AUGUST 2018 M.Sc. in Food Engineering DIMA AL HABBAL

UNIVERSITY OF GAZİANTEP

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Effect of Pectin-Wax Coating on the Quality of Fresh-Cut Apples

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IN

FOOD ENGINEERING

BY

Dima AL HABBAL

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M. Sc. Thesis

in

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Supervisor

Prof. Dr. Fahrettin GÖĞÜŞ

by

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Dima AL HABBAL

ABSTRACT

EFFECT OF PECTIN-WAX COATING ON THE QUALITY OF FRESH-CUT APPLES

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M.Sc. in Food Engineering
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Efficacy of different coating materials including citric acid (CA) as a control, pectin-wax (PW) mixture and pectin-wax mixture containing pistachio hull extract (PWE) were investigated using fresh-cut apples by considering quality attributes at time 0 and at the termination of gauged storage time. The specimens were kept under two separate temperatures at 5 °C for 8 days and at 20 °C for 32h. Changes in weight, color, total phenolic content, were examined at different time points along storage time. Results indicated that the apple pieces coated with PWE showed the lowest increase in browning index followed by specimens coated with PW. The applications of coatings were effective on delaying the degradation of specimens' colors. The effect of coating fresh-cut apples with PWE was less pronounced on a* values than on L* and b* values. The effect of coating by PW and PWE was significant compared to Sample control, furthermore coating with PW was affected L* values significantly. It is worthy to mention that temperature also was a factor affecting the specimens color. It was observed that specimens kept at lower temperature have maintained the color coordinates. Weight loss was observed significantly in uncoated specimens comparing to those prepared with coating, over time of storage at both temperatures. The coatings were effective in maintaining phenolic components where losing in phenolics was higher in non-coated specimens.

Keywords: Fresh-cut apple, browning, color parameters, pectin, wax, pistachio hull extract.

ÖZET

TAZE KESİLMİŞ ELMA KALİTESİ ÜZERİNE PEKTİN-VAKS KOMPLEKSİ KAPLAMANIN ETKİSİ

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Pektin- mum (vaks) (PW) karışımı, antepfıstığı kabuğu ekstraktı içeren pektin- mum (vaks) (PWE) karışımı ve kontrol olarak sitrik asit (CA) kullanılarak farklı kaplama malzemelerinin taze kesilmiş elmaların % ağırlık kaybı, esmerleşme indeksi, ΔE, renk değişkenleri (L*, a* and b*) ve toplam fenolik içeriği gibi kalite özellikleri üzerindeki etkisi depolama süresi boyunca incelenmiştir. Örnekler 5 ° C'de 8 gün ve 20 ° C'de 32 saat olmak üzere iki ayrı sıcaklıkta depolanmıştır. Depolama süresi boyunca farklı zaman aralıklarında ağırlık, renk, toplam fenolik içeriğinde meydana gelen değişiklikler incelenmiştir. Sonuçlar, esmerleşme indeksinde en düşük artışı fıstık kabuğu ekstraktı içeren pectin-mum (vaks) ile kaplanmış elma parçalarının göstermiş, onu pektin-mum (vaks) ile kaplanmış örneklerin takip etmiştir. Uygulanan kaplamalar örneklerin renklerinde meydana gelen bozulmayı engellemede etkili olmuştur. Taze kesilmiş elmaların fıstık kabuğu ekstraktı içeren pektin-mum (vaks) ile kaplanması L * ve b * değerlerine göre *a değeri üzerinde daha az etkili olmuştur. Pektin-mum (vaks) ve fıstık kabuğu ekstraktı içeren pectin-mum (vaks) ile kaplama kontrol ile kıyaslandığında önemlidir, ek olarak pektin-mum (vaks) ile kaplama L* değerlerini önemli ölçüde etkilemiştir. Sıcaklığın, örneklerin rengini etkileyen bir faktör olduğunu belirtmek gerekir. Daha düşük sıcaklıkta saklanan örneklerin renklerini korudukları gözlemlenmiştir. Depolama süresi boyunca her iki sıcaklıkta kaplanmamış örneklerde kaplanmış örneklere kıyasla önemli ölçüde ağırlık kaybı gözlenmiştir. Kaplanmamış örneklerde fenolik kaybının daha yüksek olması kaplamanın fenolik bileşenlerin korunmasında etkili olduğunu göstermiştir.

Anatar Kelimeler: Taze kesilmiş elma, esmerleşme, renk parametreleri, pektin, mum (vaks), antep fıstığı ekstraktı

To My Family

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LIST OF ABBREVIATIONS

CA	Citric Acid
PW	Pectin-Wax
PWE	Pectin-Wax-pistachio hull Extract
(w/w)	weight per weight
NCS	Non-Coated Sample
CS	Coated Sample
CSX	Coated Sample with extract
≥	equal and bigger or higher than
<	smaller or less than
±	higher or less than
a_w	water activity
rpm	revolution per minute
P	Pectin
h	Hour
min	minute(s)
mg/L	milligram letter
LbL	Layer by Layer
WB	Wet-basis
IP	Intelligent packaging
SP	Smart Packaging
AP	Active Packaging
HSD	Honestly Significant Difference
LSD	Least Significant Difference
AM	Acetylated Monoglycerides
MAP	modified atmosphere packaging
PVDC	polyvinylidene chloride
EVOH	ethylene vinyl alcohol copolymer

MA	Malik Acid
AL	Alginate
Mg GAE/kg	Milligram gallic acid to kilogram
FW	Fresh weight
nm	nanometers
LS means	Least Squares means
DM	degree of methylation
ANOVA	Analysis of Various

CHAPTER 1
INTRODUCTION

Packaging food is a process that demands science, art and technology of protecting edible goods when these three are combined, the product is ready for sale or to be shipped. Recently, edible coating applications have been under intentness for their great role into promoting product shelf-life. Ready-to-eat (RTE) is a trendy food and increasingly has been used in modern lifestyle. Popularity of RTE food types is growing, especially amongst women who are preoccupied with activities outside. Ongoing efforts to provide the best options to mitigate the challenges of shelf-life extension for these kinds of food. Many studies are trying to produce new technologies and preservation procedures, which include bringing them in line with the increasing volume of purchasing (Manalili, et al., 2011).

An Apple a day keeps doctor away. A very well-known phrase and is often the first sentence most people says. Apples are extremely rich in important antioxidants, flavonoids, and dietary fiber. And, it’s one of the most consumable fruits internationally. Turkey is ranked fourth globally in apple production; producing around 2,925,828 tons, annually (FAO, 2016). In respect of apple importance, the apple fruit has been engaged into the experimental design to apply the technique of coating.

Pistachios *(Pistacia vera L.)* fruit is well known for its oleaginous and edible seed. Less information is available about the hull constituted by the epicarp and the mesocarp. This part of the fruit contains an essential oil that can be valorized (Thouraya, et al., 2007).Turkey is the third top country in production of Pistachio of preceded with Iran and united states of America (FAO, 2016). Organic hull is covering the harvested pistachio fruit. A key by-product from pistachio is produced from essential process after harvesting called dehulling (remove the organic hull) applied on the pistachio fruit (FAO, 2001). Dry matter of dehulling process is a great source of antioxidant, phenolic compounds and essential oil such as a-pinene and alpha terpinolene. Moreover, green hull is a good source of protein, fat, mineral salts and vitamins (Goli et al., 2005; Chahed, et al., 2008).

The present study introduces a new coating technique using pistachio hull extract to enhance the coating process efficiency on fresh-cut apple. Considering two main issues to address; firstly, increasing demands on extending shelf life of food products and bringing them in line with highly quality standards. Secondly, huge by-products waste, along food supply chains (FSCs). Cross-linking the two facts; the Experiments were designed; in order to contribute addressing the problem, along with joint efforts by other researchers.

The aims of the study are:

- Practical application of pistachio hull extract; that was produced from by-products of pistachio (dried fruit hulls).
- To formulate new edible coating pectin-wax mixture containing pistachio hull extract (PWE).
- To examine the influence of the mixture on the quality attributes of fresh-cut apples.

CHAPTER 2
LITERATURE REVIEW

2.1 Food Packaging

Food packaging term is combining science, art and technology to have protected goods ready to sell, transport or to be shipped. In order to protect, contain, manipulate, distribute, transport and identify each article along its supply chain packaging systems are used which are manufactured with any material from raw materials to end users (Kuswandi, 2017). Food packaging systems guarantee controlled and modified atmosphere around edible products. Control or modify the external atmosphere of a product can be expressed as different concepts including intelligent, active and biodegradable packaging. While, the impact of storage on food quality, processing operations, transportation and traceability are concepts related to food quality.

Packaging materials might be either flexible or rigid. Flexible materials include films, paper sheets and foil etc. Rigid materials are glass, metal, and plastic etc. (Fellows and Hampton, 2000). Crucial responsibility of packaging is to keep high quality along storage period by the means of protecting food during distribution, storage, sell and finally when use at household level (Soroka, 2002). Protecting food products from physical, chemical, and biological degradation through packaging can extend product shelf-life, ensure safety use and sustain the quality. Therefore, packaging process is a major phase of the food supply chain (Coles et al., 2003).

The terms smart, active, or intelligent packaging are used particularly with foods and other products when shelf-life and freshness in a key factor for consumers demands (Smithers, 2016). To surmount with international trends, technological developments, and consumer inclination, increasing applications of nanotechnology, that can be identified as a technology applied on processes, materials and systems which apply a scale of 100 nm or less (Mousavi and Rezaei, 2011), promotes staggeringly altering from pliant packaging to innovative packaging in the food industry (Mlalila et al., 2016). Thus, innovations in intelligent packaging systems were the outcome to meet customers' demands for quality, safety, and shelf life for packaged food. Applications of innovative food packaging in food industry as showed in Figure 2.1 (Mlalila et al., 2016). have been expanded and is systematically being altered pliant food packaging; specifically, smart packaging, intelligent packaging and active packaging (Ampatzidis et al., 2009; Meng et al., 2015; Puligundla et al., 2012; Ranjan, et al., 2014).

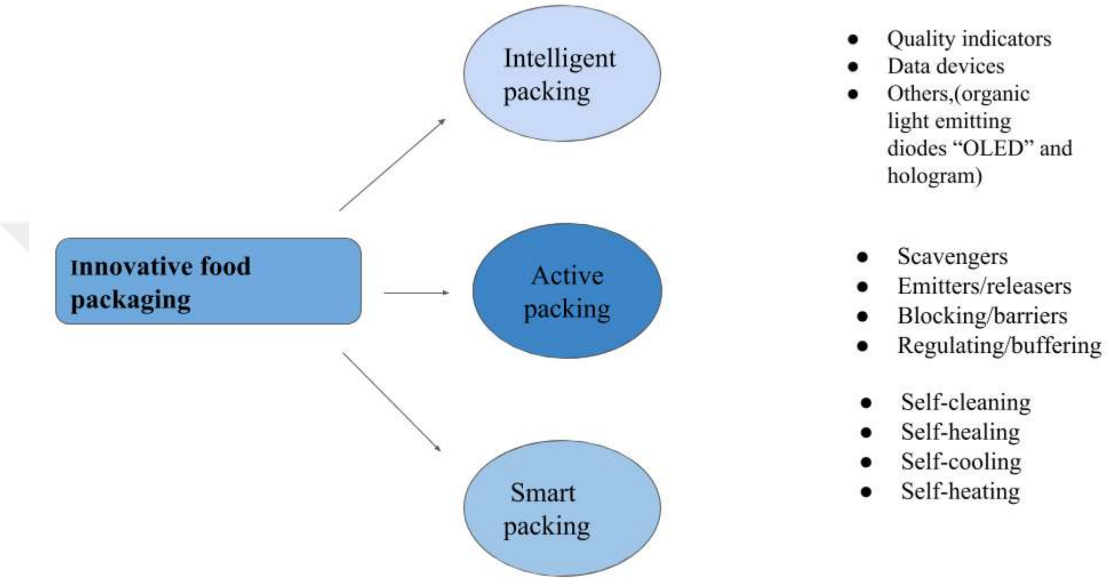

Figure 2.1 Innovative food packaging with their application examples.

Active packaging (AP) is a package system aims to monitor the condition of packaged food. In order to broaden shelf-life and preserve the caliber of food for as long as possible, AP has direct interaction with food contents. While, Intelligent packaging (IP) is a system that works based on core intelligent functions like; enhance safety, ensure good quality, and provide information, in order to communicate information about the product without direct interaction with food contents.

AP system has specific task when used for packaging for example, antimicrobial function- protection functions while, IP will communicate processing information and sense the environment of food product as examples showed in Table 2.1. Packaging systems can be classified either as IP or AP or both (Dib et al., 2014; Kuswandi, et al., 2011).

Smart packaging (SP) utilizes chemical sensors or biosensors to complete its function which is to monitor the food quality and safety from the farm to the consumers, (Mikličanin, 2017). Finally, traditional packaging that involves the use of a sheathing material, which is referred to as passive packaging is distinguished by some innate encasing, shielding or ease-of-handling qualities (López et al., 2007).

Table 2.1 Examples of active and smart packaging.

Active packaging	**Intelligent packaging**
Antimicrobial	Time-temperature indicators
Ethylene scavenging	Microbial spoilage sensors indicators
Heating/cooling	Physical shock indicators
Moisture absorbing	Leakage sensors
Odour and flavour absorbing/releasing	Allegen sensor
Oxygen scavenging	Microbial growth sensors
Spoilage retarder	Pathogens and contaminant sensors

Industrial perspective categorized three main types of utilized packages for comestible product: a) primary which's used for individual products and it's contacted with food, b) secondary used to handle primary packages and c) distribution (shipping) package, such as shipping containers and outer wrapping (Kotler, 2002; Marsh and Bugusu, 2007). Other types of packaging which are regulated by certain authors are: d) convenience packaging, e) wasteful packaging (Copley, 2004).

Observers have been anticipated a growth by rate of 3.2% annually for flexible materials market for 75-80% of the demand. Because of cost efficiency advantages compared to rigid material packages, adding to that flexibility and variety of uses (Security, 2009).

2.1.1 Key Functions of Food Packaging

Edible coatings have been extensively studied for the preservation of fruits and vegetables. over the past few years. What made chiefly pertinent to soft fruits such as the berries was their favorable effects and easy treatment. the decreased respiration estimate, extended storage cycles, firmness retention and controlled microbial growth are the essential practical advantages associated to the use of edible coatings (Fan, 2009; Garcia, 2010; Vu, 2011).

As shown in Figure 2.2 food coatings have different functions including act as a barrier that limits the contact of the product with the environment, modifies the functional properties of foods, and contributes to the control of the surface moisture preventing the agglomeration, adhesion, or disintegration of food (Salgado, 2015).

