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The Application of Essential Oils in Edible Coating: Case of Study on Two Fresh Cut Products

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Abstract

Essentials oils (EOs) among the natural compounds have been extensively investigated in recent years because of their antimicrobial and antioxidant activities. Thanks to their active components EOs can be added directly to the food, incorporated into packaging material, or used in a separate emitter.

The increasing interest in reducing packaging wastes is becoming a burgeoning problem, just considering that food packaging alone contributes to almost 66% of total packaging wastes by volume in the world. On the other hand consumers judge the food quality on the basis of appearance and freshness but also using their awareness of the environmental implications of packaging. Nowadays the application of edible films or coatings, from biodegradable materials or biopolymers, on food may reduce the package barrier requirements, incorporating natural bioactive compounds and prolonging shelf life.

Three case study on application of EOs on ready to cook products and on nutritional values were reported: the effects of anti-browning treatments and dipping in locust bean gum edible coating with or without *Foeniculum vulgare* EO on ready to cook globe artichoke slices; the addition of 0.5% (v/v) rosemary EO on potato slices packaged in sous vide bags; and the upgrade of the second study was the third on the evaluation on the nutritional content of cooked samples of slices potatoes. Sensory and microbiological data highlighted a good attitude of globe artichoke and potato slices to be processed with the addition of rosemary EO and cooked in sous vide bags. All nutritional components studied were slightly reduced after sous vide cooking. The ascorbic acid as well as total polyphenol content were well preserved after cooking, and the antioxidant activity calculated showed a loss mean value of 48% among cultivars, so we can conclude that sous vide cooked vegetables in comparison with boiled, steamed, or microwaved tubers retain nearly all their nutritive value.

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Introduction

Essential oils (EOs) were studied in depth in the past years. Already called volatile or ethereal oils they are aromatic oily liquids obtained from different plant material. One of the producing method was first used in the East (Egypt, India and Persia) and their use is mentioned by Greek and Roman historians [1], their history is as old as it is known.

The increasingly important public health issue as well as hygiene and food production techniques, concerning on food safety has meant that research has been moved through new methods of reducing or eliminating food borne pathogens, possibly in combination with existing methods, looking at the consumer attention desiring fewer synthetic food additives and products with a smaller environmental impact.

People demand for the use of natural antimicrobials instead of chemical antimicrobial agents move forward a wide spreading of the use of essential oils as additives in foods [2].

Many papers provided an extensive overview of the published data on the antibacterial activity of those EOs and their components and how they could be considered suitable for application in or on foods, describing also their possible modes of action [3].

Thanks to these previous data is possible to understand which EOs is more suitable for a food product rather than another one. Chemical composition was also extensively studied [4-19] and reported in Table 1. Tests of antimicrobial activity were performed, and most researchers cited the minimum inhibitory concentration (MIC) as a measure of the antibacterial performance of EOs; a selection of MICs for EOs and EO components tested in vitro against food borne pathogens was presented by Burt [3].

EOs are recognized as GRAS (generally recognized as safe) from Food and Drug Administration of US (FDA), most of the EOs and their components exhibit antibacterial properties, which are chiefly related to phenolic components [12] and consequently they are often used for the inhibition of pathogenic bacteria in foods. The main aromatic components identified in different essential oils as well as bacteria and yeast on which they have an inhibitory effects as reported in previous studies are detailed in Table 1.

Furthermore, due to the over or underuse of antibiotics, there has been a global emergence of multidrug-resistant microorganisms which reduces the efficacy of current antibiotic therapy and results in thousands of death. Indeed, considering last consumer concern on the recent environmental problems, EOs should be considered an excellent ally to reduce food waste, reducing microbial spoilage and increasing the shelf life of many kind of foods. To respond to many consumers' requests to reduce or eliminate the synthetic preservatives, plant derived compounds, such as EOs, are frequently used, often

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through dipping techniques or, more recently, by including them within plastic materials [20] or in edible coating [21].

Moreover plastic waste is causing a lot of public concern on their disposal, as well as chemicals used in their production, rightly, since food packaging alone contributes to almost 66% of total packaging wastes by volume in the world. The application of edible films or coatings, from biodegradable materials or biopolymers, on food, may reduce the package barrier requirements improving in such ways recycling process.

Edible packaging is defined as packaging consisting of an edible thin layer coated on a food or placed as a barrier between the food and the surrounding environment [22].

The increasing utilization of such biodegradable materials is linked with a reduction of volume, weight and costs of packaging. Considering how food undergoes deterioration from chemical and microbiological processes along the food chain production, edible packaging added with EOs could provide several benefits for foods such as preservation, maintaining foods quality and safety.

