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Extension Shelf Life of Cheese: A Review

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ABSTRACT

Cheese is a versatile nutrient-dense dairy product and susceptible to physical, chemical and biochemical spoilage. As a nutrient dense dairy product, cheese is a good source of protein, minerals particularly calcium and phosphorus which are essential components in most highly consumed foods. Therefore, extension shelf life of this dairy food is very important. This review focuses mainly on techniques used in extension shelf life of cheese. According to literatures, the main methods for cheese shelf life extension are addition of preservative, modified atmosphere (MAP), high pressure, active coating, edible coating and combination of them. Several studies have done on almost all categories of cheeses including soft fresh cheese, soft ripened cheese, surface mould ripened cheese, semi-soft cheese, hard cheese and very hard cheeses.

Key words: Shelf life, MAP, HPP, edible coating, active coating

INTRODUCTION

The stability of a food product and its consequent shelf life depends on many factors including the quality of ingredients, product composition and structure, processing conditions used during manufacture, packaging characteristics and finally the storage, handling and distribution conditions. This means that any food product is doomed to fail after a certain amount of storage time for a variety of reasons (Kilcast and Subramaniam, 2011).

The Institute of Food Science and Technology defined shelf life as “the period of time during which the food product will (1) remain safe (2) be certain to retain its desired sensory, chemical, physical, microbiological and functional characteristics; where appropriate, comply with any label declaration of nutrition data, when stored under recommended conditions”. Shelf life is an important feature of all foods, including raw materials, ingredients and semi manufactured products. Any of these products has its own shelf life and all the subjects involved in the food chain, such as growers, ingredient and packaging suppliers, manufacturers, wholesalers, retailers and consumers, have a great impact on it and should be aware of it (Nicoli, 2012).

Changes limiting shelf life of dairy product may be physicochemical, chemical or biochemical in nature. Examples of three such processes include the following: Physicochemical changes such as creaming of fat, gelation of protein solutions, syneresis of curds and crystallization of minerals; Chemical reactions such as non-enzymatic browning and oxidation of fat; Biochemical transformations such as growth of micro-organisms, enzymatic degradation, ripening of cheese and fermentation (Kilcast and Subramaniam, 2011).

The stability of short shelf life dairy products depends on the moderation of the growth of and subsequent degradation by spoilage micro-organisms. In contrast, the shelf life of intermediate and long life dairy products is largely determined by enzymatic degradation or by chemical deterioration. Heat-resistant enzymes a notable feature of the spoilage bacteria found in raw milk is their almost universal ability to produce extra-cellular enzymes. While the bacteria, mostly Gram-negative psychrotrophs are readily killed by pasteurization, such heat treatment has little effect on the extra-cellular derivative enzymes. UHT treatment represents the most severe heat treatment applied to dairy products other than those like evaporated milk and sterilized and clotted creams which are in container sterilized. An overwhelming proportion of the psychotropic flora found in milk produces heat-stable enzymes. Cheese, a versatile nutrient-dense dairy product, could be regarded as the original convenience food which may be consumed as the main component of a meal, as a dessert, as a snack, as a condiment, or as a food ingredient. In addition, new varieties of cheese continue to be developed despite the fact that there are over 500 types. This dairy product is a good source of protein, vitamins and minerals particularly calcium and phosphorus which are essential components in most highly consumed foods. Therefore, extension shelf life of this dairy food is very important (Kilcast and Subramaniam, 2011). The current study reviews the most recent/significant approaches to study the extension shelf life methods of cheese.

EXTENSION OF SHELF LIFE BY ADDITION OF PRESERVATIVES

May be addition of preservatives is one of the simple and oldest ways to extension shelf life of cheese. Preservatives in cheese processing may help to retard alterations caused by growth of microorganisms, or enable physical properties chemical composition and original nutritional value to remain unaffected. If preservatives are used, control must be exercised to prevent misuse or unnecessary use of them. Green pepper, sorbic acid, sodium benzoate plus benzoic acid and hydrogen peroxide, nisin, natamisin and chitosan as additives have been used for prolong cheese shelf life.

Nisin is a bacteriocin widely used as a food preservative in particular in cheese (Deegan *et al.*, 2006; Delves-Broughton, 2005). Nisin is active against most Gram-positive bacteria including, lactococci, bacilli, micrococci, Staphylococcus aureus, Listeria monocytogenes and Clostridium botulinum but shows little or no activity against Gram-negative bacteria, yeast or moulds (Hurst, 1981).

