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Review

Application of Natural Edible Coating to Enhance the Shelf Life of Red Fruits and Their Bioactive Content

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Featured Application: The study highlights the key health-promoting qualities of red fruits, as well as the use of natural edible coatings to extend the fruits' shelf life and ensure their sustainability.

Abstract: Red fruits contain bioactive substances including phenolic acids and flavonoids, which provide many health advantages for the human body. Industries find them intriguing because of their color and their ability to prevent chronic ailments such as metabolic, degenerative, and cardiovascular disorders. Nevertheless, the resilience of these organic molecules is influenced by several environmental, physical, and chemical phenomena. Therefore, the beneficial health properties of red fruits may diminish during postharvest processing. In this scenario, many postharvest methods have been implemented to enhance the shelf life and preserve the bioactive components of red fruits. The objectives of this review were to provide a comprehensive assessment of the health benefits of red fruits, and to explore the possibilities of edible coatings in retaining their freshness and protecting their bioactive contents. Co-occurrence networks were built using VOSviewer software to produce a two-dimensional map based on term frequency, and the examination of the 1364 keywords obtained from the scientific papers revealed the presence of at least 71 co-occurrences that provide insight into many natural components used in edible coatings for red fruits, such as proteins, polysaccharides, lipids, phospholipids, and minerals. The review examined their composition, functioning, application techniques, limits, safety considerations, legal regulations, and potential future developments. This review has shown that an edible coating may act as a protective layer on the surface of the fruit, alter the interior gas composition, reduce water loss, and postpone fruit ripening, thereby enhancing the health-promoting properties.

Keywords: edible coating; red fruits; bioactive compounds; berry; health promoting; postharvest; antioxidants; sustainability

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1. Introduction

Consumer behaviors have been greatly influenced by the substantial demand for health-conscious food items. It is commonly recognized that consuming fruits and vegetables provides significant health benefits and helps to protect against many ailments. Cheung et al. (2021) emphasized that consuming a diverse range of fruits and vegetables daily might significantly lower the risk of death [1], particularly in relation to cardiovascular disease, chronic illnesses, and cancer [2]. Red fruits, commonly referred to as berries, are diminutive fruits which are highly valued for their crimson color, tangy-sweet flavor, and advantageous effects on well-being [3]. There are several types of red fruits, but the most important ones are from the *Rosaceae* (strawberries, sweet cherries, raspberries, and blackberries), *Ericaceae* (blueberries, cranberries), *Myrtaceae* (Jaboticaba), and *Arecaceae* (Açai) families. These fruits are rich in essential nutrients and have low caloric contents. They may be consumed either in their raw form or processed into various products, such as juice, fruit pulp, jams, sweets, and fermented drinks [3].

Berries with a certain color, including blackberries (Rubus species), black raspberries (*Rubus occidentalis*), blueberries (*Vaccinium corymbosum*), cranberries (*Vaccinium macrocarpon*), red raspberries (*Rubus idaeus),* and strawberries (*Fragaria ananassa*), are frequently consumed by humans either in their natural state or after undergoing processing [4]. Red fruits are high in phenolic chemicals, with the main types being phenolic acids (hydroxycinnamic and hydroxybenzoic acids), flavonoids (flavanols, flavonols, and anthocyanins), and stilbenes (resveratrol). These are distributed in varying amounts in different regions of the fruit (epicarp, endocarp, and seeds). Furthermore, while polyphenols may be found in many plant matrices, red fruits are known to contain a high concentration of anthocyanins, which are responsible for their color [3]. Hence, the popularity and consumption of red fruits have experienced substantial growth. This can be attributed to their rich nutritional content, distinct taste, flavor, and beneficial properties for health promotion. Red fruits are recognized as dietary sources of bioactive compounds, which contribute to their known health benefits [5–8].