Fresh-cut products represent a good chance for the food industry to increase market sales with a type of product able to fully respond to the demand for healthy and convenient foods by modern consumers [20]. Minimally processed products are one of the rapid growing sectors in the food industry due to the convenience and nutritional value, but they are far more perishable and have a shorter shelf life of 4-10 days compared to the original raw material [23]; for this reason one of the last application of edible coating in the food sector is linked with the extension of the shelf life (Table 2). Value addition by processing into fresh-cut and minimally processed products is an attractive alternative since consumers will spend less time on food preparation [24]. Moreover, more than 1000 plants have been claimed to offer special

Essential Oil	Principal Components	%	References	Inhibitory Effects Against Bacteria and Yeast	References
Cilantro	Linalool	26%	Delaquis et al., 2002[18]		
	E-2-Decanal	20%			
Cinnamon	Trans-cinnamaldehyde	65%	Lens-Lisbonne et al., 1987[5]		
Clove	Eugenol	75-85%	Bauer et al., 2001[57]	E. coli; S. thphimurium; S. aureus; L. monocytogenes	Farag et al., 1989[58]; Smith-Palmer et al., 1998[59]; Hammer et al., 1999[60]
	Eugenyl acetate	8-15%			
Coriander	Linalool	70%	Delaquis et al., 2002[18]		
	E-2-Decanal	3-4%			
Oregano	Carvacrol	Trace-80%	Lawrence, 1984[4]; Prudent et al., 1995[7]	Escherichia coli S. typhimurium S. aureus	Prudent et al., 1995[7]; Hammer et al., 1999[60]; Burt and Reinders, 2003[61]
	Thymol	Trace-64%	Charai et al., 1996[8]; Sivropoulou et al., 1996[9]		
	g-Terpinene	2-52%	Kokkini et al 1997[10]; Russo et al., 1998[11]		
	ρ-Cymene	52%	Daferera et al., 2000[14]; Demetzos and Perdetzoglou, 2001[17]; Marino et al., 2001[13]		
Rosemary	a-Pinene	2-25%	Daferera et al., 2000[14]; Pintore et al., 2002[19]	E. coli S. typhimurium B. cereus S. aureus L. monocytogenes	Farag et al., 1989[58]; Smith-Palmer et al., 1998[59]; Hammer et al., 1999[60]Pintore et al., 2002[19]; Chaibi et al., 1997[62]
	Bornyl acetate	0-17%			
	Camphor	2-14%			
	1,8-Cineole	3-89%			
Sage	Camphor	6-15%	Marino et al., 2001[13]	Escherichia coli S. thphimurium S. aureus L. monocytogenes	Shelef et al., 1984[63]; Farag et al., 1989[58]; Smith-Palmer et al., 1998[59]; Hammer et al., 1999[60]
	a-Pinene	4-5%			
	b-Pinene	2-10%			
	1,8-Cineole	6-14%			
	a-Tujone	20-42%			
Thyme	Thymol	10-64%	Lens-Lisbonne et al., 1987[5]; McGimpsey et al., 1994[6]; Cosentino et al., 1999[12]; Marino et al.,1999[13]; Daferera et al.,2000[14]; Juliano et al., 2000[15]	E. coli S. thphimurium S. aureus L. monocytogenes	Farag et al., 1989[58]; Firouzi et al., 1998[64]; Smith-Palmer et al., 1998[59]; Cosentino et al., 1999[12]; Hammer et al., 1999[60]; Burt and Reinders, 2003[61]
	Carvacrol	2-11%			
	g-Terpinene	2-31%			
		10-56%			

Table 1: Principal components of essential oils and their inhibitory effects against bacteria and yeast.

benefits in the treatment of different disease, since dietary bioactive compounds from different functional foods, herbs and nutraceuticals (ginseng, ginkgo, nuts, grains, tomato, soy phytoestrogens, curcumin, melatonin, polyphenols, antioxidant vitamins, etc.) can ameliorate or even prevent diseases. Protection from chronic diseases of aging involves antioxidant activities, mitochondrial stabilizing functions, metal chelating activities, inhibition of apoptosis of vital cells, and induction of cancer cell apoptosis [25].

The term "nutraceutical" was coined in 1989 by the Foundation for Innovation in Medicine (New York, US; they may range from isolated nutrients, dietary supplements to genetically engineered "designer" foods, herbal products and processed products such as cereals, soups and beverages. Among food resources, one of the selected nutritive nutraceuticals are antioxidants [26].

Functional food has one or more compounds with biochemical and physiological functions beneficial to the human health. Anthocyanins, catechins, cyanidins and flavonols, all from food sources, are antioxidant nutraceuticals, that carry out their antioxidant activity by donating electrons and breaking radical-chain reactions, also as inhibition of LDL oxidation and often acting as superoxide scavengers [25].