Natamycin is a fungicide and belongs to polyethylene antibiotics, produced by aerobic fermentation of *Streptomyces natalensis* and related species. It is commonly employed in the food industry, especially in dairy products (cheese) for the prevention of moulds and yeasts contamination. Natamycin is used at concentrations between 1 and 20 ppm. In general yeasts are less resistant (minimum inhibitory concentration below 5 ppm) than moulds (minimum inhibitory concentration above 10 ppm). Natamycin is permitted as an antimycotic in surface and cheese treatments in 32 countries but its use as a general food additive is more limited. In the European Union, natamycin is allowed for surface-treatment of hard, semi-hard and semi-soft cheeses as well as dry sausages. The EFSA Panel on Food Additives and Nutrient Sources to foods has revised its use, concluding that, given that natamycin is very poorly absorbed, there was an adequate margin of safety in its current applications and there was no concern for the induction of antimicrobial resistance (Kallinteri *et al.*, 2013).

Ismail *et al.* (1972) investigate the effect of green pepper, sorbic acid, sodium benzoate plus benzoic acid and hydrogen peroxide on the total bacterial and lactobacilli counts and on destruction of coliform bacteria in pickled cheese during storage for 12 weeks at 10°C varied with the kind and amount of preservative. Effects on acidity, pH and free fatty acid production in cheese were also reported. According this study there were no effects on yield, moisture and fat contents. Lactobacilli were always more numerous in untreated cheese than in any preservative treated cheese. Hydrogen peroxide and green pepper did not retard growth of lactobacilli, whereas sorbic acid was less effective than benzoate. Hydrogen peroxide and green pepper destroyed most of the coliform bacteria. Free fatty acids were highest in the untreated and in the green pepper-treated cheese and lowest in the hydrogen peroxide treated cheese. Cheese with green pepper had better flavor, body and texture.

Several forms of concentrated nisin are now commercially produced and routinely used as a food additive in products such as pasteurized cheese spreads, sauces and salad dressings (Mazzotta *et al*., 1997). In the cheese industry, the use of nisin in free form, such as Nisaplin (Aplin and Barret, Ltd.), is costly and has drawbacks, including lower activity, stability and bioavailability. Moreover, free nisin may interfere with cheese-making process or reduce cheese quality by inhibiting the starter culture or nonstarter lactic acid bacteria important in ripening and flavor development (Buyong *et al*., 1998). There has thus been continued interest in developing other means of incorporating nisin into cheese, such as the use of a mixed starter culture containing a nisin producing strain. Since most starter cultures show variable sensitivity to nisin (Rada and Dlabal, 1998), nisin-producing strains should be combined with nisin resistant or tolerant starter culture to ensure a proper balance between lysed and intact cells (Benech *et al*., 2002). The efficacy of nisin can drastically vary when produced *in situ*. The bactericidal effect of nisin can drastically increase by incorporation of 10% of gelatin in the dry matter (Aly *et al*., 2012).

Na_2-EDTA and lysozyme are another additives, effective in inhibiting the growth of spoilage microorganisms such as coliforms and *Pseudomonas* spp., without any effect on lactic acid bacteria (Sinigaglia *et al*., 2008).

Chitosan is an antimicrobial agent and can use to prolong the shelf life of cheese due to it is environmentally friendly and relatively inexpensive. Chitosan is effective in inhibiting the growth of spoilage microorganisms such as coliforms and *Pseudomonas* spp. Moreover, it seems that the presence of chitosan does not affect the growth of lactic acid bacteria, saving the functional dairy microbiota (Altieri *et al*., 2005).

Addition of bioactive lipophilic compound to cheese milk can prolong the shelf life of product but high losses in whey can be obtained: 50% of phospholipids, 60% of vitamin D, 95% of enzymes responsible of cheese ripening (Banville *et al*., 2000). To overcome to this problem, immobilization method is necessary. The encapsulation of bioactive ingredients in cheese under the form of emulsified particles allowed increasing their retention in the curd, hence maintaining their bioactivity and the chemical stability of cheese during storage, with improved cheese yield (Stratulat *et al*., 2014).

