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Sodium alginate edible coating augmented with essential oils maintains fruits postharvest physiology during preservation: A review

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Abstract
Application of Edible coatings on food is an environment friendly technique to protect it from moisture loss, gas exchange or oxidation process. Edible coatings made up of different types of biological materials such as Lipids, waxes, carbohydrates, proteins, and polysaccharides. Sodium alginate edible coatings enhance the safety or even nutritional and sensory attributes of horticultural commodities. The uses of sodium alginate edible coating (polysaccharides) on Fruits to maximize their shelf life and quality discussed in this paper. Essential oils gaining more interest for food preservation due to their volatility and natural origin. The aim of this review is to summarize the most recent published and relevant advances concerning sodium alginate coating containing essential oils. Sodium alginate coating enriched with essential oils showed greater antimicrobial and anti-browning activities during fruits storage, and has significant effects on weight loss and shelf life of fruits. It enhances the security of many fresh and fresh-cut fruits and minimally processed fruits. Sodium alginate incorporated in essential oils forms a barrier and reduce exchange between environment and fruits and carry different natural antimicrobial agents to maintain characteristics and improve shelf life.

Keywords: edible coating, sodium alginate, antimicrobial agents, essential oils, antioxidant activity, shelf life

1. Introduction

Consumer's concern for safe, healthy fruits and prolonged shelf life of fruits increased day by day due to busy life style. Food industry need to meet consumer's demand and must give fresh fruits with least processing, ready to eat with minimal preparation with desired shelf life. A recent development to extend shelf life, to maintain health benefits and to prevent appearance and textural decay of fruits is the use of edible coatings. Edible coatings are characterized as a thin layer of material which can be devoured and give a boundary to moisture, oxygen and solute development to protect quality of fruits [1]. Edible coatings are an environment-friendly innovation that is used to maximize quality and shelf life of fruits. They act as agents to control moisture exchange, to control decay ratio and weight loss, oxidation procedures, to improve shelf life or even dietary and sensory qualities of fruits [2]. The best edible and biologically safe preservative coatings should have a film-forming ability, anti-microbial actions, lack of toxicity, biodegradable and biochemical properties. Edible films and coatings have been attracted more interest in the area of food preservation due to probable outcomes secured and have been freshly reviewed [3]. They have potential to carry active ingredients such as antioxidants, antimicrobials, anti-browning and anti-odorant agents. Essential oils incorporated in edible coatings receiving too much attention as they are natural source of active ingredients like antioxidants and have antimicrobial properties [4]. Sodium alginate coating enriched with essential oils significantly increases the storage life of fresh fruits. It acts as an obstruction to reduce gas transfer by reducing the rate of respiration. It prohibits the tissue softening and maintains the acidity and TSS during the storage period. It also effectively controls the process of enzymes which cause browning [5]. Sodium alginate coatings also incorporated with some active ingredients such as calcium chloride, beta-cyclodextrin, trans-cinnamaldehyde (antimicrobial), pectin, ficus Herta fruit extract which behave like a carrier of antimicrobial compounds and reduce microbial spoilage in fresh fruits.

This review discussed the potential application of sodium alginate edible coating alone and with essential oils for fruits preservation. This review base on the current situation of research and progress in the preservation of fruits. This review intended to focus on the composition of the sodium alginate coating and its relation to a mechanical barrier and active properties of essential oils. We hope that this review will give perception for researchers working in postharvest preservation.

2. Biological materials and application of edible coatings

Edible coatings are generally made up of different types of biological materials such as Lipids, waxes, polysaccharides, proteins, and essential oils (Table 1). Different types of coating materials have different characteristics. Lipids are usually hydrophobic in nature. Thereby which reduce moisture loss, show a decrease in weight loss and delayed fruit ripening [6].

Table 1: Types of edible coatings materials

Sr. No	Coating material	Food material used in coatings
1.	Lipids	Paraffin wax, beeswax, candelilla wax, carnauba wax, mineral oil, vegetable oil, acetylated monoglycerides, stearic acid, etc.
2.	Polysaccharides	Chitosan, Alginate, Cellulase, Pectin, starch, gums, Carrageenan etc.
3.	Proteins	Soy, milk, corn, wheat, casein, gelatin, Zein, eggs, albumin, etc.
4.	Essential oils	Lemongrass oil, sunflower, rosemary, Oregano, clove, cinnamon, etc.

