalysts, oxygen is trapped on all surfaces contacting the food, oxygen-sensitive food items are protected, and development of aerobic microorganisms is prevented (Çelik and Tümer, 2016; Karagöz and Demirdöven, 2017). In active packaging systems, as a result of inclusion of iron compounds in the polymer matrix, their direct contact with the food is prevented, and consumer health is protected. In addition to iron compounds, ascorbic acid is also prevalently used in oxygen conserving systems, and the effect of the ascorbic acid is supported with aluminum, alkali compounds and iron salts (Wyrwa and Barska, 2017). In addition to oxygen conserving systems, to reduce condensation in foods with high water contents such as milk and to prevent the water layer forming on the surface of dairy products such as cheese and butter, humidity-absorbing films, pads and pouches with a suitable level of water vapor permeability are also used (Karagöz and Demirdöven, 2017).

Direct addition of antimicrobial agents into food formulations not only leads to unwanted taste formation but also causes reduced antimicrobial activity due to inactivation of these agents by food components and excess use of antimicrobial agents (Van Long et al., 2016). In antibacterial packaging among active packaging systems, by addition of antimicrobial agents such as carbon dioxide, chlorine dioxide, ethanol, silver ions, spices, volatile oils, organic acids and antibiotics into the packaging system (in gas form or antimicrobial substance form) or by usage of suitable antimicrobial polymers during conventional packaging, the lag phase of pathogenic microorganisms is extended, their growth is slowed down, development is restricted or completely prevented by reducing the number of living organisms, and this effect takes place in the form of secretion, immobilization or absorption (Prasad and Kochhar, 2014; Çelik and Tümer, 2016; Karagöz and Demirdöven, 2017). Antimicrobial agents are usually found by 0.1-5% (w/w) in the composition of the packaging material. Antimicrobial packaging includes carbon dioxide, chlorine dioxide, sulfur dioxide, plant extracts, volatile oils and allyl isothiocyanate secretion systems, and antimicrobial substances penetrate a large part of the food matrix without having any direct contact with the food. Chlorine dioxide, which is one of the most frequently preferred antimicrobial agents in preservation of dairy products, may be found in the solid, liquid or gas form inside the packaging and is highly effective against bacteria, fungi and viruses during storage. Carbon dioxide is generally used at high concentrations (10-80% (v/v)) for the purpose of stopping microbial development on the surface, and inside packages with high permeability, carbon dioxide secretion is constant for the purpose of preserving the desired concentration inside (Prasad and Kochhar, 2014; Van Long et al., 2016).

Van Aardt et al. (2007), Granda-Restrepo et al. (2009) and Soto et al. (2011) reported that α-tocopherol which is used in active packaging of milk powder shows an antioxidant effect, and it prevents loss of vitamin A and rancid taste. Gomes et al. (2009) stated that oxygen scavengers protect the vitamin C content in cheeses. It was observed that degradations were prevented by adding antioxidants into polyolefin polymers used in packaging, and antioxidants such as butylated hydroxy anisole (BHA) and butylated hydroxytoluene (BHT) showed positive effects on foods with high fat content (Karaman et al., 2015). Moraes et al. (2007) showed in butter, Türe et al. (2011) showed in fresh kashar cheese and Kuorwel et al. (2014) showed in cheddar cheese that microbial development decreased by usage of antimicrobial films. Likewise, Youssef et al. (2016), Embuena et al. (2017) and Santonicola et al. (2017) stated that chitosan-containing films and coatings significantly affected microbial development in cheeses.

5. EDIBLE FILMS and COATINGS

As the world's population is rapidly increasing, food sources fall short against this increase, there is a narrow area of production, and environmental pollution has reached unpreventable dimensions, petrochemistry-based plastic packaging materials used in preservation of products in the food sector are slowly being replaced by edible films and coatings with a biopolymer basis and hydrophilic properties (Coşkun Topuz and Boran, 2018; Paulo et al., 2021). With improvement of the physical and functional properties of edible coatings, which were firstly used in China in the 12th century on oranges and lemons and utilized in Europe in the 16th century to reduce the moisture loss on meat surfaces, their usage areas have increased today (Uçan and Mercimek, 2013; Kaya Özkök, 2017).