EXTENSION OF SHELF LIFE BY MODIFIED ATMOSPHERE PACKAGING (MAP)

Maintaining cheese quality during storage requires protection against dehydration and reduction of undesirable microorganisms, especially pathogens. Protection against dehydration can be achieved by using packaging films with low water vapor transmission: semi-barrier (polypropylene, low density polyethylene) or barrier films (aluminum, polyvinylidene chloride, polyvinyl chloride, orientated polypropylene, high density polyethylene (Day, 1992). The use of MAP may reduce contamination levels but the sensory characteristics and their evolution throughout the storage time are also important. Some authors have pointed out the adverse effects of CO_2 on sensory characteristics (Scott and Smith, 1971; Daniels *et al*., 1985) (Table 1).

The potential of MAP for extending commercial life of cheese has been clearly demonstrated, although cheese packaging is dependent on the type of cheese, the starter used during manufacturing and storage conditions, among very important parameters (Gammariello *et al*., 2009). MAP has been studied for many type of cheeses in occasions to different conclusions (Table 2).

The use of protective atmospheres made up of 100% N_2 or 100% CO_2 has often proved unsuitable for packaging of hard or semi-hard long ripened cheeses such as Cheddar cheese (Colchin *et al*., 2001), Parmigiano Reggiano cheese (Romani *et al*., 1999) and Samso cheese (Juric *et al*., 2003), as it does not guarantee an optimal preservation and negatively influences the product's organoleptic characteristics, thus making the use of different mixtures of the two gases preferable. Conversely, carbon dioxide concentrations ranging from 10-50% have given interesting results both for preservation and for sensory characteristics of several dairy products, such as Cottage cheese (50% CO_2) (Fedio *et al*., 1994), Parmigiano Reggiano cheese (30% CO_2) (Romani *et al*., 2002), Samsø cheese (20% CO_2) (Juric *et al*., 2003), Taleggio cheese (10% CO_2) (Piergiovanni *et al*., 1993). Generally, when packaging fresh cheeses, atmospheres with a high CO_2 concentration (75%) guarantee the best preservation, since CO_2 inhibits microbial growth; has no negative effect on product (Eliot *et al*., 1998; Maniar *et al*., 1994; Mannheim and Soffer, 1996).

EXTENSION OF SHELF LIFE BY HIGH PRESSURE

High Pressure Processing (HPP) in the range of 200-700 MPa is a non-thermal processing technology capable of prolonging the shelf-life of a number of food products. In the last 20 years, application of this technology for reduction of microbial contaminations in different food matrices has been widely studied (Bermudez-Aguirre and Barbosa-Canovas, 2011; Farkas and Hoover, 2000; Martinez-Rodriguez *et al*., 2012; Rastogi *et al*., 2007). High Pressure Processing (HPP) has already become a commercially implemented technology, spreading from its origins in Han and Floros (1997) and slowly introduced into other countries such as USA and Spain. Equipment for large-scale production of HPP products is commercially available nowadays, showing a fast increase in the number of units installed during the last 10 years (Bermudez-Aguirre and Barbosa-Canovas, 2011). Application of high pressures can cause inactivation of parasites, plant cells, vegetative microorganisms, some fungal spores, many food borne viruses and inactivation of enzymes. Macro molecules can change conformation. Small molecules (e.g., flavors) are generally unaffected.

Evert-Arriagada *et al*. (2014), evaluated commercial application of high-pressure processing for increasing starter-free fresh cheese shelf-life. In this study, one of the first commercial industrial-scale applications of HPP on a starter-free fresh cheese, with the aim of increasing its shelf-life, is presented. The effect of 500 MPa (5 min, 16°C) on physicochemical, microbial, color, microstructure, texture and sensorial characteristics of starter-free fresh cheeses during cold storage of 21 days was studied. The results showed that pressurized cheeses presented a shelf-life of about 19-21 days when stored at 4°C, whereas control cheese became unsuitable for consumption on day 7-8. On the other hand, cheese treated at 500 MPa was firmer and more yellow than the untreated one. However, these changes which were detected by instrumental and sensory analysis, did not affect the preference for pressurized cheese. These results may lead to practical applications of HPP in the food industry to produce microbiologically safe cheese with extended shelf-life and sensory quality.