In red fruits, flavonoids, specifically anthocyanins, play a crucial role in determining their color, and they possess various beneficial effects such as antioxidant, antimicrobial, anti-inflammatory, anticancer, and cardioprotective properties [9]. However, these compounds are prone to degradation during plant growth, food processing, and gastrointestinal processes, which ultimately reduces their bioaccessibility [3]. Consequently, the primary obstacle in distributing high-quality berries concerns the need to prevent their deterioration and prolong their storage capacity. Berry fruits are particularly vulnerable to pathogen attack, over-ripening, excessive respiration, softening rate, susceptibility to mechanical damages, and decay [4,9]. The most effective techniques for preserving quality during the postharvest period are immediate precooling and storage at low temperatures. Manipulating and regulating the composition of gases in the environment, specifically increasing carbon dioxide (CO_2) levels up to 20 kPa and oxygen (O_2) levels between 5 and 10 kPa, may inhibit the development of microorganisms and delay the senescent process. However, these modified atmospheres may also have an impact on the presence of bioactive chemicals, and the specific reaction to these technologies varies depending on the cultivar [9]. Therefore, to mitigate the loss of red fruits and prolong their storage duration, it is necessary to investigate novel preservation techniques [10]. Hence, the utilization of edible coatings is a contemporary approach to preserve the quality of red fruits and decrease food waste [11,12]. It serves to prolong the postharvest lifespan and mitigate the deterioration of quality [13]. Moreover, it presents an environmentally friendly substitute to synthetic packaging materials [10,14].

Edible coatings are composed of food-grade ingredients that are safe for human consumption, and are formed into thin, semi-solid films [15]. These are specifically engineered to possess a range of functional characteristics that prevent the decay of fruits during storage and distribution. These characteristics include safeguarding against physical damage, regulating the movement of vapor and fluids, and creating barriers against UV (ultraviolet) and visible light [16]. In addition, they may be modified to include preservatives (such as antimicrobials or antioxidants) that extend the shelf life ("active packaging") or sensors that detect changes in food quality, freshness, or safety ("smart packaging") [15,17]. Food surfaces may be coated with a homogeneous layer of the required thickness through the use of methods such as panning, brushing, spraying, or dipping [18]. For edible films and coatings, it is important to use substances that are considered safe for consumption. These substances should be considered "generally recognized as safe" (GRAS) by the Food and Drug Administration (FDA) in the United States or by equivalent regulations in other jurisdictions [15,18]. In recent years, there has been a significant effort to produce effective and economically viable edible coatings as an alternative to petroleum-based coatings in order to address related issues [15,19]. Specifically, there has been an increase in consumer apprehension over the adverse ecological effects of non-biodegradable single-use plastics [16]. Natural edible coatings may address these issues and provide further advantages, such as improved health via nutritional fortification [15,20]. Hence, the advancement of edible coatings that might improve the quality and prolong the shelf life of red fruits may lead to increased consumption, thereby resulting in positive health outcomes.

The objectives of this review were to (i) analyze the health benefits of red fruits, (ii) evaluate the postharvest management and technological uses of red fruits, (iii) examine the existing literature on the potential applications of innovative edible coatings for red fruits, focusing on their ability to maintain the quality of bioactive compounds, prevent degradation, and reduce microbial contamination, and (iv) present scientific evidence concerning the effects of various sustainable and healthy edible coatings on the quality of bioactive compounds, sensory acceptability, antimicrobial properties, and shelf life of red fruits, with the aim of minimizing quality deterioration.

2. Materials and Methods

A literature review was performed for English language articles in Scopus to search for published articles relating to the application of natural edible coatings on red fruits and the impact on their bioactive content and shelf life. To gather scientific documents on the topic, the following search terms were used in the article titles, abstracts, and/or keywords of Scopus databases, using English as the filter language: "red AND fruits, AND health AND promoting, AND natural AND edible AND coating, AND bioactive, AND shelf life". The collected documents obtained through the scientific database were then manually analyzed via a reference manager tool (Zotero version 6.2) to exclude duplicates and any documents not relevant in food processing and human nutrition. The keywords analysis was based on both "all keywords" in the titles and abstracts of the collected documents and the "authors keywords". VOSviewer was used for the bibliometric mapping [21]. In this latter case, a co-occurrence network was built considering a minimum number of five occurrences for each keyword.