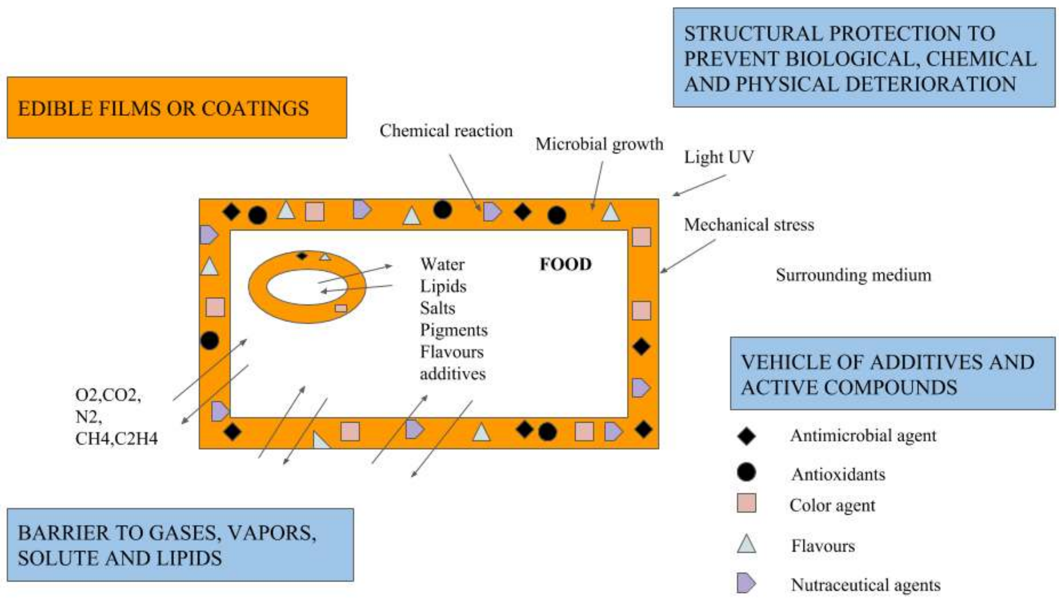

Figure 2.2 Main functions-edible films and coatings.

To hold and conserve food products from external effects and harm, and to give ingredient and nutritional information (Coles et al., 2003). The basic functions of food packaging can be summarized as following:

i. Protection and Safekeeping**:** in order to be able to obtain an extended shelf-life as well as maintain the quality and safety of food we must draw from three main external effects which are chemical, physical, and biological by means of delaying product deterioration. Glass, metal, and plastic packages minimize the chemical changes through making a barrier towards environmental factors; oxygen, moisture, or light which usually activate the negative changes in consumable products. Simultaneously through the prevention of odor transformation to the products the packaging can control the internal environment of the package against pathogens, spoiling agents, as well as insects, rodents, and other animals (Marsh and Bugusu, 2007)**.**

ii. Reduction of Contamination/Food Waste reduction**:** Addressing food losses in the value chain. Food wastage has been varying from 25% for food cereals and up to 50% for fresh produce as reported by (FAO) the Food and Agriculture Organization (Gustavsson et al., 2011). Prolonging the shelf-life of foods reduces total waste and can be achieved by the packaging of food items, thereby lengthening their utilization. The depletion of solid waste may also be provided by the use of packaging. As agricultural by-products collected at the processing plant are used for other purposes while those from homes are typically thrown away it has been observed by (Rathje et al., 1985) that packaged foods result in 2.5% total waste -as compared to 50% for fresh foods. It was discovered by (Rathje et al., 1985) that waste generated in U.S. cities as compared to Mexico City was more than one third per capita due to them holding less packaging than food waste.

iii. Marketing and information the package is the face of the product and can therefore amplify sales in a competitive environment. Information to be shown to the consumer may be retrieved by the use of labels on packages such as nutritional value, legal requirements for product identification, ingredients, volume and weight, as well as manufacturer information. Furthermore, some packages relay the cooking instructions, brand logo, and even pricing. Waste disposal may be affected by these modifications.

iv. Traceability recorded identifications allows us to trace the history, application or location of an item of activity (according to ISO 8402 standard). This entails two main aspects: firstly, identification of the product by marking; and secondly, the recording of data concerning the product completely along the production, processing, and distribution chain (FAO, 2016). In order to carry out tracking and tracing of products whilst in the distribution process, unique codes are integrated by food production companies onto the labels of their products. Printed or electronic radio frequency identification [RFID] barcodes are available and can be read manually and/or by machine.

v. Ease of Use packaging plays an essential role to reduce effort of preparing and serving foods. Different types packages can increase access to food product, ease handling and discarding; package innovation provides new packages that can ease using food products for consumers; currently customers can prepare whole meal without any efforts through using oven-safe-trays, boil-in bags, and microwavable packaging. Also, innovative packages offer easy handling for consumers; opening a package. Furthermore, flexible package martials have been shelf-life conditions for wide range of products such as a peelable seal used with packed cookies that allows re-closure after re-opening.

vi. Tamper indication to eliminate the risks of tampering with food, unique packaging features were introduced. Example of some of features are including and not limited to banding, particular membranes and specialized printing on the inside of bottles. These prints could be text or graphics indicate irreparable changes after opening. Tamper-evident packaging can provide positive features however usually some of these package systems required additional martials that might have negative effect on disposal packages issue but benefits of these features outbalance any disadvantages. Few chemically formulated packages can be used without any further packaging materials, as heat seal used on medical packaging; color will be changed when the product open.

vii. Other functions including a bounce Conveyor (for example, addition gift, and product, or coupon). Moreover, containers for another way of use by with the household thus packaging may serve other functions. The action or practice of using something again eliminates or delays entry to the waste system.

2.1.2 Evolution of Food Packaging

Food packaging systems have seen rapid evolution throughout the last 200 years from a package to contain food or product to a key pillar in the production system and a key part of entire product design – a given example of ketchup squeezable bottle; that supported extension of product shelf-life through oxygen scavengers and multilayer plastic bottle. Early in 1800s, metal cans used for food until 1950s then aluminum cans were used. Alumni cans made a revolution by use, especially for carbonated beverages such as; soda. Then in 1970; Pepsi introduced the bottle concept for the first time. In 1975 stay tab introduced as an opener tool stay associated to the can; advantage on this tool is allowing to drink directly from a bottle or can (Risch, 2009). One of the most interested accomplishment is to introduce edible coatings in food applications. Edible coatings are referring to thin layer applied directly on the surface of food such as fresh-cut fruits and vegetables (Valdés et al., 2015).

A form of edible coatings is the flexible film, which is widely used and its importance is increasing in food industry particularly in Turkey. Turkish scientists have been prepared an innovative flexible film by using egg white added to corn protein and Antimicrobial agents. The unique film expected to be five hundred time more flexible than any film available in the market and it's anticipated to launch the flexible film within the next three to four years to use it industrially (Manalili et al., 2011).

Recently, active food packaging (AP), modified atmosphere packaging (MAP), and edible films and coatings are concepts where researchers invest their efforts in order to detect new roles that packaging can play in food industry. AP technology has interesting functions than containing food, the applications of AP system in food industry includes and not limited to oxygen-scavengers, antimicrobial agents, and modified and controlled atmosphere agents, moreover, edibility functions of bio-based coatings and films.

Innovative active food packaging systems are enhancing product quality to satisfy consumers, safety products, suitability and increase access to product information. Focusing on AP and invest to improve its system is mainly to extend products shelf-life and promote safety and quality of food products (Pereira de Abreu et al., 2011). Trendy applications of active packaging in food industry which were commercialized are including moisture controller scavengers (dehydration), Carbon dioxide-absorbers, and antimicrobial systems. Furthermore, improved techniques have been incorporated to package dried foods such as a small sachet to eliminate unwanted moisture and control humidity inside the package by absorbing or releasing the moisture.

Antimicrobial application was one of the most important technique to enhance food safety by preventing molds and growth of pathogens as well as harmful microorganisms (Han, 2003). Food packaging systems continued to evolve by using practical martials with chemically or physically functions. These materials can release their active substances to control the atmosphere around the product (Coma, 2008). Another innovative food packaging system, intelligent food packaging (IP) which is mainly has functions of observe the state of the packaged food and covey product information to the external consumers (Lim, 2011).

Active packaging which is a category of intelligent packaging provides intelligent functions; these functions are required to enhance food security, safety, and quality (Han et al., 2005). Economic factors related to food industry play a major role into food packaging evolution; fast growing economies such as in Chain and India who fuel increasing demands for packaging which is the result of high demand for food supplies. Due to the modern lifestyle and increase population and their food needs in these areas of South Asia, socially and economically factors contribute into promote process food industry.

2.2 Edible Films and Coatings for Food Applications

Approximately one billion people were living in hunger across the globe in 2009, which was about 100 million people more than the 2008 level (Security, 2009). While addressing global hunger through further investment in food production is a welcome move, it should be complemented with a food loss reduction strategy, as reducing losses is among the most sustainable alternatives to increasing food production (Nellemann, et al., 2009) and is a way to advance food security as well as to feed the hungry.

The immense deficits from farm to plate are associated with weak approach, logistics, storage, and purchase/consumption demeanor. Vast budgets which should diversely be spent on more constructive activities, are actually used to make and move goods which are then just wasted. Damages at nearly all phases of the food chain could be diminished by using and applying appropriate packaging techniques. Adopting a combination of technologies and processes will lead to the curtailing of losses as packaging is a crucial part of a stable accumulative advancement process (Olsmats and Wallteg, 2009). Besides addressing food losses, the global food packaging industry has a lot to commit to, as well as ensuring food safety and including the enhancing of the global food industry, which is crucial to the economic development of fluctuating economies (Security, 2009).

The use of edible coating was first recorded in China on citrus, twelfth century. Examples of edible films and coating that were traditionally used to improve the appearance and quality of various food commodities in markets are confectioneries using chocolate coatings, meat products which use lipid films to protect them, and fruits covered by a wax layer (Hardenburg, 1967).

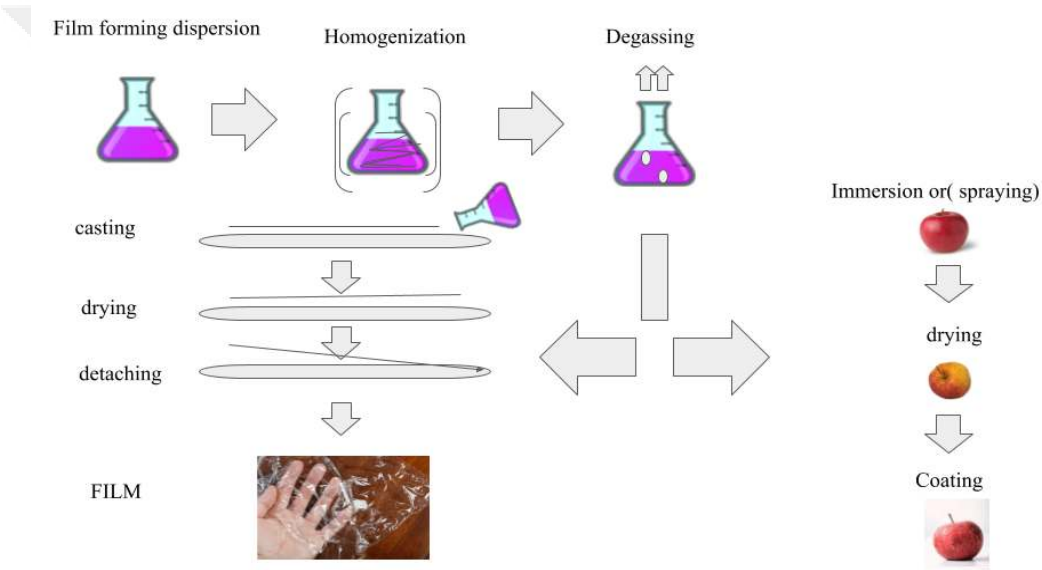

Figure 2.3 Schematic representation of production of films and coatings.

Two different production steps are depicted in Figure 2.3 to distinguish between the films and coatings manufacturing (Otoni, et al., 2017). Edible film (EF) is explained as formed thin layer and it's made of an edible formula. The thin layer might be placed on or between food components, while edible coating (EC) is a thin layer covering the surface of a food product and also made of an edible material (McHugh, 2000). Submerging products in coating materials and then allowing excess coating to drain as it dries and solidifies is how edible coatings can be applied (Baldwin et al., 2011). Films and coatings differ in how they are applied: films will be formed separately then applied onto food, whereas coatings will be applied and formed directly on the surface of food (Guilbert, 1995).

Even though, edible films and coatings are becoming popular in food industry some concerns remain asked, the main concerns are tabulated in Table 2.2 (Baldwin et al., 2012). When edible materials are applied to the exterior of the food product then a final coated product will be ready for consumption. To some, the coatings are legal and safe to use on food products only when they are edible, and to others, consumers must accept the edibility of coated food, actually implying that the edible coatings have natural value (Baldwin et al., 2012). Different countries may differ in their regulations, just as European Union (EU) processed fresh fruit cannot be coated with morpholine-fruits containing however edible coatings are routinely used in the United State (Hagenmaier, 2004).

Table 2.2 Areas of concern with edible coatings

Chemical safety	Safety is a rudimentary requirement, as with all food ingredients and additives. However, much is still being researched about the safety of all food additives, including coating ingredients.
Cost Barrier properties	Formulae and method of application. When a permitted barrier for gas exchange between food and atmosphere is formed, or between two phases of the same food item, neither too restrictive nor too permeable, this is considered to be ideal coating.
Food quality	Efforts are required to achieve changes that are good, not harmful because coatings tend to change characteristics such as appearance, flavor, and how it feels in your mouth.
Nutritive value	The nutritional value of a product could change due to the thickness of certain coatings (e.g., frosting increases the caloric value of cake).
Environment	When edible coatings dry, they sometimes release unstable organic compounds (usually alcohol).

The type of produce, its compositions and characteristics will initially identify the edible film and coating that should be used (Huber and Embuscado, 2009).

2.2.1 Film-Forming Materials (Components of Edible Coatings)

Edible coatings are made up of formulated edible materials summarized in Figure 2.4 (Salgado, 2015). Formulated materials have a processing functions such lipids, proteins, and polysaccharides. The edible martials might be alone or in combinations in order to produce an edible film or coating (Kester and Fennema, 1986). The physical and chemical characteristics of the bio-polymers greatly influence the properties of the resulting films and coatings (Sothornvit and Krochta, 2000). What distinguishes these chemical groups is their ability to formulate a long cohesive and continuous matrix therefore edible martials for edible packages are classified as lipids, proteins and polysaccharides (Cuq, 1995). These categories are able to produce edible bio-polymers. Film-forming bio-polymers can be proteins, polysaccharides (carbohydrates and gums), lipids, or a mixture of these (Han, 2014). The bio-polymers are combined with food additives and plasticizers in order to modify the processing properties and functions of the produced films. On another hand, bio-polymers can form covalent bonds through intermolecular forces such as (e.g., disulfide bonds and crosslinking) including hydrophobic, ionic interactions and electrostatic these mechanisms allow bio-polymers to forming a film.

In order to formulate an edible film, processing mechanisms should be convenient, mainly; salt additives, pH control, drying, heating/calling, solvents, and enzymatic modification. It’s very important to control the production process, because any change in treatment conditions can transform the process and reaction paths (Guilbert et al., 1996; Guilbert et al., 1997). In order to keep the formed film edible, water or ethanol are used as processing solvents. However, the produced film will be either hydrophilic or hydrophobic, or both (Peyron, 1991).