Polysaccharide coatings are naturally abundant, low in cost, stabilizer and mostly renewable. Polysaccharide coatings are generally good gas barriers and have good adhering properties. However, their hydrophobic nature makes them a good barrier to moisture 7. Protein coatings are good blockers to oxygen and will adhere to hydrophilic surfaces but in most cases, they do not resist water vapor diffusion. Lipid-based coatings are made up of waxes and oils. These coatings are a good barrier to water loss.

Edible coatings are applied in liquid form as well as in solid sheets. They applied on fruits through dipping, spraying or brushing. Process flow chart of an edible coating of fruits was in Figure 1.

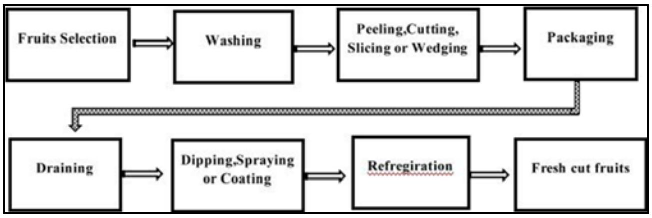

Fig 1: Process Flow chart for application of edible coatings

3. Alginate-based edible coating

Alginates are unbranched copolymers of (1→4)- connected β-D-mannuronic acid (M) and α-L-guluronic acid (G) conglomeration, If the uronic acid groups are in the acid form (–COOH), the polysaccharide *is* called alginic acid [8]. Procure of alginate assume a part in the food business, nourishment, materials, wellbeing and beauty care products. In the food business, alginates were utilized to balance out blends, scatterings, and emulsions, which expands consistency of gel Structures, for example, sticks, jams and edible coatings [9]. Alginate-based edible coatings have low water permeability, greater tensile strength. It has the potential to enhance long term quality and storage, stimulate the accumulation of phenolic compounds.

Sodium alginate is the sodium salt of alginic acid. Alginic acid is not soluble in water while sodium alginate is water soluble. Sodium-alginate is a natural polysaccharide consisting of linear polymers of α-L-guluronic (G) and β-D-mannuronic (M). It is originated from brown algae. Its chemical formula is $(C_6H_7NaO_6)$ n and its structural formula is presented in figure 2.

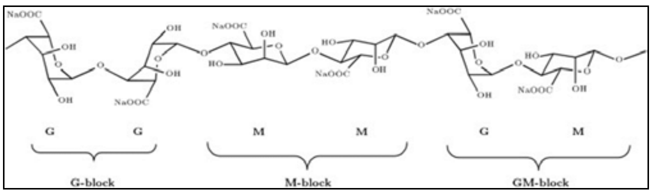

Fig 2: The structural formula of Sodium alginate

Sodium Alginate is a characteristic polysaccharide item separated from brown seaweed that grows in chilly water areas. The procedure of sodium alginate extraction from Brown algae was in figure 3. Sodium Alginate is able to dissolve in chilly and hot water with strong unsettling influence. Sodium Alginate makes a rigid and brittle film which is clear and transparent. Sodium Alginate coating is not affected by temperature. It is lingering and sticky in nature. Sodium Alginate takes place as white to yellowish brown threadlike, grainy, granular or powdered forms. It is an excellent stabilizer, thickener, gelling agent and emulsifier [10]. Sodium alginate and its derivatives have many biological activities like antioxidant, coagulant, antimicrobial, bio-compatible, wound healing, low toxicity, microenvironment, and tissue engineering effects. In addition, sodium alginate is an ideal edible coating due to its transparency biocompatibility, biodegradability, non-toxicity, physicochemical properties, rheological activities, and film forming ability. Sodium alginate edible coatings show great improvement for their application in fruits preservation [11].