Table 1: References for extension shelf life of cheese by preservative

Preservative	Cheese type	Optimum amount	Target	Results	Author
Nisin	Ricotta	2.5 mg LG^1	*Listeria monocytogenes* over long storage (70 days)	Effectively inhibit the growth of *L. monocytogenes*	Davies *et al.* (1997)
Nisin Z in liposomes and *in situ* production of nisin Z by *L. lactis* subsp. lactis biovar diacetylactis	Cheddar	300 IU gG^1 and	The inhibition of *Listeria innocua* during 6 months of ripening.	Encapsulation of nisin Z in liposomes improve nisin stability and inhibitory action	Benech *et al.* (2002)
Nisin Producing Culture and Liposome-encapsulated Nisin	Cheddar	300 IU gG^1	The inhibition of *Listeria innocua* during 6 months of ripening	Same	Benech *et al.* (2003)
Chitosan	Mozzarella		Improve the shelf-life	Inhibited the growth of some spoilage microorganisms such as coliforms	Altieri *et al.* (2005)
Nisin	Galotyri	150 IU LG^1	Stored aerobically under refrigeration for a period of 42 days	Extended the shelf-life to 21 days (N_2) with good sensory characteristics.	Kykkidou *et al.* (2007)
Lysozyme and Na_2-EDTA	Mozzarella	0.25 mg mLG^1 and 10, 20 and 50 m mol LG^1	Growth of coliforms and *Pseudomonadaceae*	Extend the shelf life of mozzarella cheese	Sinigaglia *et al.* (2008)
Phospholipid nano vesicles containing a bacteriocin-like substance			Control of *Listeria monocytogenes*	The encapsulated BLS showed inhibitory activity against *L. monocytogenes*	Teixeira *et al.* (2008)
Non-starter lactic acid bacteria	Tosèla			Influenced positively the sensory characteristics and shelf-life of the final product	Settanni *et al.* (2011)
Nisin	Lighvan	200 IU gG^1	Physicochemical properties	Extension shelf life	Amir *et al.* (2013)
Nisin, natamycin and/or their combination	Galotyri	Nisin (100 IU gG^1), (200 IU gG^1), Natamycin (0.01% w/w), (0.02% w/w)	Improve the shelf-life	Shelf life data, longest for N_1- NA_1, N_1-NA_2, N_2-NA_1 and N_2-NA_2 cheese samples (>28 days)	Kallinteri *et al.* (2013)
Lactobacillus amylovorus as an antifungal	Cheddar		Appearance of *Penicillium* growth	Six-day delay in the appearance of mycelia on the cheese surface	Lynch *et al.* (2014)
Ozone	Mozzarella			Water acting as carrier of spoilage microorganisms can be successfully treated with ozone in order to reduce microbial cheese contamination	Segat *et al.* (2014)

Table 2: References on modified atmosphere packaging of cheese

Cheese type	MAP conditions studied (%)	Optimal MAP (%)	Effect of CO_2 on sensory properties	Author
Cottage	100 N_2; 100 CO_2	None	Yes	Scott and Smith (1971)
Cottage	100 N_2; 100 CO_2	Both	Yes	Rodrigues-Aguilera *et al*. (2011a)
Fresh cheese	61.7/26.3/6.6 $CO_2/N_2/O_2$; Air	61.7/26.3/6.6 $CO_2/N_2/O_2$	No	Rodrigues-Aguilera *et al*. (2011b)
Taleggio	100 N_2; 10/90, 20/80, 30/70 CO_2/N_2; Traditional wrapping	10/90 CO_2/N_2	Yes (20 and 30)	Piergiovanni *et al*. (1993)
Cottage	100 CO_2; 75/25 CO_2/N_2	100 N_2 100 CO_2; 75/25 CO_2/N_2	No	Rodrigues-Aguilera *et al*. (2011a)
Cottage	100 CO_2; Air	100 CO_2	No	Mannheim and Soffer (1996)
Mozzarella	100 CO_2; 50/50 CO_2/N_2	100 N_2, 100 CO_2	No	Rodrigues-Aguilera *et al*. (2011b)
Mozzarella	Air; 100 N_2; 10/90, 25/75, 50/50, 75/25	75/25 CO_2/N_2	Not indicated	Eliot *et al*. (1998)
Cameros	Air; 20/80, 50/50, 40/60 CO_2/N_2; 100 CO_2; Vacuum	50/50 or 40/60 CO_2/N_2	Yes (100)	Olarte *et al*. (1999)
Requeijao	100 N_2; 50/50 CO_2/N_2; 100 CO_2; Air	50/50 CO_2/N_2; 100 CO_2	No	Rodrigues-Aguilera *et al*. (2011a)
Requeijao	Air; Vacuum	Vacuum	No	Rodrigues-Aguilera *et al*. (2011b)
Parmigiano Reggiano	50/50, 30/70 CO_2/N_2; Vacuum	50/50, 30/70 CO_2/N_2	No	Rodrigues-Aguilera *et al*. (2011a)
Provolone	100 CO_2; 10/90, 20/80, 30/70 CO_2/N_2;	30/70 CO_2/N_2	Yes (100)	Favati *et al*. (2007)
Greek whey cheese	30/70, 70/30 CO_2/N_2; Vacuum	30/70, 70/30 CO_2/N_2	No	Papaioannou *et al*. (2007)
Stracciatella cheese	CO_2:N_2:O_2 gas mixtures [50:50:0 (M_1), 95:5:0 (M_2), 75:25:0 (M_3) and 30:65:5 (M_4)	M_1 and M_2	No	Gammariello *et al*. (2009)
Arzúa-Ulloa	Vacuum packaging (VP) and (MAP)-100 N_2 and 20 O_2/80 N_2	(MAP)-100 N_2 and 20 O_2/80 N_2	No	Rodriguez-Alonso *et al*. (2011)
Anthotyros	MAP_1:40 CO_2, 55 N_2, 5 :O_2, MAP_2: 60 CO_2, 40 N_2 and MAP_3: 50 CO_2, 50 N_2	MAP_2	No	Arvanitoyannis *et al*. (2011)
Graviera	MAP_1: 40 CO_2/55 N_2/5 O_2, MAP_2: 60 CO_2/40 N_2 and MAP_3: 50% CO_2/50 N_2.	MAP_2	No	Arvanitoyannis *et al*. (2011)
Surface mould ripened cheese	0% O_2, 27±6% CO_2 and 2 ± 1% O_2, 19 ±2% CO_2	2 ± 1% O_2, 19±2% CO_2	No	Rodrigues-Aguilera *et al*. (2011c)
Sliced Mozzarella cheese	Vacuum (V) and using a gas mixture of equal parts of CO_2 and N_2 (G)	Both	No	Olivares *et al*. (2012)