The opportunity for consumer to find fresh-cut products rich in healthy compounds is very high and continues to grow, develop and evolve to offer new opportunities for new product development and marketing. As said before such products are far more perishable and the interest from researchers is moved to prolong their shelf life adopting integrated approaches.

Several studies have been done to determine the effects of edible coatings on fresh-cut fruit such as mango [27], papaya [28,29], pear [30], banana [31], pineapple [32-35] and strawberry [36] as well as on vegetables as red bell pepper [37].

The incorporation of antimicrobial agents in edible coatings may widen the functionality of coatings in protecting the fresh-cut fruit from microbial spoilage and thus extend their shelf-life [38].

For example, alginate-based edible coating formulation incorporated with 0.3% (w/v) lemongrass has potential to extend the shelf-life and maintain the quality of fresh-cut pineapple [39].

Increasing shelf life of fruits and vegetables for reducing postharvest disease and food waste during the supply chain is the main goal for the third millennium. Edible coating allows the opportunity to incorporate natural bioactive compounds as i.e. rosemary extracts that thanks to carnosol and carnosoic acid, inhibit peroxidation of oils operating as antioxidant nutraceuticals [25].

Among antioxidant compounds, EOs has been extensively investigated for their antimicrobial and antioxidant activities. Thanks to their active components EOs can be added directly to the food, enriching it in flavouring compounds, or incorporated into packaging material, or used in a separate emitter.

EOs are volatile, aromatic compounds of leaves, flowers, bark, stems, roots, resin, and seeds. They have many typical characteristics considering that different countries and different seasons give back different chemical composition and thus may exhibit different biological activities [40-43,2].

Additionally, their effect on the control of pathogenic microorganisms in foods is very important and there are many researches on this subject.

The ecological conditions of different countries may influence the chemical profile of the plant materials, because some compounds may be accumulated at a particular period in response to environmental conditions [42-49].

Consumer prefer the use of natural antimicrobials instead of chemical antimicrobial agents.

The emergence of multi-drug resistant strains due to incorrect use and overuse of existing antimicrobials is becoming a formidable threat in the fight against disease. Alternative natural therapies are often used as additional treatment regimens to fight infection.

Experiments

The globe artichoke is a natural source of minerals, fiber, inulin, and polyphenols, and in recent years its reputation as functional food and its economic value have increased, because inulin was confirmed as reducing blood cholesterol and triglyceride levels and for the ability to oppose the increase of glycemia [50].

A ready-to-cook (RTC) version of this product could improve its commercialization and consumption [21]. The effects of anti-browning treatments (citric acid 0.5% + ascorbic acid 2%, or cysteine 0.5%, w/v) and dipping in locust bean gum (LBG) edible coating with or without the addition of *Foeniculum vulgare* (EO) were studied. Physico-chemical traits, microbiological and sensory descriptors were determined [21].

Edible Coating	Food Applications
Alginate	Shelf life extension of fresh-cut pineapple[65, 66], guava [67], sauced silver carp [68]; developing an antibacterial film [69]; fresh-cut cantaloupe [70]; raspberry fruit [71]; fresh fruits [72]
Chitosan	Shelf life extension of guava [67]; of strawberries [73]; improve quality of cold-stored cucumber [74]; of raw grass carp [75]; of lamb meat [76];
Locust Bean Gum	Improving postharvest decay of mandarin fruit [77]; quality maintenance of white shrimps [78]
Metilcellulose	Conservation of red guava [79]; of plum [80]; postharvest quality of citrus fruit [81]; Shelf life extension of sauced silver carp [68]; of walnuts [82]; cold stored grapes [83]
Pectin	Minimize post-harvest decay of tomatoes[84]; shelf life extension of strawberry [85]; fresh cut apple [86]; raspberry fruit [71];

Table 2: Edible coating and some applications studied.

The results showed that, despite the antioxidant treatment used, when EO was added to LBG, all microbiological groups underwent an average reduction of 0.50 log CFU g^{-1}.

The ability of LBG edible coating with added EO in maintaining microbiological, physical, chemical, and sensory qualities, makes it a promising processing tool for the preservation of RTC globe artichoke slices during storage for 11 days at 4 °C [21].

The next case was aimed at assessing the suitability of six early potato cultivars, for minimal processing. In particular, the sous vide packaging method and 0.5% (v/v) of rosemary essential oil (REO) were evaluated as a strategy for the quality preservation of sliced potatoes. Physical, mechanical, chemical, microbiological and sensory characteristics were monitored [20].

Results demonstrated that the synergic use of REO and sous vide packaging had a positive effect on texture, and limited the growth of mesophilic bacteria (TMB) and Enterobacteriaceae (TEB) over the storage period; it also ensured a certain retention of ascorbic acid (AsAc), total phenol content (TPC) and antioxidant activity (AA).