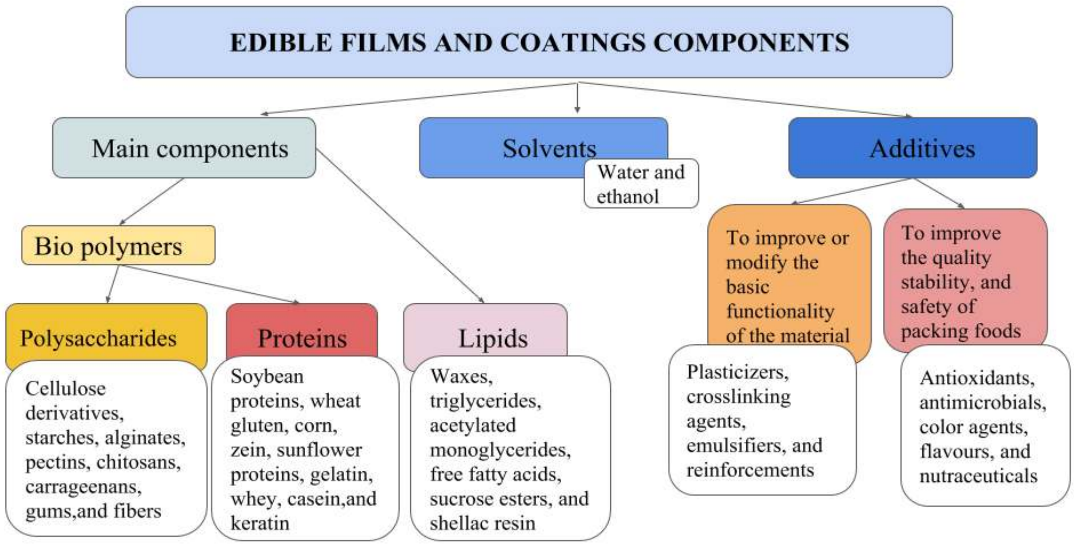

Figure 2.4 Edible films and coatings compositions.

Among materials currently used in food packaging, polymers have taken a major share because of their versatility and advantageous performance/cost ratio (Valdés et al., 2015). Films characteristics are changeable based on the type of polymer used to form. And the type of forming martials are vary to produce wide ranges of edible films and coatings for different food applications. In order to incase the film capacity, films can be produced by layer-by-layer technique by using multiple compositions such as forming a lipids layer over a protein layer or polysaccharide/protein layer. (Debeaufort et al., 2010; Yildirim and Hettiarachchy, 2016). Since, each polymer type has its own unique, therefore mixing bio-polymers can combine all desirable features in a film (Han, 201Commercial usage of edible coatings includes application to coverage fresh fruits (Correa-Betanzo et al., 2011), chocolate and vegetables products (Castro Freitas et al., 2009; Fadini et al., 2013). Examples of common used materials: cellulose, starch, chitosan, carrageenan, alginate, zein, gelatin, whey, gluten, fatty acids, carnauba, and beeswax (Shit and Shah, 2014).

2.2.1.1 Protein

As discussed, protein is used to formulate an edible film. Protein had unique macromolecules structure of amino acid as Figure 2.5 (Damodaran and Parkin, 2017). Protein-based edible coatings have distinctive properties compared to other forming materials; such as electrostatic charges, denaturation and amphiphilic nature.

Moreover, the secondary, tertiary, and quaternary structures are able to modified in order to obtain the preferable processing characteristics, examples of modification are pressure, acids or alkalis, metal or salts, and heat for denaturation etc. by these various treatments, food industry can improve the quality and mechanical properties of produced coatings and films. Sources of protein for coatings and films protein-based are animal and plant tissues, eggs, oil seeds and cereal (Krochta, 2002).

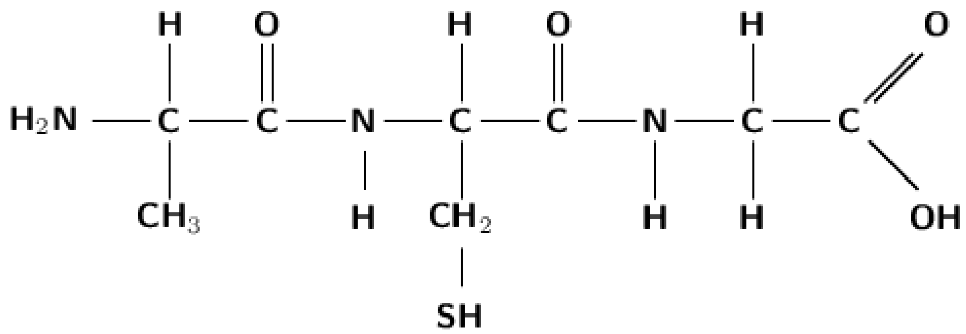

Figure 2.5 A primary structure of amino acids in a protein.

2.2.1.2 Polysaccharide

Polysaccharides derived from plant foods are major components of the human diet, with limited contributions of related components from fungal and algal sources. In particular, starch and other storage carbohydrates are the major sources of energy in all diets (Lovegrove et al., 2015).

Hydrogen bonds in polysaccharide-based films and coatings are playing the most significant role in films and coatings fabrication because of high number of hydroxyl groups. Fibers, starch, carbohydrates, gums and non-starch are examples of polysaccharides materials used to produce films. Construction Unit of polysaccharides is amino acid. Polysaccharides structure is simpler compared to proteins, however forming polysaccharide structures is complicated, since the structure includes large molecular weight than protein one. Mostly, carbohydrates are neutrally charged, but gums found a negatively charged with very limited cased positively charged. rheological characteristics of polysaccharides categories; such as pectin, gums, alginate are extremely changeable based on pH of the environment whether it’s alkaline, neutral or acidic as well as presence of multivalent cations. polysaccharide films and coatings have a positive impact on extending shelf life of muscle foods through preventing browning, oxidative rancidity, and dehydration.

Polysaccharides are hydrophilic so a poor capacity to maintain moisture (Nisperos-Carriedo, 1944). A mixture of polysaccharides contain 1,4-linked α-D-galacto syluronic acid residues are forming pectin Figure 2.6 (Alvarez-Pérez et al., 2015). It's worthy to mention that third of cell wall of higher plants are made up of pectin. The lamella cell is containing the highest concentration of pectin (Kertesz, 1951).

Pectin substances are considerably linked with cellulose, hemicellulose and lignin structures (Anuradha et al., 2010). Pectin performs as anti-poisoning substance, also pectin act as a scavenger removing toxic mercury from the gastrointestinal tract and respiratory organs (Kohn, 1982).

Pectin-based films distinctive of making up chain which has an excellent gas permeability characteristic. Furthermore, pectin-based films are crispy, compact, hard, thick and viscous. Pectin as a forming material has the ability to form a gel. So, pectin has desirable properties of modifying atmosphere that extend shelf life through preventing anaerobic conditions (Baldwin et al., 1995).

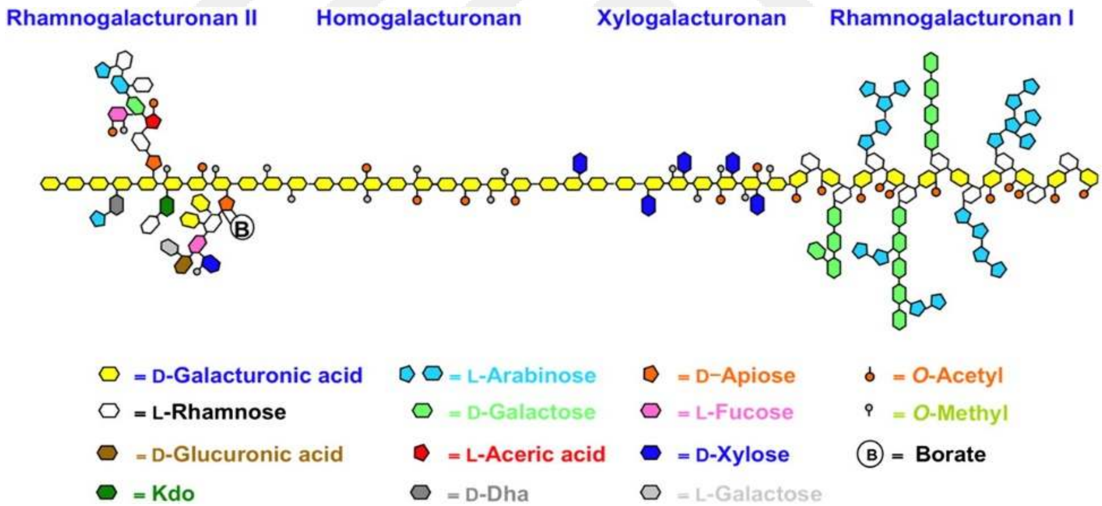

Figure 2.6 Schematic representation of pectin structure.

Pectin can impart hardness, crispness, compactness, thickening quality, viscosity, adhesiveness, and gel forming ability to a variety of edible films. Pectin-based films because of the make-up of the polymer chains exhibit excellent gas permeability properties, resulting in desirable modified atmospheres that enhance the shelf life of the product without creating anaerobic conditions (Baldwin et al., 1995).

Additionally, polysaccharide films and coatings can be used to extend the shelf-life of muscle foods by preventing dehydration, oxidative rancidity, and surface browning, but their hydrophilic nature makes them poor barriers for water vapor (Nisperos-Carriedo, 1944). Pectin acts as a natural prophylactic substance against poisoning with toxic cations. It has been shown to be effective in removing lead and mercury from the gastrointestinal tract and respiratory organs (Kohn, 1982).

Pectin classified based on degree of methylation (DM) to two different DM degrees as shown in Figure 2.7 and 2.8. Each type had its own applications (Stephen and Phillips, 2016):

- High DM pectin (HM) is containing 50% or higher of galacturonic residues. HM pectin is used to prepare jams and jellies, clarifying juices, preserve fruit, dairy production, glazing and soft drinks. Hydrophobic interactions in a presence of acid, water and sugar allows pectin to form a gel.

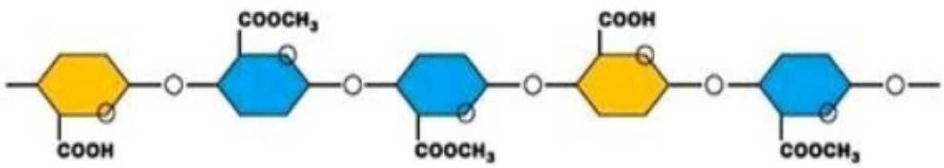

Figure 2.7 Pectin of high degree of methylation- (HM) pectin (DM > 50)

- De-esterification of HM pectin under controlled conditions results a low DM Pectin (LM pectin) which is containing between 20% and 30% galacturonic residues (Hua et al., 2015).

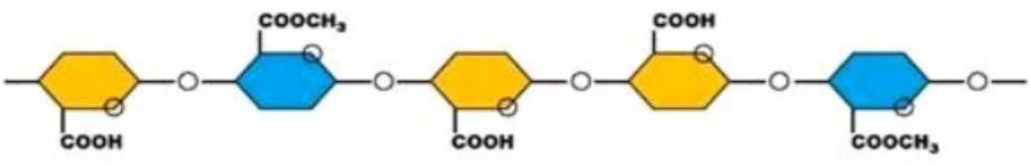

Figure 2.8 Pectin of low degree of methylation-(LM) pectin (DM < 50).

Both pectin types are used in food industry mainly as thickening and gelling agent and pectin properties allow to use pectin as crystallization inhibitor and stabilizer. However, all pectin applications require modified molecular masses and add methyl groups to yield methoxides in order to improve processing ability (Ovodov, 2009).

2.2.1.3 Lipids and Resins

Lipids and resins are not polymers; however, they are used to produce edible films and coatings. Most of resins are soft solids at room temperature. Casting and molding process can transform resins into any shape causing reversible phase transitions between fluid, soft-solid, and crystalline-solid states.

Both lipids and resins are hydrophobic, therefore lipids and resins films and coatings have very high-water resistance and low surface energy. The main influence of lipids used in edible coatings are their efficiency as water-vapor barriers (Callegarin et al., 1997). Emulations are formed by combing lipids with protein or with polysaccharideto form emulsion film, which is increase resistance to water permeation (Gennadios et al., 1997; Vargas et al., 2006; Mehyar et al., 2012; Gautam and Kumar, 2017).

Wax is a lipid, which is an ester of a long chain alcohol and a fatty acid. There are several kinds of lipid chains, in Figure 2.9 different fatty acids chains were given for different types of waxes such as; beeswax, carnauba wax, candelilla wax, sunflower oil wax and some synthetic waxes. Some of them are used to form emulsions and natural edible films and coatings (Lee, 1999). Waxes and lipids are utilized in a wide range of important industrial applications (Sin et al., 2014).

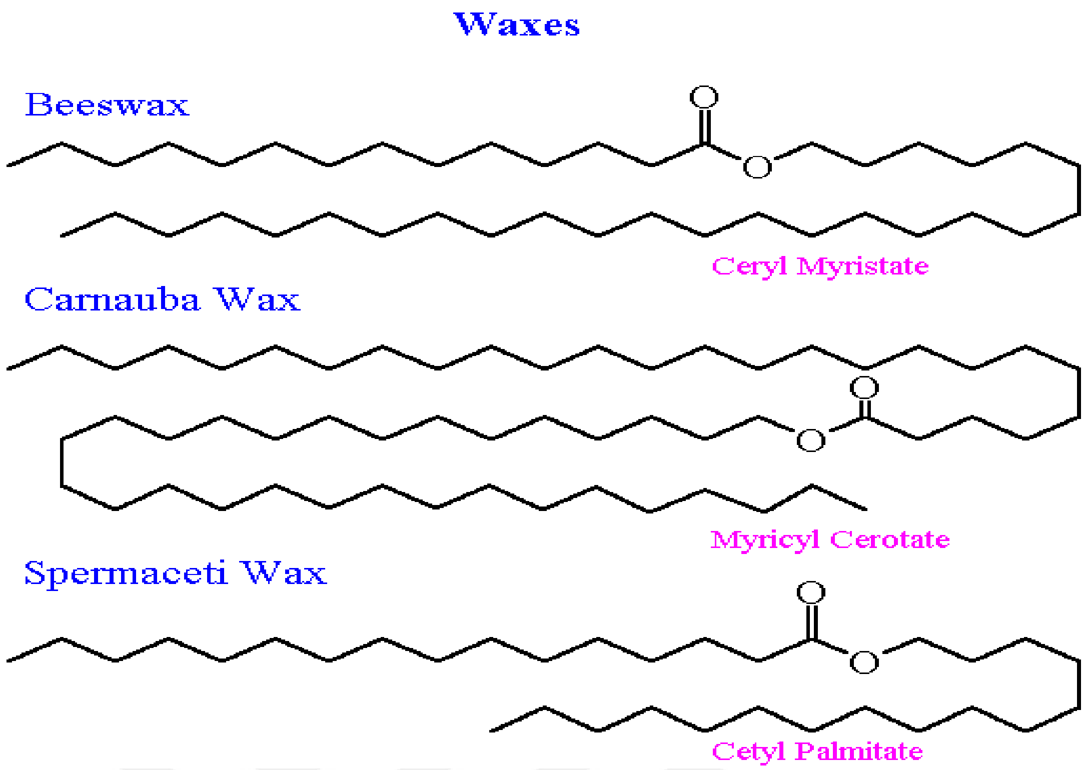

Figure 2.9 Fatty acid chains of beeswax, Carnauba and Spermaceti wax-different wax types.

Leaves of Copernicia prunifera are producing Carnauba wax, therefore it is considered as a nutria wax. Pure Carnauba wax is yellow color and it consists of different fatty acids; alcohols and ester ones, Carnauba wax also contains hydrocarbons. Carnauba wax is obtained then refined and it has a varies applications. The melting point of Carnauba wax is high 82-86 °C. Furthermore, as lipids, Carnauba wax is insoluble in water and harder than concrete. Other properties include hypoallergenic and non-toxicity. Carnauba has high gloss. All unique characteristics of Carnauba wax led to varies application including and not limited to food industry, furniture, coating for dental floss (Helmenstine, 2018).