Sodium alginate films and coatings are promising systems to be used as carriers of active ingredients. Active ingredients incorporated with sodium alginate coatings received much attention because of the higher potential for biological activities. Active ingredients like cinnamon, eugenol, citral, and carvacrol in the form of essential oils incorporated in Sodium alginate coating for storage of fruits. Sodium alginate coating contains essential oils can significantly enhance the shelf life of fruits.

Sodium alginate coating is able to reduce weight loss, prevent moisture loss by decreasing transpiration. It has efficient mechanical properties like it delays the browning index by decreasing enzymatic activities.

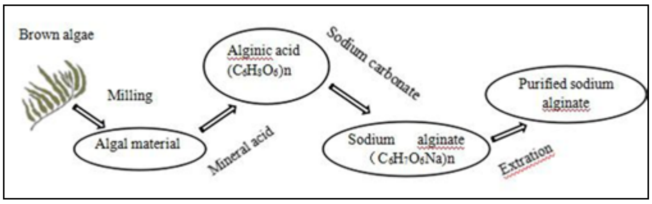

Fig 3: The procedure of sodium alginate extraction from Brown algae

4. Essential oils

Essential oils are naturally occurring volatile organic compounds which extracted from different parts like flowers, fruits, seeds, stems and leaves of plants, spices and herbs. Essential oils are basically colorless liquids which are volatile and have specific aroma and flavor [12]. On basis of chemical composition essential oils consists of terpenes, terpenoids, phenylpropenes, aldehydes, ketones, ethers, and phenolics which exhibit great antioxidant and antimicrobial potential. Essential oils play vital role different fields like food preservation, pharmaceuticals, cosmetics, perfume industry and in drug delivery system due to their antimicrobial and antioxidant properties. Different essential oils have different active ingredients which are responsible for their antioxidant activities like thymol, citral, eugenol, carvacrol belongs to basil and thyme and oregano oil [13]. Essential oil has limited use for preservation of fruits because of their pungent fragrance, toxicity and high cost. Due to this direct use of essential oil cause rejection of consumer for commodity and also lose its effectiveness with time being. In this scenario, to maintain effectiveness of Eos, a recommended approach is to reduce doses of Eos for fruits preservation and could be incorporated in edible coatings. The aim of this review is to focus on this approach to summarize relevant and recent publications about sodium alginate coating containing Eos and its mechanism of action with or without Eos.

5. Mechanisms effected by Sodium Alginate edible coating enriched with essential oils

5.1 Microbial activity

Microbial activity cause postharvest losses and affects fruits nutrition as well consumers health. Antimicrobials could destroy microorganisms that might carry diseases and cause microbial spoilage. Many factors, such as pH, humidity, water availability, nutrients, oxidation-reduction reaction, physiological and morphological structures of commodity and the possible presence of natural antimicrobial agents, affect the antimicrobial activities [14]. An antimicrobial edible coating could be a compelling postharvest strategy to guarantee microbial safety and, in the meantime, hold the general nature of the fruits. Fresh fruits are a basic portion of a healthy diet, and capable to reduce the hazard of many cardiovascular diseases. Fresh fruits as a whole and fresh-cut fruits are more vulnerable to the attack of microorganisms like fungi, bacteria, viruses, yeasts, and parasites. Sodium alginate can be employed as a carrier for integrating active elements, also used for the synthesis of antimicrobial or nutraceutical compounds that could enhance the effectiveness of sodium alginate to reducing microbial spoilage without affecting sensory and nutritional qualities [15]. Many studies have demonstrated the wide range of antimicrobial activity of essential oils with sodium alginate edible coating. Sodium alginate coating enriched with essential oils employs a wide spectrum antimicrobial activity in opposition to bacteria and fungi. It can possibly postpone the onset of parasitic deferral and delay the development of mold capacity as a boundary against the gaseous exchange. Sodium alginate coating has the function of carrying antimicrobial agents, and reduce microbial decay significantly. So these coatings enriched lemongrass essential oil are preferred to preserve quality and postharvest life fresh-cut pineapple and diminish the danger of microbial development significantly as compared to other treatments [16]. The antimicrobial properties of sodium alginate edible coating were analyzed by comparing the counts of yeast for fresh-cut fuji apples which showed significant results of microbial spoilage decrease without affecting sensory and nutritional qualities of fresh-cut fuji apples. It has been reported that sodium alginate coating carry different essential oils as natural antimicrobial agents to maintain characteristics, reduce microbial attack and enhance security of many fresh and fresh-cut fruits and minimally processed fruits such as fresh-cut pears and apples strawberry, Fresh cut nectarines, fresh-cut cantaloupe, fresh-cut melon, grapes minimally processed peaches, and Chinese winter jujube [17]. Sodium alginate has great potency against the microbial activity. Similarly, sodium alginate with essential oil like citral, eugenol, carvacrol, limonene, cinnamon and lemongrass applied on different fruits showed high antioxidant capacity and retard the growth of *Escherichia coli*, *Staphylococcus aureus*, fungal activity and microbial deterioration.