Hossein (2008) evaluated the possibility of using HPP to extend the refrigerated shelf-life of fresh cheeses by controlling the outgrowth of spoilage yeasts and moulds and the continued acidification by starter bacteria was investigated in a commercially manufactured fresh lactic curd cheese (pH 4.3-4.4) and fermented milk models (pH 4.3-6.5). The effects of HPP at 300 and 600 MPa on inactivation of glycolytic enzymes of lactic acid bacteria were also evaluated. Fresh lactic curd cheeses made from pasteurized bovine milk using a commercial *Lactococcus* starter preparation were vacuum packaged and treated with high pressures ranging from 200-600 MPa (at 22°C, for 5 min) and subsequently stored at 4°C for 8 weeks. In samples subjected to 300 MPa pressures, the outgrowth of yeasts and moulds was effectively controlled for 6-8 weeks. Treatment of cheese within the range of 300-600 MPa had no significant effect on variation of titratable acidity within the first three weeks of storage, although it reduced the viable count of *Lactococcus* by 5-7 logs.

EXTENSION OF SHELF LIFE BY ACTIVE COATINGS

Active packaging is one of the innovative food packaging systems that has been introduced in market. Major active packaging techniques include substances that absorbing moisture, oxygen, carbon dioxide, ethylene, flavors and odors or releasing carbon dioxide, antimicrobial agents, antioxidants, flavors. Several applications of active packaging systems that have been commercialized including oxygen-scavenging, carbon dioxide-absorbing, moisture-scavenging (desiccation) and antimicrobial systems. Oxygen-scavenging systems have been commercialized in the form of a sachet that removes oxygen. An oxygen-free environment can prevent food oxidation and rancidity, as well as the growth of aerobic bacteria and mold. In summary, the major objective of active packaging technology development is to design functional packaging materials that contain chemically or physically active substances that are released in a specific, controlled manner (Vermeiren *et al*., 1999).

The most important active coating systems include antimicrobial materials. Independently of the technique used for incorporation, the antimicrobial packaging systems are divided in two main categories: (1) Those in which the anti-microbial agent migrates from the package into the food and (2) Those in which the antimicrobial remains immobilized in the package.

Different incorporation mechanisms are currently being used in food industry include:

Addition of sachets: This technique has been applied for volatile compounds from essential oils (Nadarajah *et al*., 2005). No direct surface contact occurs and volatile antimicrobials are released into the headspace of the package where they retard the growth of pathogenic bacteria (Skandamis and Nychas, 2000).