The main components of edible films and coatings, which are obtained from natural sources (plant and animal origins), can be consumed with foods, does not pose a risk for the environment as they are biodegradable, allow integration of pigments, aromatic compounds and vitamins inside the packaging, improve the organoleptic properties of products with the help of additives (taste and color additives) and play an important role in stopping browning reactions, reducing loss of moisture and flavor, consist of proteins (wheat gluten, maize zein, soy protein, gelatin, collagen, keratin, whey protein, casein), polysaccharides (pectin, alginate, chitosan, gums, starch and derivatives, cellulose and derivatives), lipids (glycerides and natural waxes) and resins (Eştürk and Ayhan, 2008; Oğuzhan Yıldız and Yangılar, 2016; Sarıtaş Küçük et al., 2017; Tural et al., 2017). Proteins used in packaging increase mechanical durability, polysaccharides control the passage of oxygen and other gasses between the outer environment and inside the package, and lipids reduce the passage of humidity. Similarly, in addition to these main components, plasticizers (monosaccharides, disaccharides, oligosaccharides, polyols etc.), colorants, flavor substances, emulsifiers, browning-preventing agents, antimicrobial substances and antioxidants may be used. The use of plasticizers inside packaging increases the glossiness of polysaccharide films, improves mechanical properties and affects permeability in the positive direction (Tural et al., 2017). The disadvantages of edible films and coatings include that consumers do not have sufficient knowledge on them as they are a new technology, the number of materials to be used is low, implementation costs are high, and carcinogenic effects may form due to the antioxidants that are added (Işık et al., 2013).

The effectiveness of edible films and coatings in preservation of foods may differ based on food properties, bioactive compounds added to increase functionality (organic acids, peptides, enzymes, bacteriocins, natural antimicrobial substances and antioxidants), relative humidity and hydrogen ion effects, as well as different application methods such as submersion, spraying, pouring and painting (Oğuzhan Yıldız and Yangılar, 2016; Kaya Özkök, 2017; Candan and Bağdatlı, 2018). In the submersion method, after the product dipped into the film solution for 5-30 seconds absorbs the solution, it is drained, dried and solidified. By coating the surfaces homogenously with the coating material and removing the excess coating material, a desired thickness of the film layer can be obtained. In the spraying method, by spraying the film solution onto the product that is stationary on a platform via air-sprays and high-pressure sprayers, only one surface is thinly and smoothly covered. The spraying method is utilized to create an extra film layer on products that have been previously coated and make cross-binding easier in methods of coating with two different substances such as calcium-alginate. In the pouring method, the solution that will form the film is poured onto the product surface at a desired thickness and in a suitable manner, dried, cooled, and at the end, the coating is obtained. In the pouring method that is used in addition to the submersion and spraying methods, the film structure varies based on the drying conditions, film pouring thickness and solution composition. In case the film thickness increases, there may be degradations in the product as the gas permeability of the package decreases. In the painting method, by painting onto certain parts of products with a brush, a thin and homogenous film layer is obtained. The film layer is dried in a short time at room temperature or with the help of a heater (Oğuzhan Yıldız and Yangılar, 2016; Kaya Özkök, 2017; Tural et al., 2017).

Torlak and Nizamoğlu (2011), Kavas et al. (2015) and Yangılar and Oğuzhan Yıldız (2016) revealed in their studies that edible films showed an antimicrobial effect in kashar cheese and increased the quality throughout storage. It was determined by Di Pierro et al. (2011) in ricotta cheese, Zhong et al. (2014) in mozzarella cheese, Pena-Serna et al. (2016) in minas padräo cheese and Resa et al. (2016) in port salut cheese that edible films and coatings provided positive results. Kaya Özkök (2017) determined that the edible films they obtained by using three different protein sources (whey protein, gluten protein and soy protein) showed protective properties in cheeses and balanced moisture loss.

6. CONCLUSION

The most important goal of the food industry is to protect consumer health and minimize economic losses by preserving foods against all physical, chemical and microbiological degradations that may occur between production and consumption. In addition to the desire of consumers to access as natural as possible, unprocessed or minimally processed, healthy and fresh foods, the fact that functional properties expected of packaging increased with development of technology, and petrochemistry-based packages that are frequently used carry great risks in terms of health and the environment has made it a necessity to use novel methods in the packaging of milk and dairy products that are among foods which are prone to degradation. By the use of new packaging methods in the dairy industry, the gas composition inside the packaging can be taken under control, monitorability can be achieved by indicators, sensors and RFID tags in the storage process, the nutritional values of products can be preserved by achieving enzymatic and microbiological inactivation with the help of active systems in packages, shelf life is extended, the use of preservatives that lead to unwanted taste, smell and flavor formation is reduced, chemical interaction between foods and packaging materials is prevented, and with the help of biodegradable structures, environmental pollution is prevented. It is believed that, by raising more awareness among consumers about the importance of packages, reducing the implementation cost of new packaging methods, broadening the product range and eliminating carcinogenic effects that may occur due to some antioxidants that are added, the MAP technique, smart packaging, active packaging and edible films and coatings will be more popular in the future, and they will become more prevalent in other food industries in addition to the dairy industry.

Author Contributions: All authors have contributed equally, read and agreed to the published version of the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

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