2.2.1.4 Additives

Additives to food packaging materials could be antioxidants, colorants, antimicrobial agents, and emulsifiers, and reinforcements. The main task of these additives is to improve the functions of the package material and to enhance safety, stability and quality of the packed food (Cooksey, 2007). Pistachio-hull extract PHE can be extracted by aqueous solution, and it’s rich with phenolics Extraction by water has tyrosinase inhibitory activity. Furthermore, PHE extraction could reduce enzymatic browning in sliced raw potatoes (Abolhasani et al., 2018).

A study by Roostaee et al. (2017) where a phenolics of PHE were incorporated into nanoliposomes (NLs) to form encapsulate for soybean. The encapsulate could improve the stability, gradual release and solubility of phenolic compounds in soybean oil. Also, maintain the color.

2.3 Effect of Edible Packaging on Food Quality

Term food quality has a wide range of attributes and categories; like food safety, Nutritional, value, packaging and processing (Baker, 2004). Edible films and coatings work as a barrier for losing water, by the meaning of maintained the moisture content (MC) in food product (Dilkes-Hoffman et al., 2018). Edible films also have gas-barrier behavior, edible films can eliminate oxygen moderately. Their permeability to oxygen is lower than low-density polyethylene (LDPE), however two to three orders higher than polyvinylidene chloride (PVDC) and ethylene vinyl alcohol copolymer (EVOH) at -24°C (Miller and Krochta, 1997).

Edible coatings of plasticizers can also reduce the loss of flavor, nutrients, and color, in particular fluid foods during processing and distribution (Buss, 1996). Food safety in another major topic linked to food quality. On another hand, edible coatings are key element to promote food quality through their function of carrying additives such as vitamins, colorants, antimicrobial and antioxidants, and flavoring enhancers. Benzoate, ascorbate, and propionate were integrated into edible films and coatings.
Moreover, antimicrobial agents such as benzoic acid, and sorbic acid, propionic acid have been incorporated into edible films to retarded the bacterial growth on different products including cheese and meats (Cagri et al., 2004). The fact that edible coatings can conceivably reduce the complexity and improve recyclability of packaging; Therefore, reducing packaging wastes adding to that edible coatings have a key role in maintaining food quality attributes (Krochta et al., 1994). The type of coating required and the application method differ depending on food products. Different types of food products, with their coating components, and coatings benefits were listed in Table 2.3 (Baldwin, et al., 2012).

Table 2.3 Benefits of edible coatings and various types of edible coatings components applied on food products.

Benefit	Foods to be coated	Main components of coatings
Inhibit transfer of moisture and oxygen	Nuts Raisins Frozen chicken Fish fillets Eggs	Zein Whey protein Alginate Chitosan Protein and vegetable oil
Reduce transfer of moisture	Cake Crackers with cheese Sausage Fresh fruit Breaded poultry	Sugar and butter Vegetable oil Collagen Shellac, carnauba wax Gellan gum
Reduce mold growth	Cheese Smoked fish Baked goods	Agar and galactomannan Whey protein Carrageenan with fungicides
Reduce frying fat uptake	Potato Doughnut	Methyl cellulose
Improve appearance	Fresh fruit Chocolate candy	Shellac Zein
Reduce adhesion to cooking surface	Lasagna Poultry	Sauce with cheese or meat Cellulose and protein

Major function of edible films and coatings is to promote food quality, by the means of protecting the packaged products from chemical, physical, and biological deterioration (Kester and Fennema, 1986; Gennadios and Weller, 1990). Other functions linked to physical strength, applying edible coatings can readily improve it. Furthermore, edible coatings reduce particle clustering, and enhance the appearance of product surface (Cisneros-Zevallos et al., 2006; Cuq et al., 1995). Moisture migration, microbial growth on the surface, light-induced chemical changes, and oxidation of nutrients are all factors affecting food quality and safety and applying coatings and films can protect and delay deterioration (Kester and Fennema, 1986). Moreover, edible coatings and films play roles against oil, vapors of gases (Kester and Fennema, 1986; Gennadios and Weller, 1990; Guilbert, 1995).

Inherently, edible film and coating materials are biodegradable (Krochta, 2002). In fact, this biodegradability is one of the greatest benefits of edible films and coatings

(Debeaufort et al., 2010). Potential non-food applications include films for agricultural uses (e.g., mulching, tunnel and bale wrap), grocery bags, paper/paperboard coatings, and cushioning foams. Many functions of edible films and coatings are similar to those of synthetic packaging films; however, edible film and coating materials must be chosen for food packaging purpose according to specific food applications, the types of food products, and the major mechanisms of quality deterioration (Guilbert, 2002; Petersen, et al., 1999).

The use of edible films and coatings as primary packaging can potentially replace conventional packaging materials, partially or totally, which can reduce the overall utilization of synthetic materials (Petersen, et al., 1999). Due to their protective functions, edible films and coatings may simplify the total packaging structure (Debeaufort et al., 2010). For example, cookie packaging with a plastic primary bag in a secondary cardboard carton can be simplified to coated cookies in a cardboard carton without the plastic. Considering the most important feature of edible films and coatings which is their edibility and their ability of biodegradability determination (Guilbert et al., 1996; Krochta, 2002). Wherefore, all forming martials whether polysaccharides, additives, proteins, or lipids should be should be acceptable for food processing. Furthermore, all equipment, facilities and processing tools suitable for human use (Guilbert et al., 1996). Standard of operations and protocols should be inspected by responsible agencies to claim their biodegradability commercially in the case of biodegradable film applications.

Fresh color is attracting the consumers to buy fresh-cut fruits, also it’s one of major elements to evaluate a quality of food product Freshness of cut-fruits and cut-vegetables is identified by color brightness and the absence of visual defects or drip (Shewfelt, 1999). Therefore, one of the main functions of edible coatings and films application is to maintain the color and delay pigments deterioration (Barrett et al., 2010). Edible coatings and films can carry a colorant substances and anti-browning agents thus maintain product color (Pranoto et al., 2005).

2.4 Applications of Edible Films and Coatings in Foodstuffs

2.4.1 Fruit and Vegetables

Quality of fruit and vegetables is essential for consumers. Quality attributes include shelf life and safety therefore edible coatings have been used long time to preserve fruit and vegetables such as apples, citric fruits and cucumber (Baldwin et al., 1996; Lia and Barth, 1998). Edible coatings are applied on the surface of fruit and vegetable by spraying or dipping to form a thin layer of a semi permeable membrane as shown 'n Figure 2.10 (Dhanapal et al., 2012), Edible coating on fruits and vegetables have various functions including control moisture (Thompson, 2008).

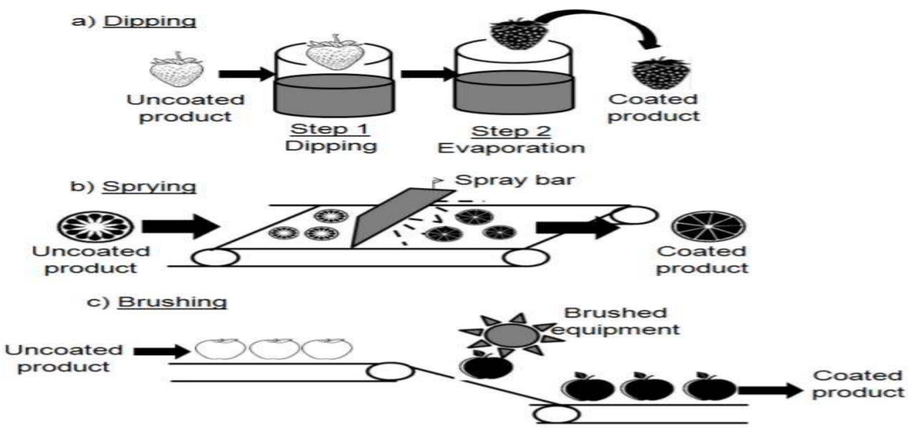

Figure 2.10 Examples of coating methods are used in coating fruit and vegetables.

Lipids-based edible coatings are mainly used in fresh food industry. Variety of lipids Including waxes (candelilla, carnauba, beeswax, rice bran and paraffin), as acetylated monoglycerides (AM), and surfactants to formulate edible coatings applicable to cover

Whole surface of fruits and vegetables (Paredes-López et al., 1974; Lawrence and Iyengar, 1983). Applications of edible coatings on fruit and vegetables reduce surface abrasion also, serving as moisture barrier (Hardenburg, 1967). Colloidal suspensions of oils or waxes dispersed in water were typical early fruit-coating formulations.

Edible coatings and films are in continuance improvement, many food researchers are innovating with new bio-components for edible films including investigate on new applications techniques. Layer by Layer (LbL) was key approach for rational design of edible coatings (Falguera et al., 2011). Moreover, new based materials of edible coating for fruit and vegetables were studied such as whey protein, starch, chitosan and pectin (Feng, et al., 2018; Sapper and Chiralt, 2018; Nair et al., 2018).

Wang et al (2018) reported utilizing mushroom-processing waste discharge, insoluble fiber Flammulina velutipes (FVIF) from aged stipe was prepared with a series of wet milling steps to form a film by casting method. Also, trends on additives are anticipate to growing up Grande-Tovar et al (2018) reported to use chitosan incorporated with essential oils to increase bio-preservation of films against fungus.

2.4.2 Cheeses

Edible films and coatings for cheeses include active ingredients carried by agents that presence in coatings formulation e.g. antioxidants and Antimicrobial agents. Releasing active substances during storage can preserve cheeses flavor and delay lipids oxidation. Other edible coatings of cheeses can promote nutritional functions of chess by the means of incorporating functional agents into the coating material. Edible cheeses coatings can include flavor enhancers, sweetener agents, and dyeing agents and coatings remain edible since they are bio-based formulated (Artiga-Artigas et al., 2017).

Using gelatin chicken bones (CBG) as an edible film on mozzarella cheese was reported by Kim, Beak et al. (2017) CBG was incorporated with cinnamon bark oil (CBO) as an additive by 1% concentration. The role of additives was to control the microbial growth. CBG edible film along with the additive showed antimicrobe capacity as well as antioxidants function thus such a coating can enhance chess shelf life. It’s worthy to mention that CBG edible film was applied to contaminated chess with *Listeria monocytogenes*, Number of bacteria has been decreased after twenty days
of storage.

2.4.3 Meat

Meat products usually characterized by a short shelf-life. The key function for edible coating for meat products is reducing oxidation or microorganism spoilage during display (Acevedo-Fani et al., 2015; Ruiz-Navajas et al., 2013). Trendy edible films and coatings include using of essential oils on beef products. Essential oils are rich with antioxidants therefore coatings with essential oils can extend product shelf life. For example, a study by Molayi et al. (2018) reported using Oregano and rosemary essential oils (EOs) in coating of beef and (Vital et al., 2018) used edible whey protein coating to extend shelf life of chicken thigh meat that was stored at (4±1°C). Both of the studies had positive indicators and the edible coatings could control microbial load thus delay spoilage and extend product shelf life. Additionally, antioxidant agents are used in films and coatings for meat. These active substances will interact with meat and the surrounding environment. Antioxidant agents is responsible for trapping substances that are with high oxidation potential. So, meat films and coatings can delay lipids oxidation through releasing anti-oxidants components. Currently, active packaging is major system in meat and meat products industry. Integrated fully active packaging systems in meat industry is deepening on their cost efficiency (Domínguez et al., 2018).

Polysaccharides-based edible film developed from potato incorporated with five percent green tea by Nisa et al. (2015), the developed edible coating was applied directly on fresh beef. Similarly, Yang et al. (2016) has developed protein-based coating from grain, the coating was incorporated with extracts of different tea types including: oolong, back and green tea. The edible coating was applied on a fresh pork meat with positive post-experiments impact.

CHAPTER 3
MATERIALS AND METHODS

3.1 Materials

Pectin APA 168 DB powder and carnauba wax were procured from /Cagdas kimya, Istanbul, Turkey/. Pectin was used in the present study as hydrophilic phase for coating formulations and wax formed the lipid phase of the coating mixtures. Wax-Pectin mixture formed an emulsion coating solution. Then, pistachio hull extract (PHE) was added to the coatings as antioxidants enhancer.

Citric Acid (CA) $C_6H_8O_7$ Ultra; ≥ 99.5% (T) and Folin, Ciocalteu's phenol reagent both products purchased from (Sigma-Aldrich Chemie GmbH, Taufkirchen, Germany). Citric Acid solution used to immerse cut fresh apple during preparations process in order to prevent oxidation of the fruit surface. Deionized water used to prepare all experiments solutions.

3.2 Preparation of Treatment Solutions

Two different coating mixtures were prepared to coat the fresh fruit cuts as Figure 3.1 illustrates the main steps to formulate the coating materials starting with:

- Wax emulsion (mixture 1): wax solution (40%, w/l) was prepared through mixing 10 g wax-flakes in 250 ml heated water using bain marie at 80±5 °C. After wax started softening a homogenizer used to homogeneous the mixture at 15000rpm for 15 min. using IKA® ULTRA-TURRAX® T18 Homogenizer by IKA.
- Pectin colloidal (mixture 2): pectin solution (80%, w/l) was prepared by dissolving 20 g powdered pectin into 250ml water at 80±5 °C throughout bain marie. Then, the mix stirred at 300rpm for 30 min, so perfect homogeneity

Mixture 1 added to mixture 2 at 80±5 °C using bain-marie then 15 minutes stirring applied at 15000rpm. So, the first coating material pectin-wax (CS) 500ml solution was formed. Finally, the solution cold down to room temperature 25 °C then used immediately. Another PW solution was prepared using the same method but adding 1g of Pistachio hull extract solution to form the second coating solution pectin-wax with pistachio hull extract (CSX). The solution kept to cool down to room temperature 25 °C then used.

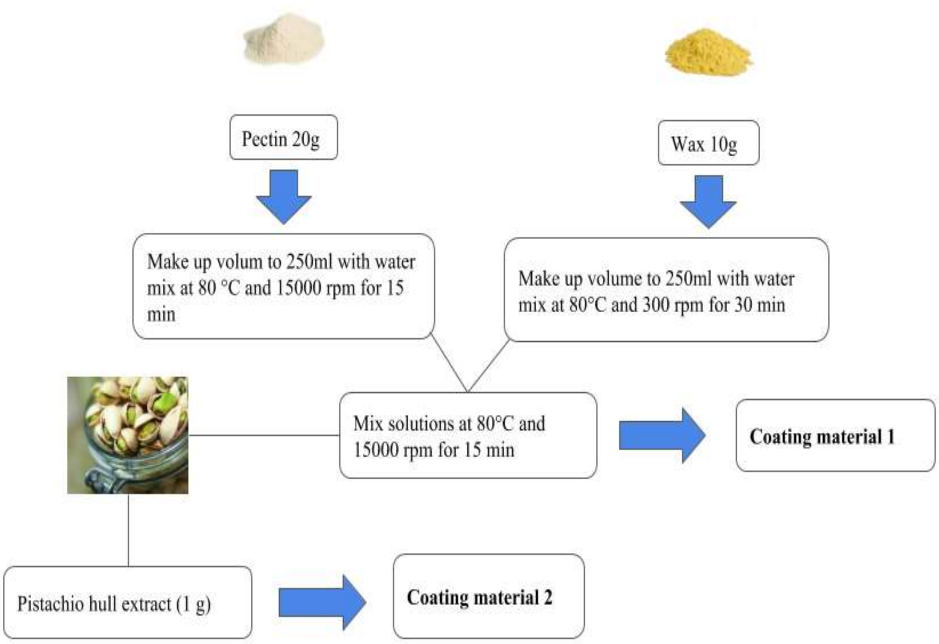

Figure 3.1 Experimental procedure for edible coatings preparations starting from pectin and wax.