5.2 Browning activity

Color is one of the most important elements to observe the quality and perishability of fruits. The characteristic pigments, such as chlorophylls, carotenoids, and anthocyanins, make the chemical foundation of color. Discoloration, enzymatic and non-enzymatic browning is primarily determined by PPO activity and peroxidase activity. Browning is caused by the interaction of polyphenol oxidase (PPO) with the phenols released during minimal processing. PPO and peroxidase lower the antioxidant activities of fruits by decreasing the anthocyanins and other polyphenol's content which leads to browning [18]. Sodium alginate indicated a remarkable control in PPO and peroxidase activities in fresh-cut nectarines during storage which delay flesh browning, postharvest aging and maintain quality. While a high rate increase in these activities showed in control samples. Combination of essential oils as anti-browning agents with sodium alginate coating suppressed the PPO and peroxidase activities to delay browning in fresh-cut pears for two weeks without affecting the firmness of fruit wedges of fresh cut pears [19]. Anti-browning activities of NaAlg coating also observed on fresh-cut kent mangoes when it is used with a combination of ascorbic acid and citric acid. The utilization of alginate edible coating in association with anti-browning agents (ascorbic and citrus extract) to mango cubes kept up higher shading values (L* and °Hue) and expanded vitamin C content contrasted with mango cubes treated just with alginate coating or control [20]. Browning is the main factor which is directly related to the shelf life of fruits and consumer’s purchase decision. Essential oils incorporated into sodium alginate coating to delay browning have been investigated and showed excellent anti-browning activities in fresh-cut cantaloupe, *Arbutus unedo L.* fresh fruit, fresh-cut melons, fresh cut pears and apples. Table grapes bright color and glossiness due to the anthocyanin’s pigments and polyphenolic compound present in it which show instability during storage due to PPO and peroxidase activities. Table grapes color and glossiness maintained by treating with NaAlg coating during storage which inhibit browning mechanism. Fruits coated with sodium alginate inhibits the PPO activities and enhances anti-browning activities which delay color changes and browning index. Color change in fruits mostly measured by chromameter and the apparatus was calibrated by using a standard white plate. Sodium alginate composite film could significantly reduce the browning index by reducing PPO and peroxidase activities.