The proposed technological strategy is a valid solution for the preservation of RTC sliced potatoes, contributing to limit the quality decrease until 11 days of cold storage, for the most suitable cultivars identified (Fontane and Marabel).

The addition of REO significantly ($P \leq 0.05$) controlled the growth of TMB and TEB when compared to the relative control samples, although with different efficacy among varieties.

The REO treatment reduced, at the end of storage, TMB counts differently among different cv, with any significant variation in Elodie cv. Conversely, the yeast and mould (YM) population was not affected by EO with the exception of Elodie cv, confirming how said before on different activity respect different microbial population.

Results showed that the synergistic use of REO and vacuum packaging, combined with refrigerated storage, can be a viable strategy for the quality preservation of minimally processed potatoes, intended to be cooked with the sous vide technique [20].

With regard to the sensory analysis, only potato samples without REO showed the negative descriptors off-odors and off-flavors at the end of the considered period, thus highlighting a good attitude of potato slices to be processed with the addition of REO and next cooking in sous vide bags.

The EO addition also ensured a certain retention of AsAc, TPC and AA. Among cultivars, Marabel reported a significantly higher TPC and the lowest reduction for the AsAc level during cold storage, underlining the importance of the cultivar choice as well as the environmental conditions in determining the overall quality of early potato tubers [51].

So, after the previous experiment, we hoped to detect such positive effect played by EOs, also after cooking process in sous vide bags on nutritional compounds.

Almost all information about the main nutrients in foods: AsAc, TPC and AA are often monitored in freshly harvested or in raw food products also in RTC products. So the upgrade of the previous work was to study how the nutritional content was affected by REOs addition and cooking in sous vide bags [52].

The AsAc content was slightly low in all samples, ranging from 4.9 to 3.2 mg/100 g of fresh weight, taking into account that this compound is commonly considered heating sensitive.

In particular, considering how the retention values of boiled tubers ranged from 54% to 97%, we can affirm that sous vide cooking probably thanks to the additional treatment with REO, better preserve the AsAc keeping values nearest to the raw tubers with moderate loss to a maximum of 20% in Erika.

TPC is well preserved after cooking, of course the varieties with the highest content are able to save a high amount of the compound studied; the AA was reduced in sous vide cooked potato slices, with a loss mean value of 48% among cultivars, Fontane showed the highest AA value and Erika the lowest whereas considering the reduction from initial AA on the raw material Elodie kept the highest AA content.

Conclusions

Considering results obtained from reported experiments and looking towards the aim of most recent papers and projects, some clear evidence are underlined.

In particular the interest in application of edible coating and EOs is increasing; new researches are focused on new methods of application of edible coating like nanoemulsion-based edible coatings enriched in EOs [53-54] as well as pointing out the activity of EOs against new resistant microorganism or against foodborne pathogens [55] and using nanoemulsions which contribute to support the use of EOs in foods [56].

Sure enough the use of EOs in consumer goods is expected to increase in the future due to the rise of 'green consumerism' improving nutritive quality for final consumers.

Results of cited experiments showed that the synergistic use of antioxidant treatment (anti-browning agent) and LBG coating with *F. vulgare* EO can be a valid strategy to preserve the quality of RTC globe artichoke slices. The positive and significant effect were on PPO inhibition, texture, color, AsAc, TPC, and AA. When EO was added to LBG, all microbiological groups underwent an appreciable decrease and the overall sensory attributes had the highest score [21].

The synergistic use of REO and vacuum packaging, combined with refrigerated storage, can be a viable strategy for the quality preservation of minimally processed potatoes, intended to be cooked with the sous vide technique. The addition of REO to the fresh-cut product had a positive effect on texture, and on the growth of mesophilic bacteria and Enterobacteriaceae over the storage period, also ensured a certain retention of AsAc, TPC, and AA and also on sensory analysis [20].

Looking at the positive results obtained previously, the synergistic use of REO and vacuum packaging, combined with refrigerated storage had a positive effect on nutritional compounds in minimally processed potatoes. Specifically on AsAc, TPC and AA that were slightly reduced after sous vide cooking. Of course among cultivars studied, exist a natural attitude to be processed and to keep the highest nutritive values. Nutritional characteristics pointed out in the experiment, were kept by the samples, suggesting as more study are require before EOs and sous vide cooking bags can be reliably used in commercial applications, as well as major investigations should be done on interaction with AsAc in food matrix [52].

Analysis of nutritional characteristics after the application of the different kind of edible coatings available and the enrichment with existing EOs should be improved, further study we'll be extend with these aims on different food materials.

Competing Interests

The Authors wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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