3.3 Sample Preparation and Treatment Procedures

The green uniform sized, defect-free apples (variety) were purchased from local market. The fresh apples stored at 4°C before processing. The preparations started with washing apples and peeling them off. Apple cut off into rings after that to pieces approximately (2.5cm×2.5cm×0.7cm) for each piece. A sharp stainless-steel knife was used throughout the process to reduce mechanical bruising and specimens were processed in a temperature-controlled room at 20±1°C. Meanwhile, 100 mg L^{-1} citric acid (pH≈3) was prepared by mixing 5g of citric acid salt and made up the volume to 500ml with deionized water.

The fresh-cut pieces immersed into citric acid for 5 minutes at room temperature before coating process in order to avoid the enzymatic browning. Afterwards, fresh-cut apples were dipped into two types of coating materials; part of specimens were dipped into CS coating solution and other part into CSX coating material for three minutes per each coating type, then all pieces drained over Metal mesh for ten minutes. A maximum of 15 apples were processed at the same time to minimize excessive exposure to oxygen. Control specimens were drained from citric acid and kept without any further treatment. Four apple pieces were placed in each foil tray, a total of 69 trays were prepared for all treatments. All coated and non-coated specimens were stored covered with plastic wrap.

The specimens stored under two different temperatures; 5±2°C and 20±2° C for 9 days and 32h, respectively. Storage devices adjusted to keep fixed temperatures throughout storing period. (Binder - Stability Chamber KB 115-UL, Germany). All specimens have been stored in oven devices, and the storage conditions kept constant along the experiments period.

3.4 Methods of Analysis

3.4.1 Weight Loss Measurements

Results were expressed as the percentage loss of initial weight (%) for non-coated and coated specimens. Initial weight was measured at (h_0) and at the different sampling times (6, 12, 22, 26 and 32 h. of storage) at 20 °C on two single sample replicates for each treatments and sampling date. Similarly, weight loss (%) was measured for non-coated and coated specimens at (day 0) and at different sampling times (1, 2, 3, 4, 5, 6, 7, 8, and 9 days of storage) at 5 °C on two single sample replicates for each treatments and sampling date. Specimens weight was measured using electronic scale (Mettler Toledo™ MS-TS Analytical Balance, New Zealand).

The % weight loss on wet basis (wb) of specimens was defined through the following equation: the linearized form of the Peleg equation

$$\%\text{Weight Loss WL} = \frac{W_{L_t} - W_{L_o}}{W_{L_o}} \times 100; \qquad (1)$$

Where;

W_{Lt} = weight of the sample at any point (g)

W_{L0} = initial weight of the sample (g)

3.4.2 Color Measurements

Specimens color was assessed during storage period at two different temperatures; 5 °C and 20 °C according to (Palou et al., 1999). The color was assessed by a HunterLab ColorFlex instrument (Hunter Associates Laboratory, Inc., Reston, VA, USA).

Identifying color differences by using color coordinates L* (whiteness or brightness/darkness), a* (redness/ greenness) and b* (yellowness/blueness) at any time, respectively as shown Figure 3.2. Range of Colorimeter coordinates is from; L = 0 (black) to L = 100 (white), - a* (greenness) to +a (redness), and - b (blueness) to +b (yellowness).

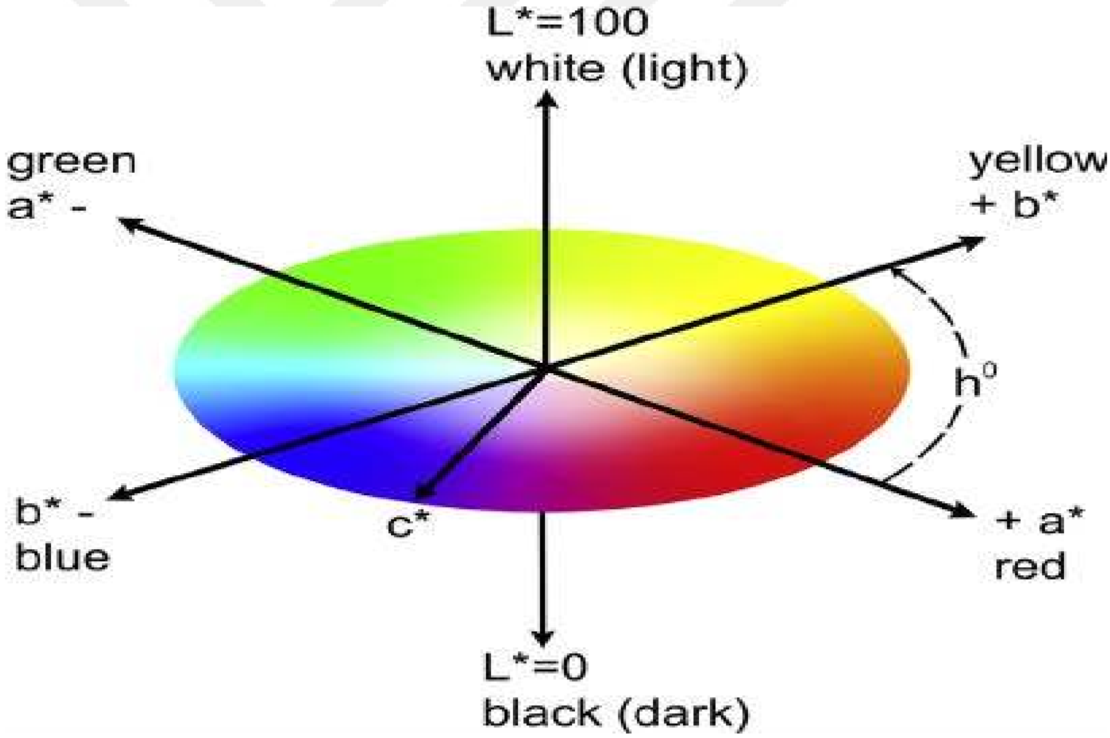

Figure 3.2 LAB color model defined by the L*a*b* axes and hue angle h is indicated

A Minolta standard white plate (L* = 92.4, a* = -0.7, b* = -0.9) and the colorimeter was calibrated each time against a standard white and black tile. The measuring head set with 51 mm diameter viewing port and used the system of diffuse illumination with 10^{o} viewing geometry.

Furthermore, Browning Index (BI) was measured using the following formula:

$$BI = \frac{[100(x-0.31)]}{0.17} \quad (2)$$

Where:

$$x = \frac{(a^*+1.75L^*)}{(5.645L^*+a^*-3.012b^*)} \quad (2.1)$$

And the total color variation (ΔE (Eq. (3)), chroma C* (Eq. (4)), Hue angle (Eq. (5)) was calculated from the Hunter L*, a*, b* values and used to describe the color changes during storage;

$$\Delta E = \sqrt{(L_o - L^*)^2 + (a_o - a^*)^2 + (b_o - b^*)^2} \quad (3)$$

Where symbol ``o" in ΔE refers to the color reading of fresh apples. Fresh apples were used as the reference and a larger DE denotes greater color change from the reference material.

$$\text{Chroma} = \left(a^{*2} + b^{*2}\right)^{½} \quad (4)$$

$$\text{Hue angle} = \tan\left(\frac{b^*}{a^*}\right)^{-1} \quad (5)$$

The color of the specimens was measured at the beginning of storage (time 0) and (6, 12, 18, 24 and 32 h. of storage) at 20 °C on three single sample replicates for each treatments and sampling date. In other hands, color assessed for coated specimens at (day 0) and at different sampling times (1, 2, 3, 4, 5, 6, 7 and 8 d of storage) at 5 °C on on three single sample replicates for each treatments and sampling date.

3.4.3 Total Phenolic Contents

The total phenolic content was determined according to (Singleton and Rossi, 1965; Song et al., 2010) using Folio–Chocolate reagents with analytical grade gallic acid as the standard. 0.50 mL of the diluted sample was added (0–500 mg/L) was added to deionized water (10 mL) and Folin–Ciocalteu phenol reagents (1.0 mL). After 5 minutes, 20% sodium carbonate solution (2.0 mL) was added to the mixture. After being kept in total darkness for 1 h, the absorbance was measured at 760 nm using a spectrophotometer (UV VIS Spectrophotometer model SP 3000 Nano, Japan). Amounts of TP were calculated using gallic acid calibration curve. The results were expressed using gallic acid as a reference equivalents (mg GAE/g apple) of wet sample matter (Ghasemzadeh et al., 2010).

Eight different specimens kept at two different storage times; four specimens at 20 °C and other fours at 5 °C. The specimens were used to determine the deterioration of the total phenolic components over storage time. The analyses were accomplished in duplicate for each sample.

3.5 Statistical Analysis

Effects of the coating on quality parameters were interpreted relating the coefficients of the parameters and corresponding P values. The P value below 0.05 indicates a confidence interval of 95%.

For weight loss and total phenolic components experiments, two sample replicates were analyzed at each corresponding time whereas for color assessment three sample replicates were analyzed at each corresponding time. The LS means values were considered for all recorded data. XLSTAT (Microsoft® Excel® 2016 MSO (16.0.9226.2126) 46-bit.) was used to conduct Analysis of Variance (abbreviated one-way ANOVA) was used if significant difference was detected between the specimens.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Weight Loss

Fruits cutting cause damaged surface area thus a higher respiration rate along with higher ethylene production. This contributes into acceleration of browning process, softness, microbial growth and enzymes loss (Wiley and Yildiz, 2017). Therefore, edible coatings help to decrease water loss of fresh-cut products (Raybaudi-Massilia et al., 2008). Since, fresh-cut products have elevated water transpiration rates (Toivonen and Brummell, 2008). And, highly vulnerable to lose weight (Watada and Qi, 1999). It's greatly important to evaluate weight loss for fresh-cut fruit during storage.

Average weight of the non-coated sample (NCS) and coated sample (CS) was recorded during storage period at 5 °C and 20 °C and weight loss (%) was calculated. Both variables; storage time and temperature are affecting the weight loss indicator. Figure 4.1 is showing specimens weight loss versus storage time at 5 °C. Coating maintain weight and delay losses of moisture positively.

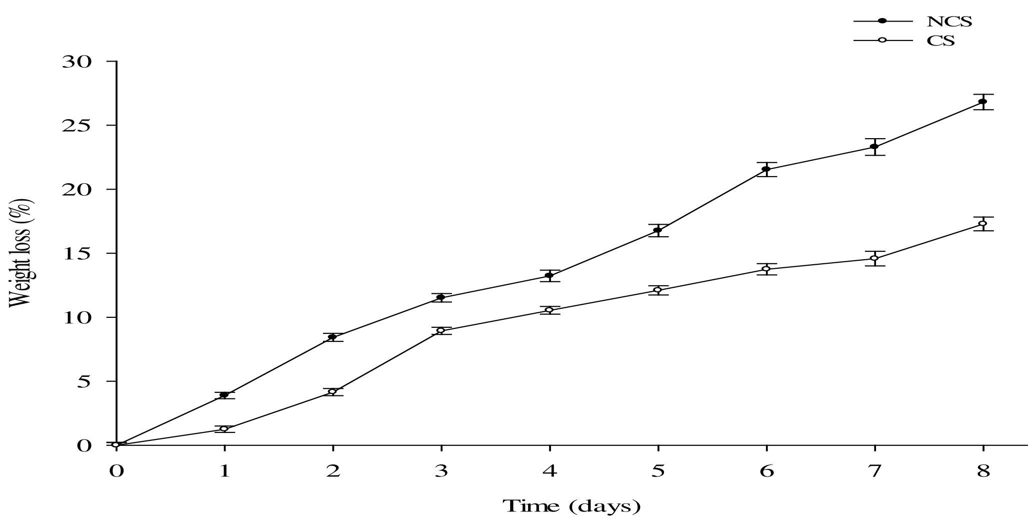

Figure 4.1 Effect of coating process on cut-fresh apple specimens on weight loss values during storage time at 5 °C.

Similarly, as shown in Figure 4.2 coating process could maintain weight and lower losses values were recorded for specimens kept at 20 °C.

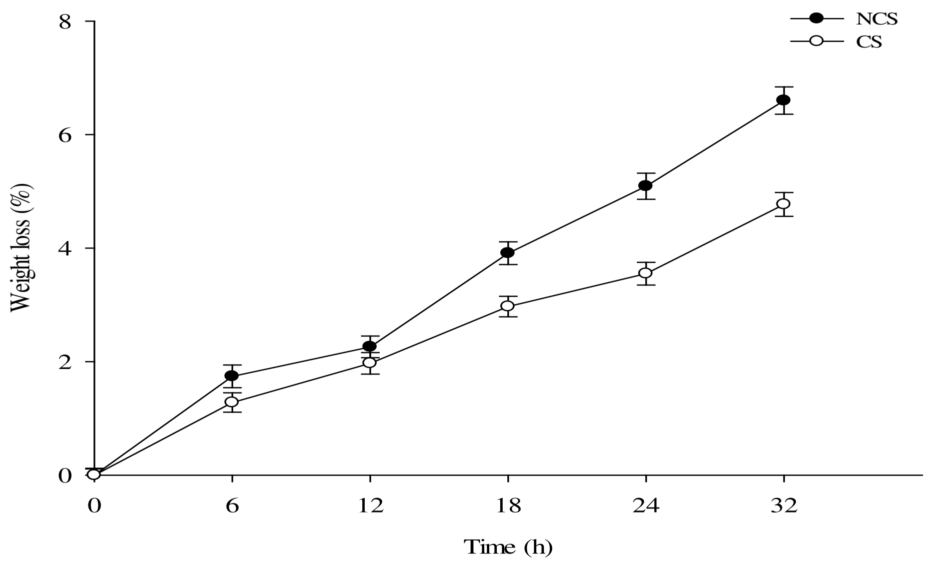

Figure 4.2 Effect of coating process on cut-fresh apple specimens on weight loss values along storage time at 20 °C temperature storage

Both Coated and non-coated specimens experienced a significant weight loss during storage time as given in Table 4.2 and 4.3. However, data indicates a dramatically lower percent weight loss in CS apple comparing to NCS ones. CS recorded considerable different at 4.77% weight loss after 32hrs. at 20 °C compared to 6.60% weight loss in NCS after the same treatment. Similarly, the results showed a lower weight loss at 17.29% in CS compared to 26.81% weight loss percent in NCS after 9 days at 5 °C.

Table 4.2 Impact of coating process on weight loss (%) for NC and CS at 5 °C

Time (days)	**Average Weight (g)**		**Weight loss (%)**	
	NCS	CS	NCS	CS
0	16.00±0.21	20.00±0.23	0.00	0.00
1	15.38±0.28	19.75±0.44	3.89±0.25	1.25±0.25
2	14.65±0.25	18.57±0.38	8.43±0.31	4.15±0.28
3	14.16±0.24	18.21±0.43	11.52±0.33	8.94±0.28
4	13.88±0.26	17.89±0.44	13.23±0.45	10.54±0.30
5	13.32±0.26	17.58±0.42	16.77±0.48	12.10±0.36
6	12.55±0.22	17.25±0.39	21.54±0.55	13.75±0.44
7	12.27±0.23	17.09±0.38	23.30±0.65	14.58±0.57
8	11.71±0.21	16.54±0.32	26.81±0.60	17.29±0.54
Total loss (%)			26.81±0.60	17.29±0.54

Average weight of the NCS and CS was recorded nine-times during storage period at 20 °C. Then, Wet Basis (wb) was used in calculations for weight (%) and weight loss (%) for all variables. specimens weight loss was measured for the same versus storage time.