Dispersion of antimicrobial agents in the packaging polymer: Antimicrobials can be incorporated by extrusion, heat-press, or casting. The main disadvantage of extrusion is the use of high temperatures and shearing forces that can reduce antimicrobial activities. Heat-resistant antimicrobials such as nisin and imazalil are suitable for these packages (Han and Floros, 1997).

Coating or dipping-Coatings and dips serve as carriers of antimicrobial compounds and are in direct contact with the food surface: The advantages of this method are that the compounds are not exposed to excessive heat (Cho *et al*., 2009) and can be applied at any stage of the food supply chain (Rodrigues and Han, 2000; Rodrigues *et al*., 2002).

Antimicrobial macromolecules with film-forming properties: This is the case of the polymer chitosan (Srinivasa and Tharanathan, 2007).

To design an antimicrobial package, it is essential to select the right antimicrobial agent for the right package and food and to strike a balance between release of the antimicrobial and microbial growth. Antimicrobial-package, package-food interactions and environmental conditions are crucial for ensuring the efficacy of a system. Mechanical, physical, chemical and microbiological mechanisms determine the efficacy of a particular antimicrobial package for a specific food. Only multidisciplinary investigations can explore all the potential applications of packaging systems and make them viable for commercialization. Packaging materials can be formed by biodegradable materials such as starch, cellulose, proteins, hydroxyl butyrate and hydroxyl valerate, or other synthetic materials derived from petroleum polymers such as polyethylene and polystyrene. Natural biopolymers, for example, could be easily used in conventional processing lines (Cutter, 2006).

Experimental active packaging systems that have been used for prolong of cheese shelf life summarized in Table 3.

EXTENSION OF SHELF LIFE BY EDIBLE COATINGS

Edible films and coatings are produced from edible biopolymers and food-grade additives. Film-forming biopolymers can be proteins, polysaccharides (carbohydrates and gums), lipids, or a mixture of these (Gennadios *et al*., 1997). Plasticizers and other additives are combined with the film-forming biopolymers to modify the physical properties or other functionality of the edible films. Edible films and coatings protect from physical, chemical and biological deterioration. The application of edible films and coatings can readily improve the physical strength of food products, reduce particle clustering and improve visual and tactile features on product surfaces. It can also protect food products from moisture migration, microbial growth on the surface, light-induced chemical changes and oxidation of nutrient.

Edible coating has been used for extension shelf life of cheese for several years. Proteins (casein, whey protein, wheat gluten), polysaccharides (starch, modified starch, modified cellulose, alginate, carrageenan, chitosan, gellan gum, chitooligosaccharides (COS)), lipids (sunflower oil, Tween 20, waxes (beeswax)) as film-forming materials; glycerin, propylene glycol, sorbitol, sucrose, polyethylene glycol, corn syrup and water as plasticizers and antioxidants, antimicrobials, nutrients, nutraceuticals, pharmaceuticals, flavors, colors as functional additives have been used for extension shelf life of cheeses. Several coating application methods including dipping, dripping, foaming and fluidized bed coating have been studied.

Experimental edible coating packaging systems that have been used for prolong of cheese shelf life summarized in Table 4.

EXTENSION OF SHELF LIFE BY COMBINED METHODS

Combination of some methods that described above can effect positively the shelf life of cheese. Del Nobile *et al*. (2009) evaluated the combination of chitosan, coating and modified atmosphere packaging for prolonging Fior di latte cheese shelf life on the packaged cheese stored at 4°C microbiological, pH, gas composition and sensory changes were monitored over an 8-day period. Results showed that the combination of chitosan, active coating and MAP improved “Fior di latte” cheese preservation in comparison with the traditional packaging. In fact, the latter showed a very short shelf life limited to more or less 1 day, whereas the integrated approach developed in this