5.3 Weight loss

Fruits are alive after harvest; all physiological processes continue such as respiration and water loss. Weight reduction of fruits connected with the rate of respiration and water vanishing through the skin. The water loss causes weight loss due to which sale decrease and direct economic loss [21]. Respiration includes the oxidation of starches to create carbon dioxide, water, and warmth. These biochemical changes increase the rate of respiration which causes weight reduction. This undesirable procedure causes deterioration of starch substance including loss of nutrition value, changes in texture and flavor weight and loss of weight. The lean skin of fruits makes them water vulnerable to quick water loss, bringing about wrinkling and weakening. Fresh cut fruits are more susceptible to invasion of microorganisms. Microorganisms speed up some biochemical changes like the deterioration of sugars, actuation of more ethylene production, increase enzymatic activities and generation of new metabolites. Sodium alginate edible coating act as a semipermeable boundary to limit water exchange. This decrease moisture loss, respiration rate, oxidative responses and delay physiological aging of fruits. Sodium Alginate coating shield fruit skin from mechanical wounds and little injuries as well as delay dehydration [10]. It was reported that Sodium alginate application to fresh fruits can prevent weight loss. Postharvest exogenous application of Sodium alginate edible coating led markedly to reduce weight loss and acidity loss in sweet cherry fruit during 21 days of storage at 4°C. It was also that William pears treated with 2% sodium alginate coating stored at 25°C for 15 days showed the least weight reduction. 2% sodium alginate coating has lower water vapor permeability and good elasticity; hence it could be used as a preservative film for these fruits [22]. Some studies have shown that sodium alginate coating can maintain quality parameters and inhibit water loss from fruits like mango, Malu grapes, and golden silk jujube respectively. The weight loss seems to be the superior factor to know about the storage life and quality of fruit. Essential oils are also added with sodium alginate coating to retain moisture loss and other sensory qualities. The addition of essential oils and surfactants improves the water holding ability of the coating. It is found that alginate edible coatings connected to fresh-cut apples were powerful in controlling water reduction when the formulation contained 0.025 ml sunflower oil/100 ml film framing arrangement. In this way, the utilization of sunflower oil could keep up surface because of the oil-interceded moisture maintenance of the covered fruit [23]. Reduction of weight in fresh fruits mainly caused by water loss due to respiration and transpiration activities. In the strawberry fruit, it is supposed that major cause of moisture loss is thin peel. As strawberry stored for 5days at 20 ◦C, Yan fan and others (2009) found that strawberry coated with sodium alginate reduced weight loss as compared to control, and was sufficient to maintain a good appearance and quality. It implied that under cold storage conditions the sodium alginate alone and with essential oils coating was gainful for the shelf life of the fruits.

5.4 Antioxidant activity

Fruits are full of minerals, vitamins, and antioxidants which protect from cancer and cardio- and cerebrovascular diseases. Fruits are necessary for human health because great source of polyphenols which contribute to diet natural antioxidants [24]. Antioxidants prevent from the risk of many diseases such as endothelial dysfunction which was associated with age affiliated ailments like atherosclerosis, hypercholesterolemia, and hypertension. Fruits are also loaded with colors, aroma, relish, and delicious, however minimal processing of fruits create some detrimental effects on fruits quality, like browning, off-flavor development, loss of total soluble solids and decrease antioxidants activity [25]. In line with these derived benefits and problems NaAlg coating was effective for maintaining antioxidants, in cherry fruits, with the increase of anthocyanins, phenolics, delay loss of titratable acidity and ascorbic acid content during cold storage for 21 days at 4ºC [26]. NaAlg coating significantly lowered the active oxygen level, reduced the activities of defensive enzymes, maintained total soluble solids, titratable acidity and ascorbic acid contents which increase the antioxidant activities. Sweet cherry fruit has high antioxidant activity due to its total phenolics, titratable acidity and ascorbic acid contents which loss during storage markedly after 8 days of storage at 2 °C plus 2 days at 20 °C, compared to the treated fruit. While NaAlg-coated cherries had higher antioxidants activity, titratable acidity, and ascorbic acid contents and could be preserved with the ideal quality and high antioxidants activity up to 16 days at 2 °C in addition to 2 days at 20 °C. Reported that antioxidant potential and phenolic content increased with reduction of wound stress in Alginate treated fresh-cut melon for 15 days of cold storage [17]. It was also reported that NaAlg edible coating enriched with essential oil showed higher antioxidants activity when essential oil added in high amount. The studies published on the effect of NaAlg coating alone and enriched with essential oils for fruits preservation have revealed diverse results. It was observed that table grapes treated with combination of NaAlg and grape fruit essential oil showed higher antioxidant potential, antifungal activity, firmness, total phenolic content and anthocyanins content as compared to untreated samples. Similarly, NaAlg edible coating enriched with citral and eugenol helps to maintain antioxidant activity, anthocyanins and phenolics in raspberry and fresh-cut apple respectively during refrigerator preservation. NaAlg had film forming ability, therefore, it created a semipermeable barrier around the fruits and modify the inner gas atmosphere by lowering oxygen and /or raising CO2 and inhibiting ethylene production which help to maintain antioxidant activities of fruits [27].