Table 4.3 Impact of coating process on weight loss (%) for NC and CS at 20 °C.

Time (h)	**Average Weight (g)**		**Weight loss (%)**	
	NCS	CS	NCS	CS
0	17.50±0.30	20.00±0.19	0.00	0.00
6	17.20±0.20	19.57±0.25	1.74±0.20	1.28±0.17
12	17.11±0.32	19.61±0.10	2.26±0.19	1.97±0.19
18	16.82±0.15	19.41±0.18	3.91±0.20	2.97±0.18
24	16.61±0.18	19.29±0.25	5.09±0.23	3.55±0.20
32	16.35±0.30	19.05±0.21	6.60±0.24	4.77±0.21
Total loss (%)			6.60±0.24	4.77±0.21

The results suggest a significant influence of the coating process to preserve fresh weight loss thus extend the shelf life of treated specimens with coating solution. Since, losing water from fruit cells cause faster exhaustion of nutrients and speedy depletion of sensory properties. Reduction in turgidity is a major cause of fruit deterioration (Nunes, 1998). The findings are in harmony with a study by Kraśniewska et al. (2014) reported using pullulan coating on pepper and apple to sustain quality. The experiential design assessed the effects of pullulan coating on weight loss and color change in pepper kept at 16°C for 14 and 28 days. Also, apple at 16°C and 2°C for 14 and 28 days, respectively.

The obtained data showed that coating process resulted extension of storage time by the means of preserve weight and reduction of water transportation.
Furthermore, it was noticeable that the coating solution prevented further surface shrinkage of coated specimens comparing to un-treated ones for both pepper and apple. A fact may explain the findings, that generally polysaccharide coatings have an impervious barrier prevents oxygen transfer. Since, the coatings will reduce the rate of oxygen transfer comparing to non-coated martials. The coating materials minimize fruit breathing (Chlebowska-Śmigiel, 2009).

Impact of edible coating was evaluated by Azarakhsh et al. (2014) on the respiration rate on fresh-cut pineapple during 16 days of storage at 10 °C. the coating martial made off lemongrass essential oil incorporated into an alginate-based and sunflower oil 0.025%. the findings showed that an alginate-based edible coating formulation incorporated with 0.3% (w/v) lemongrass has potential to extend the shelf-life and maintain quality of fresh-cut pineapple. Additionally, the weight loss percentage was remarkably lower in all coated specimens than for uncoated ones.

Trends in a study by Xu (2001) showed that coating kiwifruit with mixture of soy protein, pullulan, glycerol and stearic acid has decreased the volume of release ethylene and delay in releasing time. The study reported that control released 3-4 times more ethylene than of the coated Kiwifruit. Respiration rate is closely attached to the volume of ethylene release therefore the results indicate that coating could delay the senescence and control the process of gas exchange thus preserve the fruits.

Previous work by Perez-Gago (2005) on cut fresh apples treated by difference emulsion coatings that coating application did not significantly improve moisture loss compared to the control. The study used lipid and hydrophilic based coatings, on two different temperatures 20 °C, or 7 days at 5 °C under various storage conditions cover/uncovered apple pieces. Therefore, there was no unify behavior of all treatments leads to not have clear conclusion on the efficiency of coating process on weight loss. Specimens kept at lower temperature 5^{o}C could maintain the weight further (15.07g loss) compared to specimens on higher temperature 20^{o}C (18.67g loss). Moreover, the effect of storage temperature on weight loss was significant (p=0.0001).

4.2 Color Properties

Fresh color of fruits and vegetables is enhancing the customers' appeal to consume the products. And also, color contributes in quality features of market products that should meet the consumer's expectation. During storage, color change is one of the most important changes in fresh-cut fruit which directly affects perception of quality by customers (Olivas and Barbosa-Cánovas, 2005).

In the study context, color measurements were an essential factor to evaluate the impact of coating process on cut-fresh apples. Further analysis was conducted after measuring the color coordinates L*, a* and b* for all coated and non-coated specimens. A better understanding of the fluctuation of color coordinates was explored through calculating chroma, hue angle, browning index (BI) and ΔE-the color variation. Enzymatic browning increased throughout storage period at both temperatures 5 and 20 °C, for all three treatments of fresh-cut apple pieces. Increased enzymatic browning during storage was accompanied by an increase in colorimetric a*- and b*-values, and a decrease in lightness (L*) and hue values as the experimental data showed. However, the coating process could delay the browning and maintain the colors. Moreover, coating specimens with PHE showed lower BI values and the differences were significant.

Table 4.4 Significant difference analysis of L*, b*, a*, BI, and ΔE after applying different treatments by using LS means values.

Treatment	L*	a*	b*	BI	ΔE
NCS	70.44±0.98^{b}	1.40±0.04^{a}	26.21±0.64^{a}	49.24±0.80^{a}	9.06±0.25^{a}
CS	72.34±0.87^{a}	0.62±0.10^{a}	23.43±0.52^{b}	41.06±0.64^{b}	6.65±0.12^{a}
CSX	69.64±0.75^{b}	0.54±0.02^{a}	22.33±0.43^{b}	37.79±0.25^{b}	6.75±0.20^{a}

^{b} Means within the same column with different letters are significantly (P≤0.05) different.
^{a} Not Significant difference at (P≥0.05).

As LS means values listed in Table 4.4, NCS treatment has a significant positive effect on L* values (*P*≤0.05), while CSX treatment has decreased L* values significantly. Both coating treatments CS and CSX had significant effect (*P*≤0.05) on b* values. Maintaining the values of b* and a* was reflected in browning index, thus coating process with both types had a positive impact on delaying product browning. It's worthy to mention that treatments did not have significant effect (P≥0.05) on a* values.

Also, significant positive impact on reducing BI was observed after coating process. CSX showed the lowest value for BI and both CS and CSX showed almost the same values of ΔE however the values were less than ones for NCS. The differences were not significant amongst all values for ΔE.

As Figure 4.3 shows the coating treatment with pistachio hull extract had a significant negative effect (*P*≤0.05) on L* values; by the means of the lowest L* values (LS means=69.64) in the end of storage period at 5 °C whereas coated specimens with PW recorded the highest ability of maintaining L* (LS means=72.34) amongst the treatments followed by the CS (LS means=70.446). Significant differences were found between specimens coated with PW compared to CSX ($p \leq 0.05$). No significant differences were observed between NCS and CS regarding L* values (P=0.27).

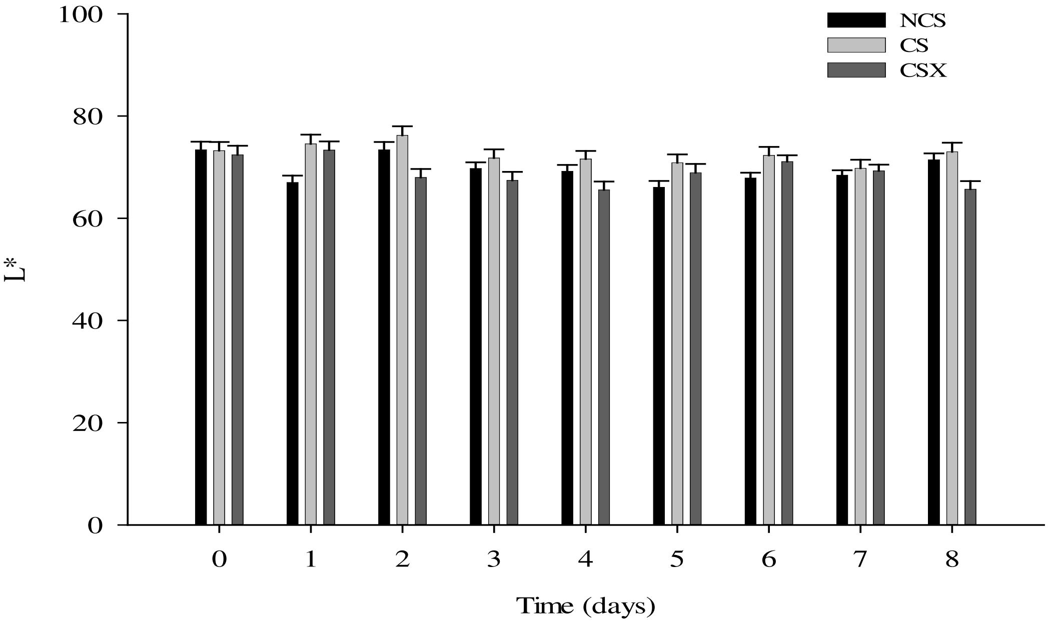

Figure 4.3 values of L* for specimens during storage temperature at 5 °C.

At 20 °C the highest values of L* were for CS as Figure 4.4 followed by NCS and CSX, this might be explianed by the effect of the light brown color of Pistachio hull extract that affect L* values and brightnees of specimens.

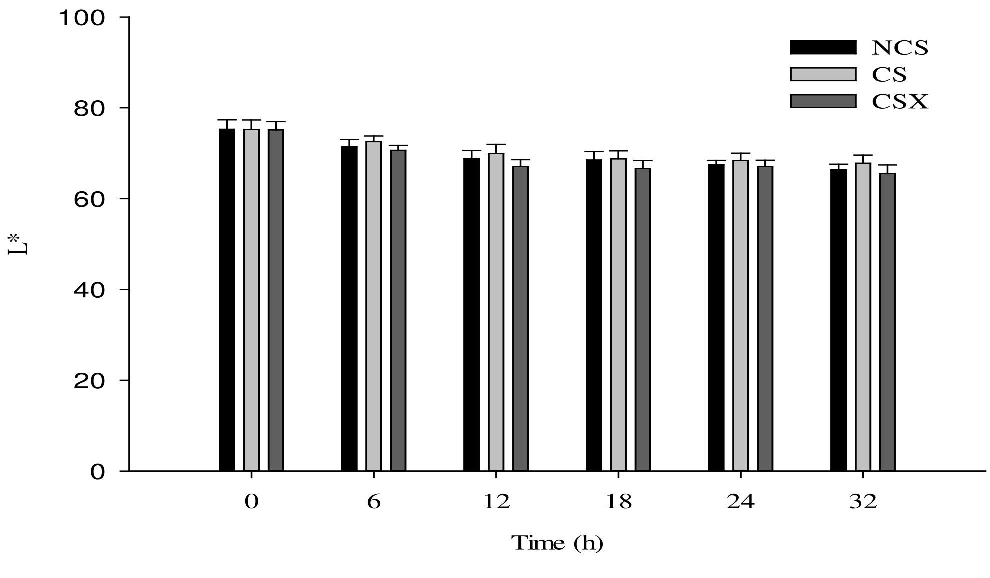

Figure 4.4 values of L*for specimens during storage temperature at 20 °C

Bringing the results of L* values in line with Liu et al. (2013) that explain Millard reaction effects when reducing sugar presences along with amino groups, chitosan component, so melanoidins formed giving brown color to product and reducing by this L* values. Besides of b* values that were sustaining throughout storage period in coated mangos, otherwise decreased b* values of uncoated mangos. Similarly, for C* or chroma parameter that reflects color saturation.

The current study analysis introduces contrast findings to the ones from Azarakhsh et al. (2014) that investigated the color change on coated and uncoated fresh-cut pineapples during 16 days of storage at 10 °C. Edible coating was containing lemongrass essential oil incorporated into an alginate-based and sunflower oil. Post-experimental analysis showed that coated specimens could sustain color values significantly compared to uncoated specimens. The trends of the study showed that L* values were maintained when edible coating with different lemongrass oil concentrations were used to treat the specimens compering to untreated ones. The different findings can be referred to add ascorbic acid and citric acid with alginate-based in coating formulations. These acids function as anti-browning agents.

The opposite, findings of the research is in line with Salinas-Roca et al. (2018) effort to improve Fresh-cut mango quality. The study used a poly polysaccharide-based edible coating as a treatment for mango. The specimens stored during 14 days at 4±1°C. The prepared coatings were with alginate, pectin, carboxymethyl cellulose or chitosan. In brief, the research has been introduced that uncoated mango slices did not have any different of L* values throughout storage whereas different L* values were observed at the day 14 of storage for coated mango slices. Coated Mangos with alginate and pectin recorded lower L* values that could be backwards to lack of translucence of pectin and alginate solutions (Espitia et al., 2014).

Coating fresh-cut apples with PWE was a significant source of variation in regards of b*. Significant differences were found between CSX and NCS (P=0.001), similarly between CSX and CS (P=0.001). However, no significant effect was found between CSX and CS (P=0.06). Figure 4.5 is showing b* values at 5 °C after 8 days of storage.

The positive effect of the PWE was observed at both storage temperature. As a result, lower b* values were shown with CSX (LS means= 22.33) followed by b* values of CS (LS means= 23.43) and higher b* values recorded of NCS (LS means= 26.21). Therefore, the coating process played a significant role to protect the degradation of b* values, thus maintaining the yellowness of the specimens.

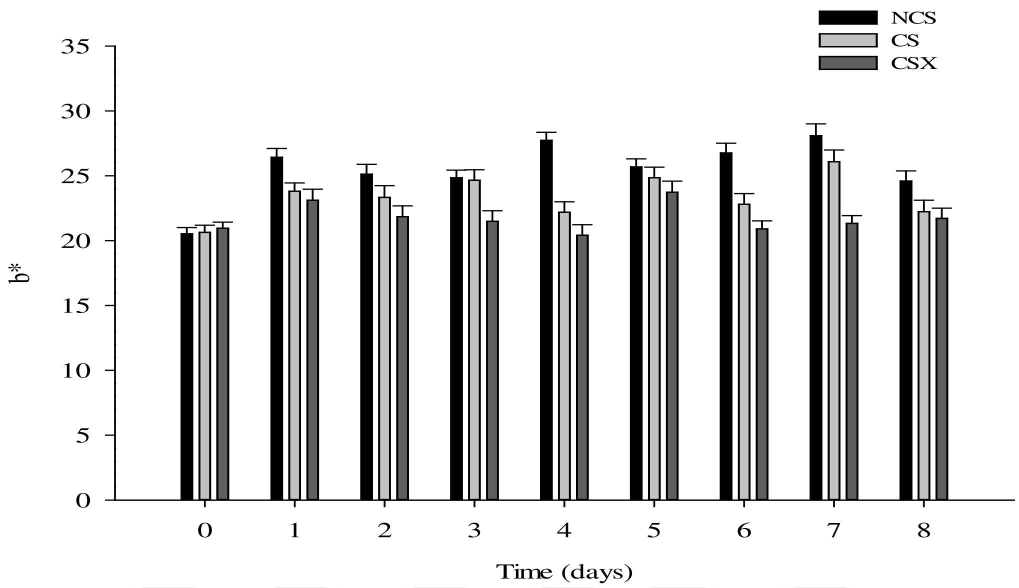

Figure 4.5 Effects of treatments on b* of specimens during storage temperature at 5 °C.