Table 3: Experimental active coatings for extension shelf life of cheese

Antimicrobial agents	Packaging mterials	Cheese	Microorganisms	References
Imazalil	LDPE	Cheddar	*Penicillium* spp.	Weng and Hotchkiss (1992)
Benzoic acid	LDPE	mozzarella	Moulds	Dobias *et al*. (2000)
Chitosan	-----	Emmental	*L. monocytogenes*, *Listeria innocua*	Coma *et al*. (2002)
Allyl isothiocyanate	Paper pad	Danish Danbo	*Penicillium* spp., *Geotrichum* spp., *Aspergillus* spp.	Winther and Nielsen (2006)
Oxygen absorbers (by Atco)	PA/PE laminate	White cheeses	Yeast and moulds and coli group	Panfil-Kuncewicz *et al*. (2006)
Humidipak/perforated plastic	Humidipak/perforated plastic	Saloio		Pantaleao *et al*. (2007)
Natamycin	Cellulose	Gorgonzola	*Penicillium roqueforti*	De-Oliveira *et al*. (2007)
Lemon extract	Agar	Mozzarella	Total bacteria	Conte *et al*. (2007a)
Lysozyme	Polyviny alcohol		*M. lysodeikticus*	Conte *et al*. (2007b)
Lysozyme chickpea albumin extract (CPAE), bovine serum albumin (BSA) and disodium EDTA	Zein		*Escherichia coli* and *Bacillus subtilis*	Güçbilmez *et al*. (2007)
Basil extract linalool or methyl chavicol	LDPE	Cheddar	Total bacteria	Suppakul *et al*. (2008)
Lysozyme	Cellulose acetate		*E. coli* and *Bacillus amyloliquefaciens*	Gemili *et al*. (2009)
Natamycin	Wheat gluten (WG) and methyl cellulose (MC) biopolymers	Kashar	*A. niger* and *Penicillium roquefortii*	Ture *et al*. (2011)
BHT	LDPE	Asadero	Oxidation and odor stability	Soto-Cantu *et al*. (2008)
Silver nanoparticles	Agar haydrogel	Fior di Latte	Total bacteria	Conte *et al*. (2011)
Chitosan	Whey protein film	Ricotta	*Mesophilic* and *Psychrotrophic*	Di Pierro *et al*. (2011)
Sorbic acid	Lacquer	Gouda	*Escherichia coli*, *Listeria monocytogenes* and *Saccharomyces cerevisiae*	Hausera and Wunderlicha (2011)
Chitosan	Whey protein film	Ricotta	*Mesophilic* and *Psychrotrophic*	Di Pierro *et al*. (2011)
Cinnamaldehyde	Gliadin films	Pasteurized white	*Penicillium expansum* and *Aspergillus niger*	Balaguer *et al*. (2013)
TiO_2	HDPE	Short-ripened	Lactic acid bacteria and coliforms	Gumiero *et al*. (2013)
Lysozyme	Alginate Nano-laminate	Coalho	Total bacteria	Medeiros *et al*. (2014)
Potassium sorbate (PS), sodium benzoate (SB), calcium lactate (CL) and calcium ascorbate (CA)	Sodium alginic	Mozzarella	Total bacteria	Lucera *et al*. (2014b)
Essential oil from Origanum vulgare (OR) and Ethyl Lauroyl Arginate HCl (LAE)	Polypropylene and polyethylene terephthalate	Zamorano	*Escherichia coli* O157:H7 strains	Otero *et al*. (2014)
Sorbic acid/sorbates	OE, BOPP, PET		Migration test	Han and Floros (1998a, b)

Table 4: Experimental edible coatings for extension shelf life of cheese

Coating type	Active material	Cheese type	Target	References
k-carrageenan, alginate and gellan		White brined cheeses	Phsiycal e and sensory evaluation	Kampf and Nussinovitch (2000),
Chitosan		Emmental	*L. monocytogenes*	Coma *et al.* (2002)
Casein	Natamycin	Kashar	mould growth	Yildirim *et al.* (2006)
Agar, gluten and methyl cellulose	Natamycin (NA), rosemary extract (RE) and NA+RE		*Aspergillus niger* and *Penicillium roquefortii*	Ture *et al.* (2008)
Galaktomannan, chitosan		Regional	Cheese spesification	Cerqueira *et al.* (2010)
Wheat gluten (WG) and methyl cellulose (MC)	Natamycin	Kashar	Growth of *Aspergillus niger* and *Penicillium roquefortii*	Ture *et al.* (2011)
Sodyum cazeinat (SC) chitosan (CH) SC/CH coatingr		Cheese	Antimikrobiyal activity	Moreira *et al.* (2011)
Beeswax		Kashar	Mould counts	Yilmaz and Dagdemir (2012)
Whey protein isolate, glycerol, guar gum, sunflower oil and Tween 20	Lactic acid, natamycin and chitooligosaccharides	Queijo Saloio	water loss, hardness and color	Ramos *et al.* (2012a)
Whey protein isolates as a base material and glycerol as a plasticizer	Chitooligosaccharide, lactic acid and sodium benzoate	D. Pedro	Gram-negative and Gram-positive bacteria, yeast	Ramos *et al.* (2012b)
Starch-chitosan(WSC) Mung bean starch-Chitosan (MSC)		Mongolian cheese	Cheese spesification	Mei *et al.* (2013)
Tapioca starch	Natamycin and nisin	Port Salut cheese	*Saccharomyces cerevisiae* and *Listeria innocua* in a mixed culture	Resa *et al.* (2014)
Sodium alginat Probiyotic (*Lactobacillus rhamnosus*) and prebiyotic fructooligosaccharides		Fiordilatte	*Pseudomonas* spp. ve *Enterobacteriaceae*	Angiolillo *et al.* (2014)