5.5 Shelf life

The shelf life of fruits is basically the acceptable quality of fruits for consumer's purchase decision. Quality of fruits and fresh-cut fruits depend upon appearance, texture, flavor, aroma and nutritional value. Many factors lead to quality losses like respiration, ethylene production and moisture loss which decrease the shelf life of fruits [76]. Metabolic activities in postharvest fruits cause deterioration of nutrients, color, and flavor. It causes economic damage to producers by reducing the shelf life of fruits. Fresh cut fruits have very low shelf life due to processing methods. Processing operations cause damages such as tissue softening, cut surface browning, presence of off-flavor and micro-organisms and decrease nutritional value. Sodium alginate also could increase the storage life of fresh-cut fruits by decreasing changes in color, reducing detrimental changes, decreasing respiration rate and other metabolic activities. It was reported that sodium alginate coating was compelling on deferring the advancement of the parameters identified with postharvest maturing, for example, shading, softening and loss of acidity, and decreasing breath rate in sweet cherry fruit. The most extreme storability time frame for control fruits were 8 days at 2 °C in addition to 2 days at 20 °C, while alginate-coated cherries could be preserved with ideal quality and increase antioxidants activities up to

16 days at 2 °C in addition to 2 days at 20 °C [30]. Jujube (*Ziziphus jujube*) is an important subtropical fruit grown over a large area in tropical and subtropical regions of the world. Recent researches showed that jujube coated with sodium alginate could delay ethylene release rate and respiration rate, reduce weight loss and increase total soluble solid contents, but it did not have any remarkable effects on ascorbic acid titratable acidity loss. In conclusion, 2.0% of sodium alginate coating was the best to improve the preservation quality of jujube fruit. Contamination on fruit flesh mostly occur due to abrasions on fruit's skin which increase fruit decomposition, derive biochemical degradation like browning, off-flavor development, and texture breakdown and reduce fruit quality which reduces the shelf life of fruits. Previous studies have reported that sodium alginate coating independently and incorporated with essential oils helps to control respiration and significantly improve shelf life of fruits (Table 2).

Table 2: Application of sodium alginate edible coating alone and with essential oils for shelf life extension of fruits

Fruits	coating + Essential oil	Main benefits	References
Strawberry	Sodium alginate + Eugenol	considered the best for preserving quality through shelf-life of strawberries	31
Fresh-cut Papaya	Sodium alginate + Thyme and Oregano	Decrease pH changes, increase shelf life, prevent from senescence, decrease water loss.	32
Fresh cut pear	Sodium alginate	Significantly reduce the browning index, delay the respiration rate, inhibit the loss of TA content, maintain freshness and extend shelf life.	33
Plum	Sodium alginate	Decrease ethylene production, delay weight loss, acidity loss, and color changes.	34
Mexican Guava	Sodium alginate	Preserve water loss as a good barrier against water respiration. It also maintains sensory qualities and prolongs shelf life.	35
Fresh-cut Fuji apples	Sodium alginate	Maintained quality parameters such as flavor, color, juiciness, firmness, reduce microbial spoilage and significantly enhances the shelf life of apple wedges.	36
Raspberry	Sodium alginate + Citral and Eugenol	Does not affect quality parameters, reduce microbial attack risk significantly and enhance storage life up to 14 days.	27

6. Conclusion
It is concluded that sodium alginate coating is very effective and efficient for the preservation of fruits. Therefore, it can be used for quality control of fruits during storage and transportation. It also saves the cost of preservation as compared to low temperature and other methods. It is applied for the protection of postharvest fruits for improving organoleptic and nutritional characteristics and extending shelf life. Despite the fact that recent studies have reported significant improvements in specific applications of this edible coating**,** there is still a need for more work and a better understanding of the composition-structure-processing-properties relationships in Sodium alginate edible coating for food packaging, both at the laboratory and industrial scale. The antioxidant and antimicrobial potential of Sodium Alginate coating can be improved by combining with essential oils.

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Conflict of interest
None of the authors show any conflict of interest.

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