Meighani et al. (2015) reported in a study conducted on pomegranate fruit, that coating process by using three different coating materials; resin wax (Britex Ti), carnauba wax (Xedasol M14), and chitosan (1 and 2 % w/v) has a positive effect on color properties including b* values after evaluating the quality parameters during 40, 80 and 120 days storage at 4.5 °C and 3 additional days at 20 °C. Based on the research findings carnauba wax could maintain considerably higher fruits quality in compare to other coating materials. The laboratory studies showed significant increase of b* values in the last days of storage and the analysis reported lower b* values of the coated sample compared to control. Though no significant differences were observed among coating treatments.

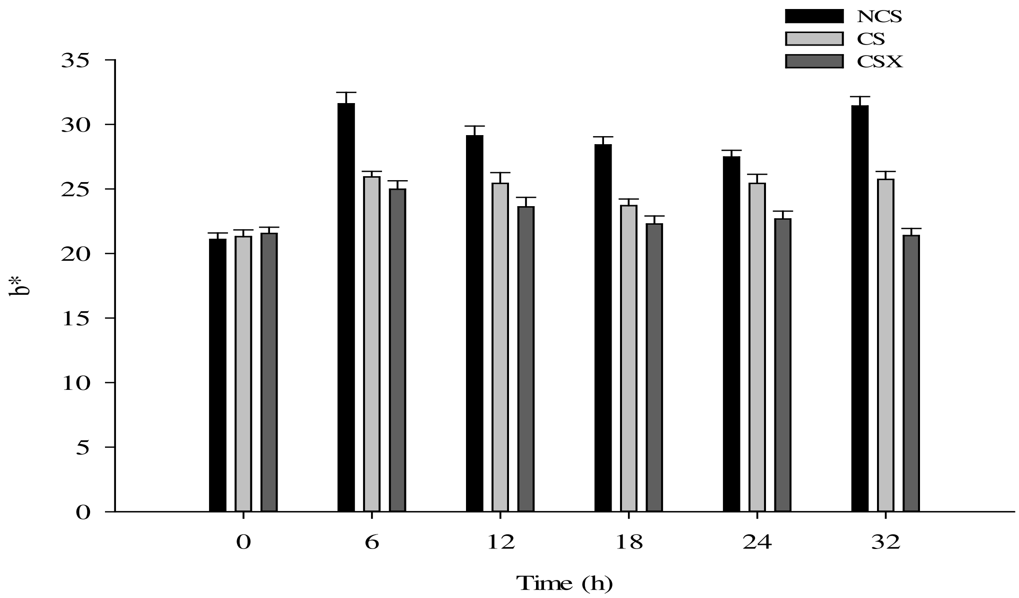

Figure 4.6 Effects of treatments on b* of specimens during storage temperature at 20 °C.

The findings of this study are completely in line with what reported by Meighani et al. (2015). It's worthy to mention that at the end of storage, the highest and lowest b* were recorded with PWE and control fruits with mean 26.21± 0.6 and 22.33 ± 0.5, respectively. while, b* values for the PW coating recorded 23.44±0.3 as showed in Figure 4.6. No significant different was observed in regards of a* values amongst all treatments at ($p \leq 0.05$); however, referring to Figures 4.7 and 4.8 the CSX shows the highest ability to maintain a* values along storage at lower and higher temperatures. LS means of a* showed lower values of CSX specimens (LS means=0.54) followed by CS (LS means=0.62), lastly, higher values of a* recorded for NCS (LS means=1.40).

A research by Alves et al. (2017) showed that applying soybean coating incorporating with ferulic acid antioxidant on fresh-cut apple could have significant positive impact on a* values by the means of reducing the rise of a* values for the treated apples after 7 days of storage at 10°C. whose increase is associated with an increase in red color.

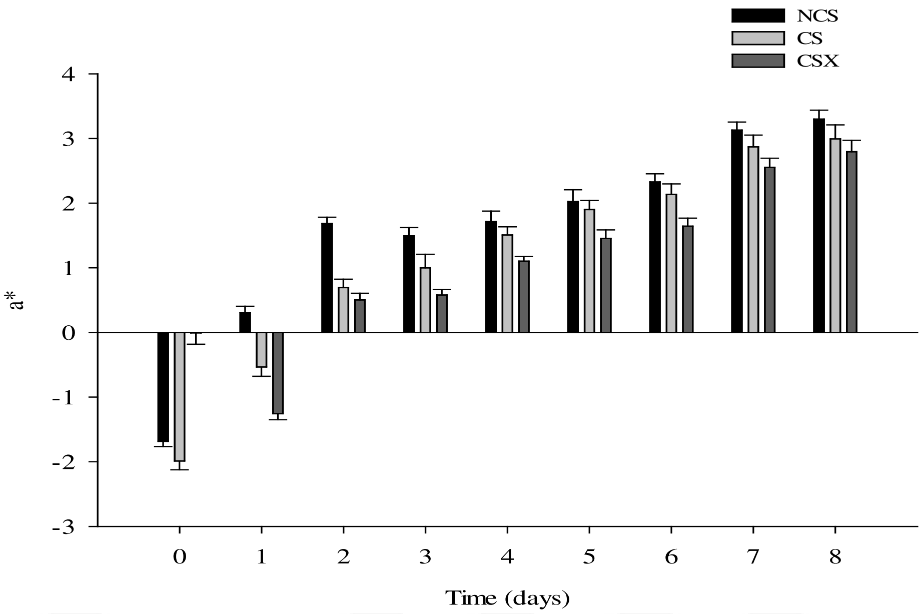

Figure 4.7 Effects of treatments on a* values during storage temperature at 5 °C.

The findings associated to what Moalemiyan et al. (2012) addressed that coating process controls the production of ethylene from fruit surface through making a barrier towards oxygen and carbon dioxide. Natural pigments of fruit will be releasing from cell wall to surface to maintain the color.

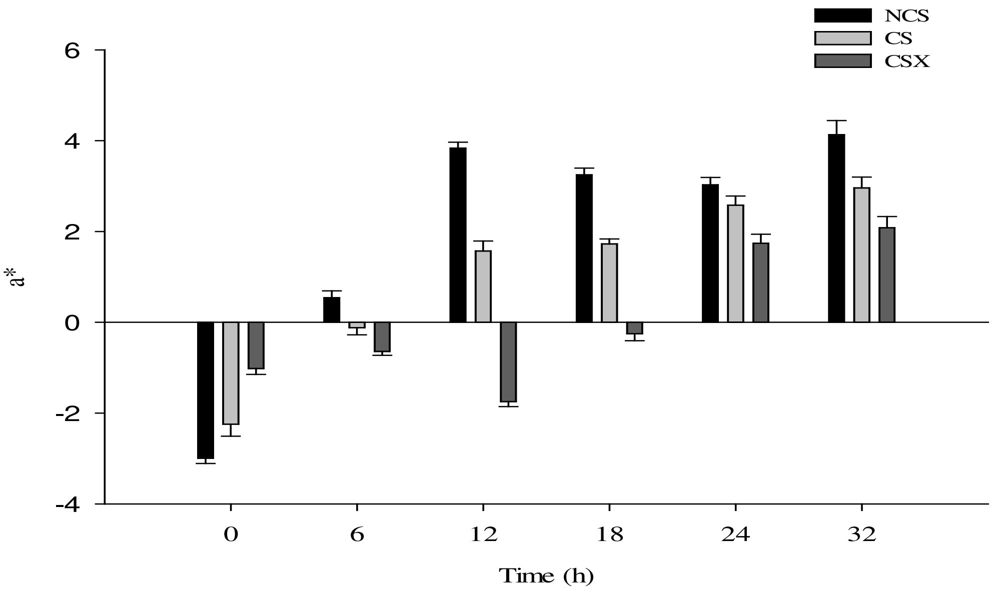

Figure 4.8 Effects of treatments on a* values during storage temperature at 20 °C.

In previous study, Perez-Gago (2005) observed weight loss and color changes on cut-fresh apples treated by edible composite coatings were prepared from whey protein. Two different phases were used to form the emulsion coatings by using hydroxypropyl methylcellulose (HPMC), whey protein isolate (WPI) or whey protein concentrate (WPC) as the hydrophilic phase and beeswax (BW) or carnauba wax (CarW) as the lipid phase, suspended in water. The specimens were tested for 1 day at 20 °C, or 7 days at 5 °C. A part of specimens were kept uncovered during storage at each suggested temperature. The experimental data explored that coating composition significantly affected the color of the fresh-cut apples. Application of all the emulsion coatings significantly reduced BI compared to control apples, except for uncovered specimens stored at 5 °C where HPMC–CarW coatings did not control browning compared to control specimens. Furthermore, whey protein–lipid-based coatings were generally more effective in maintain apple pieces color than HPMC–lipid-based coatings.

BI values obtained by Equation 2. The obtained results demonstrate a significant effect on BI values of coated specimens in a respect of control specimens($P \leq 0.05$) as given in Figure 4.9. However, no significant differences were observed between CS and CSX($P \geq 0.05$). The lowest BI value was recorded for CSX (LS means= 37.79) while NCS (LS means=49.24) and CS reported value (LS means=41.06). The color variation ΔE showed insignificant differences amongst all treatments($P \geq 0.05$). NCS scored the highest value of ΔE (LS means=9.06) followed by CSX (LS means=6.75) and the lowest value recorded for CS (LS means=6.65). Coating the specimens with PWE has the highest effect on browning index BI, significant different at ($p \leq 0.05$); found with coated sample with PWE compared to CS and NCS.

Storing specimens on a lower temperature (5 °C) showed lower browning index records in a respect to data recorded for specimens stored at 20 °C however the differences were not significant($P \geq 0.05$).

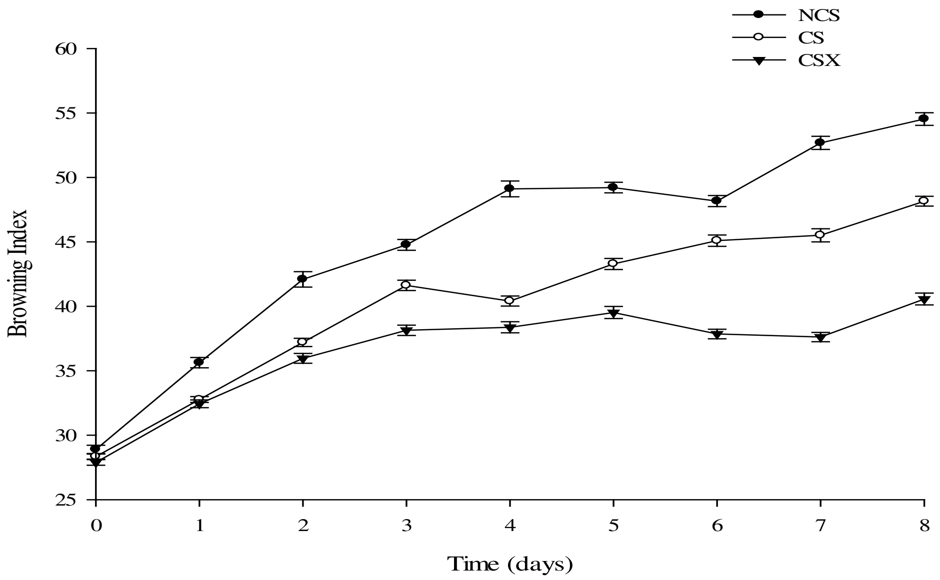

Figure 4.9 Effect of treatment on browning index of specimens during storage temperature at 5 °C.

Other work by Oms-Oliu et al. (2008) reported using alginate- and gellan based coatings incorporated into anti-browning agents; N-acetylcysteine and glutathione. The research used fresh-cut pears to investigate the impact of the coatings solutions incorporated with antioxidants substances after storing specimens for 14 days at 4°C. Dark brown color observed on NSC as per Figure 4.10 by the end of storage period at 20 °C comparing with lighter brown color on Coated and coated with extracts specimens.

The analysis showed that incorporate antioxidants into coating solutions has a positive influence in avoiding browning and intercept browning edges in pears pieces over storage period. on the other hands, substantial decrease observed after calculating the Hue angle values, related to browning development, in both coated or non-coated fresh-cut pears that not handled with antioxidants.

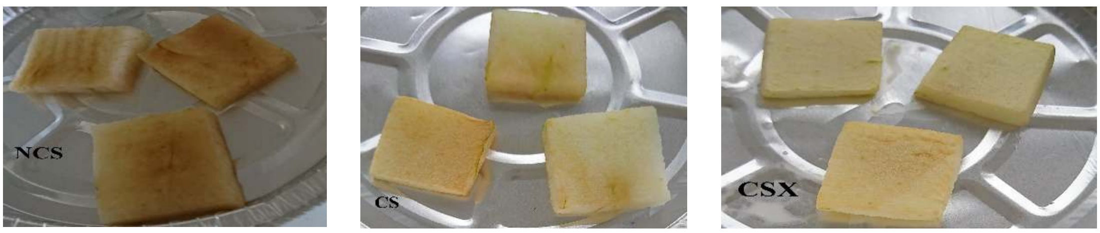

Figure 4.10 Specimens at the end of storage time at 20 °C- NCS specimens showed darker color by the end of experiments compared to CS and CSX

Various preserve technology applied on potato cubes by Ceroli et al. (2018) including application of edible coating, osmotic dehydration and antioxidants, and immersion in antioxidants. The purpose was to determine major changes in quality indicators including color indexes; L*, a*, b*, BI and ΔE. Tubers were kept in cold storage at 8 °C and 95% humidity for 1 month. Final results indicated that a*, ΔE and BI showed differences between conservation technologies, otherwise no significant variations showed between treatments for L* and b* parameters. Immersing potato cubes into antioxidants resulted lower values of a*. Also, lower value of ΔE amongst all other treatments. The positive impact of antioxidants it could be explained with the capabilities of antioxidants against oxygen interaction that causes enzymatic browning and facilitating color changes. As demonstrated in Figure 4.11 browning index of CSX was the lowest followed by CS then the highest BI recorded for NCS at 20 °C storage temperature.

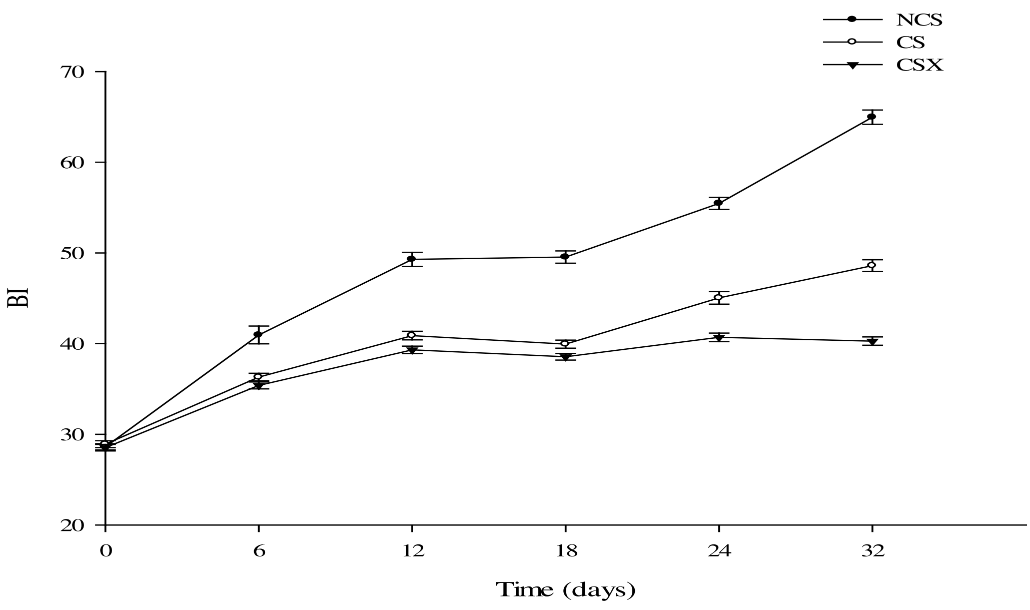

Figure 4.11 Effect of treatment on browning index of specimens during storage temperature at 20 °C.