study allowed us to obtain a significant shelf life prolongation to 5 days, most probably due to the synergic effect between the active compounds and the atmospheric conditions in the package headspace.

Conte *et al*. (2011) evaluate the effect of active coating and modified-atmosphere packaging to extend the shelf life of Fior di Latte cheese. The active coating was based on sodium alginate (8% w/v) containing lysozyme (0.25 mg mLG^1) and EDTA, disodium salt (Na_2-EDTA, 50 mM). The MAP was made up of 30% CO_2, 5% O_2 and 65% N_2. The speed of quality loss for the Fior di Latte cheese, stored at 10°C, was assessed by monitoring pH and weight loss, as well as microbiological and sensorial changes. Results showed that the combination of active coating and MAP improved Fior di Latte cheese preservation, increasing the shelf life to more than 3 days. In addition, the substitution of brine with coating could allow us to gain a double advantage: Both preserving the product quality and reducing the cost of its distribution, due to the lower weight of the package.

Gammariello (2011) investigated the bio-based coating containing silver-montmorillonite nanoparticles (0.25, 0.50 and 1.00 mg mLG^1) combined with MAP (30% CO_2, 5% O_2 and 65% N_2) on microbial and sensory quality decay of Fior di latte cheese. The combination of silver-based nanocomposite coating and MAP enhanced Fior di latte cheese shelf life. In particular, product stored in the traditional packaging showed a shelf life of about 3 days, whereas coated cheese stored under MAP reached a shelf life of more than 5 days, regardless of the concentration of silver nanoparticles. The synergistic effects between antimicrobial nanoparticles and initial headspace conditions in the package could allow diffusion of dairy products beyond the local area.

Conte *et al*. (2011) evaluate the Lysozyme/EDTA disodium salt and modified-atmosphere packaging to prolong the shelf life of burrata cheese. In this study, 3 concentrations of enzyme were combined with packaging in air and under MAP (95:5 CO_2:N_2). The decline in quality of burrata cheese stored at 8°C was assessed by monitoring microbiological and sensory quality, in addition to pH and headspace composition. The combination of lysozyme/Na_2-EDTA and MAP prolonged cheese shelf life, especially at the highest lysozyme concentration.

Lucera *et al*. (2014a) investigated the effect of active coating (based on sodium alginate (2%, wt/vol) and potassium sorbate (1%, w/v)) on the shelf life of low-moisture Mozzarella cheese packaged in air and MAP(75% CO_2 and 25% N_2 (MAP_1), 25% CO_2 and 75% N_2 (MAP_2), or 50% CO_2 and 50% N_2 (MAP_3)). Results showed that the combination of active coating and MAP was able to improve the preservation of low-moisture Mozzarella cheese. Specifically, the shelf life increased up to 160 days for samples stored at 4°C and 40 and 11 days for those at 8 and 14°C, respectively. A faster quality decay for untreated samples packaged in air was observed.

CONCLUSION

Cheese is a nutrient-dense dairy product and susceptible to physical, chemical and biochemical spoilage. Growing of mesophilic and psychotropic microorganisms, weight loss, oxidation of lipids and enzymatic decomposition are the main factors that affect the stability of cheese. Methods that can control of these factors, capable to extension of shelf life of cheese. MAP system can extend shelf life of cheeses but in this case temperature control and selection of proper packaging material is important. Addition of preservative can prolong shelf life of cheeses but in selection of proper additive, sensory properties of special cheese and dosage of additives must be considered. Although HP method can inactive parasites, plant cells, vegetative microorganisms, some fungal spores, many food borne viruses and enzymes, using of special equipment made it some expensive. On the other hand, applying HP in small plants is not feasible. Active and edible coating in order to prolong of cheeses shelf life has been increased in recent years. Because of diversity of cheese and subsequent difference in properties design of packaging system to each cheese must be specialized. Combination of described methods due to their synergies can extend shelf life more effectively.

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