A review by Muñoz-Labrador et al. (2018) shows that pectin coatings had better behavior in the color variation (ΔE) after applying the citrus pectin treatment as an edible coating on strawberries during storage. Generally, the pectin coatings presented a better behavior in the variation of color with respect to the control.

The Chroma (C*) relates the chromatic parameters a*, b* and L*, and reflects the enzymatic activity being greater whenever that value decreases (Muñoz-Labrador et al., 2018). CSX showed the lowest values of C* (LS means= 22.33) preceded by CS (LS means= 23.78) and NCS had the highest C* values at (LS means= 26.71) as values given in Table 4.5 at 5 °C storage temperature, and Table 4.6 is giving LS means values of C*, hue, and ΔE when specimens are kept at 20 °C storage temperature.

Significant differences were observed between coating and uncoated specimens C* values (*P*=0.001). In contrast with, hue values where CSX showed the lowest hue values (LS means= -4.39), On the other hand, PW specimens had (LS means=2.02) and the highest hue values recorded for NCS (LS means=-0.42) and the differences were not significant amongst the treatments(*P*≥0.05).

Table 4.5 C*, hue, and ΔE values of NCS, CS and CSX samples at 5 °C.

Time	**NCS**			**CS**			**CSX**		
	C*	hue	ΔE	C*	hue	ΔE	C*	hue	ΔE
0	20.59	2.53	0	22.59	0.42	0	20.96	0.35	0
1	26.53	-0.38	7.53	21.79	29.15	2.62	23.15	2.03	1.90
2	25.18	-0.58	6.06	23.31	0.17	2.89	21.85	-26.17	7.33
3	24.84	-0.01	8.03	24.67	2.74	6.84	21.53	-0.12	7.98
4	27.90	-1.57	10.72	22.21	1.50	5.73	20.53	-51.95	9.92
5	25.72	0.08	7.56	24.88	-1.19	9.50	23.89	-0.73	10.00
6	26.83	0.05	7.84	22.83	0.27	6.79	21.01	2.70	7.66
7	28.28	-0.77	10.66	26.12	0.06	10.40	21.42	0.49	9.18
8	24.60	-0.16	5.21	22.26	-2.29	6.24	21.77	2.93	9.71

The table records values of C*, hue, and ΔE along with storage time of all NCS, CS, CSX.

Table 4.6 C*, hue, and ΔE values of NCS, CS and CSX samples at 20 °C.

Time	**NCS**			**CS**			**CSX**		
	C*	hue	ΔE	C*	hue	ΔE	C*	hue	ΔE
0	21.31	-1.04	0.00	19.43	0.93	0.00	21.58	0.99	0.00
1	31.83	-0.40	13.73	21.98	0.18	5.90	25.04	0.17	5.07
2	29.30	-2.04	11.10	25.49	-0.67	8.53	23.61	-4.80	5.63
3	28.41	-5.90	9.60	23.71	-2.74	7.65	22.28	1.27	7.95
4	25.62	-0.61	20.32	27.59	0.36	12.28	22.73	2.03	7.38
5	31.69	0.26	14.98	25.82	-5.12	11.78	21.59	0.73	8.91

The product color was also different depending on storage temperature, the LS means values in a respect to storage temperature as given in Table 4.7 showed that fresh-cut apple that kept at lower temperature 5 °C had the more ability to maintain the values of the color coordinates L* and b*, in particular, comparing to fresh-cut apple kept on higher temperature.

Table 4.7 Effects of storage temperature on color coordinates.

Temperature	L*	a*	b*
20 °C	71.01±0.87^a	0.60±0.03^a	24.44±0.34^a
5 °C	70.60±0.75^a	1.11±0.10^a	23.54±0.20^a

On L* values, storage temperature has not a significant effect (p=0.5), however L* values at 5 ^{o}C were lower (LS means=70.60) than L* values (LS means=71.01) for fresh-cut apple stored at 20 ^{o}C. Furthermore, a* values were not significantly affected (p=0.2) by storage temperature. Moreover, a* showed a lower average value (LS means=0.61) at 20 ^{o}C and higher value (LS means=1.11) at 5 ^{o}C. No significant differences ($P = 0.076$) were observed between storage temperatures on b* values but b* values (LS means=24.44) at 20 ^{o}C were higher comparing to lower values (LS means=23.54) at 5 ^{o}C. As per Figure 4.12 after 30 hours of storage at 20 °C the color differences were visually clear. NCS were the browner while CSX were the less brown.

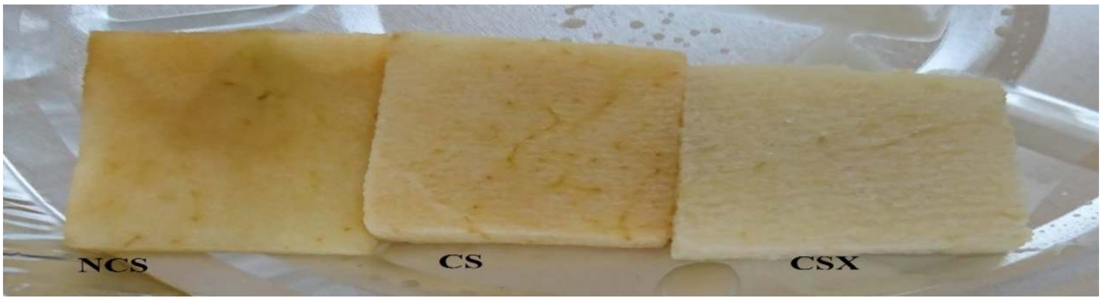

Figure 4.12 Specimens after 30 hours of storage at 20 °C- The effect of coating process to maintain Specimens' color and reduce browning.

Lower storage temperature could maintain product color for longer time, a finding reported by Drake et al. (1988). Furthermore, the study found that color became darker when temperature increased. The analysis made for 'Bing' Sweet Cherry (*Prunus avium L.)* was coated by wax and the quality of fruit was studied considering influence of storage temperature. After 3 weeks of storage significant differences on color parameters were observed for all three temperatures (0, 4.5, 10°C) were found. It's worthy to mention that storage temperature has an essential role in changing levels of endogenous O_2 and CO_2. Temperature can control reactions that led to lose flavor and anaerobiosis. High temperature can activate undesirable reactions that have negative impact on product quality including color (Hernández-Muñoz et al., 2008).

by the fifth days of storage at 5 °C, development of brown color was faster in NCS as per Figure 4.13 compared to coated and coated specimens with extract.

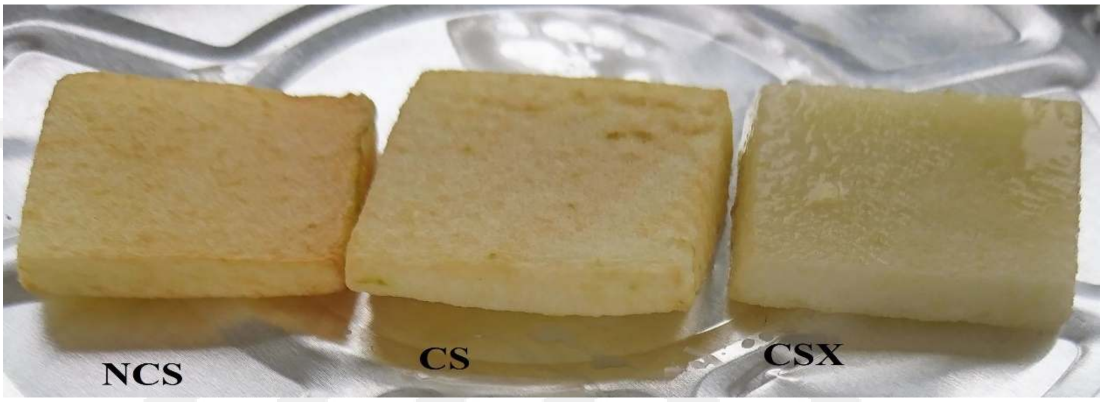

Figure 4.13 Specimens after 5 days of storage at 5 °C- The effect of coating process to maintain Specimens' color and reduce browning.

4.3 Total Phenolic Contents:

Total phenolic content (TPC) stands as another main pillar of product quality. Testing the concentrations of phenolic/antioxidants contents in a product provides a summary on processing activities and treatments were used. Also, gives an idea about product deterioration throughout storage process. Furthermore, oxidize phenolic components forming o-quinones which is speeding up the process of browning reactions eventually brown pigments formulation happened (Sapers, 1993).

Enhancing pectin-wax coating with pistachio hull extract to form edible PWE coating has a positive impact on sustaining the concentration of TPC in fresh-cut apples at both 20 and 5 °C temperatures. Table 4.8 shows TPC values by testing total phenolic levels at time zero and by the end of experiments when TPC reordered 187.86, and 1990.80mg Gallic equal. (mg GAE/100g apple), for uncoated and coated with extract specimens at 5°C, respectively. while TPC test showed values of 128.89

and 130.53 after 32h storage time at 20°C for uncoated and coated specimens with extract, respectively. thus, it was observed that specimens treated with pistachio hull extract-based coating have higher levels compared to non-coated specimens. Increasing total phenolic contents for coated sample with pistachio hull extract extracts can be supported by the extract contribution since pistachio hull is known that as by natural antioxidants content is very high.

Table 4.8 The amounts of total phenolic components TPC (mg GAE/100g apple),of both NCS and CSX during storage at 5 °C and 20 °C.

Sample	**5°C**		**20°C**	
	Time (days)		Time (h)	
	0	8	0	32
Control	120.56±0.87	187.86±0.95	120.56±0.89	128.89±0.80
Coated with Extract	122.36±0.72	199.80±0.99	122.36±0.76	130.53±0.86

However, the effect of PWE was not significant (*P*≥0.05) with a confidence interval of 95%. In regards of storage temperature effect, analysis indicates that storage temperature did not have a significant effect on NCS and CSX, however specimens kept at lower temperature could maintain higher TPC values (LS means=157.64) compared to (LS means=125.58) at 20 °C. The findings are aligned with Salinas-Roca et al. (2018) study that reported the individual or combined influence of pulsed light (PL), alginate (AL) coating, and malic acid (MA) dip on quality parameters of fresh-cut mango throughout 14 days. Data inspection showed that untreated mango slices exhibited 960.4 ± 100.2 (mg GAE/kg), whereas treated mango slices recorded total phenolic components ranged from 955.16±152.1 to 1762.2±138.2 (mg GAE/kg). Dramatic deterioration of Phenolic contents observed jointly in treated and untreated mangos between day 3 to 7 of storage, however the treated mangos yet showed the highest concentration of phenolic contents by the end of storage period in comparison to those untreated ones. Increasing phenolic contents in fresh-cut mangos is commonly linked with abiotic stress (Becerra-Moreno et al., 2015). When, physical stress applied to mango such as cutting. Cutting process will activate the phenylpropanoid metabolism that control phenols synthesis (Charles et al., 2013). Afterwards, oxidation reactions most probably will be taking a place thus, suspending phenylpropanoid metabolism. This might justify phenols decreasing after almost 3 days of storage. Coating plays a role of barrier to oxygen and moisture.

Controlling the atmosphere of mangos will minimize phenolic content degradation. Another effect of coating is to reduce enzymatic activity by preventing substrate to react with active site of the enzyme (Dang et al., 2008; Robles-Sánchez et al., 2013).

Another review by Santagata (2018) where edible coatings based on pectin and honey were used on dehydrated cut fruits; apple, cantaloupe melon, mango and pineapple. The purpose of the study was to promote fruit conservation. Initial total phenolic contents for specimens ranged between 80–225 mg GAE/100 g of dry sample weight. The coated and non-coated fruits reported losing in total phenolic components, however values of coated specimens were shifted at higher concentration interval, specifically 100 and 270 mg GAE/100 g. This result is attributed to the significant PH fruit dehydration, followed by the increasing in substances contents such as; solutes and bioactive (Torreggiani and Bertolo, 2001). Furthermore, using honey-based coating might contribute into supporting phenolic contents of treated dried fruits. It's known that honey by natural has very high polyphenols content (Al-Mamary et al., 2002). It is worthy to mention that coating process affect the dehydration percentage positively in all tested specimens.

Authors reported in a study Simões et al. (2009) using Modified atmosphere packaging (MAP) and edible coating on carrot sticks. The combined application of an edible coating containing 5 mL L^{-1} of chitosan under two different MAP conditions (10 kPa O2 + 10 kPa CO2 in Pack A and 2 kPa O2 + 15–25 kPa CO2 in Pack B) over 4 °C for 12 days. The application aims to extend shelf-life of product by means of sustaining quality parameters throughout storage. The paper described that some phenolic components identified at day 0 were lost by the end of storage evaluated period. whereas, new undetected phenolics were formed in respect of carrot sticks coated in Pack A. Tudela et al. (2002) reported similar findings explored with testing fresh-cut potato. Synthesized Phenolics might explained by wounding the product and cooling storage temperature by the means of mechanism of abiotic stress (Cisneros-Zevallos, 2003) .

Other authors elaborated on chitosan role as an exogenous elicitor in plant tissue inducing different responses such as the de novo biosynthesis of phenolic compounds (Benhamou et al., 1996). Initial phenolic contents in both coated and un-coated carrot sticks were about 0.16 mg/100 g fresh weight (FW). Ending of evaluated storage time, analysis showed increasing in phenolic contents; levels were higher by 2.5–6 times in uncoated and coated specimens, respectively. Eventually, increasing in phenolic contents was clearly noticeable in coated carrot sticks stored under moderate O_2 and CO_2 levels. The combined application of edible coating containing chitosan and moderate O_2 and CO_2 levels-maintained quality and enhanced phenolic content in carrot sticks.

CONCLUSION

The results of this study give some insight into incorporating extract of Pistachio by-products (pistachio-hull extract) in edible coating for cut-fresh apple. The findings showed that edible coating has a significant role to maintain product color and reduce the browning of fresh-cut apples. Furthermore, coating process can extend the shelf-life of apple pieces.

Sustainable food production is a key objective to save the future of billions of people around the globe. Sustainability term is built on three main pillars; environmental, social, and economical. In order to achieve the sustainable production, investments in these three pillars are a key. Investing in innovative food packaging techniques such as edible coatings is extremely important to maintain the food value chains and increase the food production to its maximum thus, contributes into protecting environment and reduce the massive plastic packages are used in food industry around the globe. Adoption of suitable packaging technologies by the food industry can be useful to extend the shelf life, improve quality, safety, and provide information about the product. Research on these smart packaging technologies can result in further improvement of the existing system. In future untapped opportunities exist for smart packaging to offer consumer benefits and convenience.

The findings of this research can open the door for further studies on incorporating pistachio-hull extract as a natural additive into edible coating materials, and the opportunities to scale up the production of this innovative coating materials for industrial purposes.

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