3. Results

3.1. Bibliometric Analysis

Bibliometric data outcomes of the scientific search in Scopus databases, using the keywords (red AND fruits, AND health AND promoting, AND natural AND edible AND coating, AND bioactive, AND shelf life) returned 132 scientific articles published between 2013 and 2024. These articles mainly defined the terms "red fruit health benefits," "edible coating", "benefits", "application method", and "influence on bioactive compounds and shelf life". There were eighteen subject categories in all, and, for nine of them, at least seven publications could be located. Engineering and agricultural and biological sciences were the most popular topics in edible coating research, as shown in Figure 1, which lists the top 10 research areas based on the quantity of publications. These two fields combined made up 60% of all articles. Scientists' principal attention is thus on redesigning naturally edible coatings and contrasting them with conventional coatings.

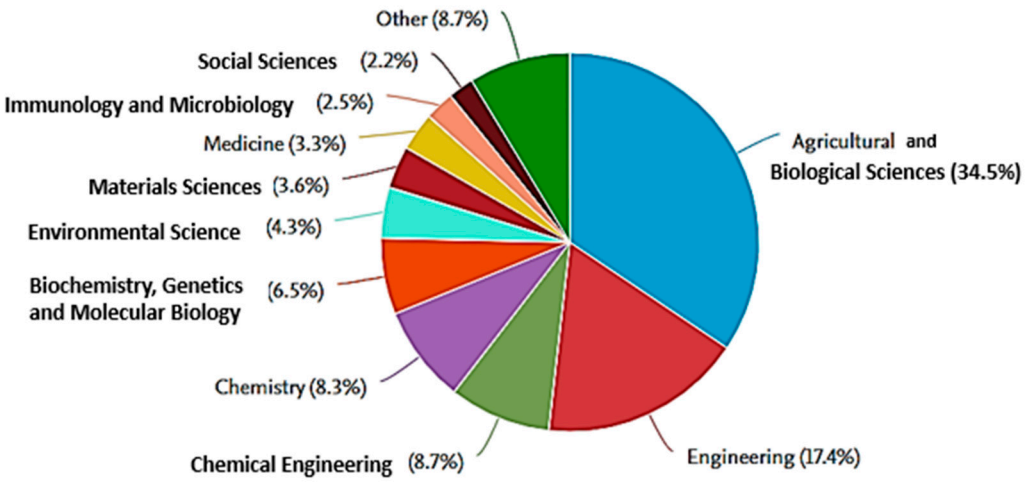


Figure 1. Bibliometric data: documents by subject area.

3.2. Keywords Clustering

The co-occurrence network of keywords shown in Figure 2 was acquired using VOSviewer version 1.6.18. The examination of the keywords included in the articles that were retrieved provides useful assistance, as does its visual depiction as a co-occurrence network (Figure 2). From the 136 scientific publications available in the Scopus databases, a total of 1364 keywords were obtained. These keywords were then sorted and categorized according to how frequently they appeared in the red fruits and edible coating topic. Figure 2, which shows the network of terms with at least five occurrences, provides important information. There were seventy-one keywords in all, arranged into four clusters. The first group was symbolized by red color and was primarily concerned with health-promoting qualities. It included terms such as bioactive compounds, antioxidants, functional foods, carotenoids, health benefits, fruits, vegetables, and food waste. This cluster depicts the variability and diversity of red fruits studied by scientists and nutritionists to better understand their influence on human health. The green color helped us to identify the second cluster, which is primarily concerned with food preservation and shelf life, using terms such as food packaging, active packaging, packaging materials, food manufacturing, food preservation, nanotechnology, and their influence on food safety and quality. This demonstrates that one of the primary goals of scientific study was to link edible coatings to shelf life and bioactive content preservation. The inclusion of the term "nutraceuticals" is of major value in characterizing the health-promoting features of this cluster, which is closely associated with red fruits. The blue cluster focuses on the production and application of edible coatings, with keywords including chemistry, biochemistry, spray drying, electrospinning, and encapsulation. The smallest cluster, in yellow, comprised terms related to natural edible coating and sustainability, including proteins, plant extracts, biological characteristics, metabolism, sustainable development, chitosan, biopolymers, and biodegradability. This cluster serves as a junction/continuity point for the red, green, and blue clusters, all strongly connected to subjects relating to sustainable food processing and nutrition.

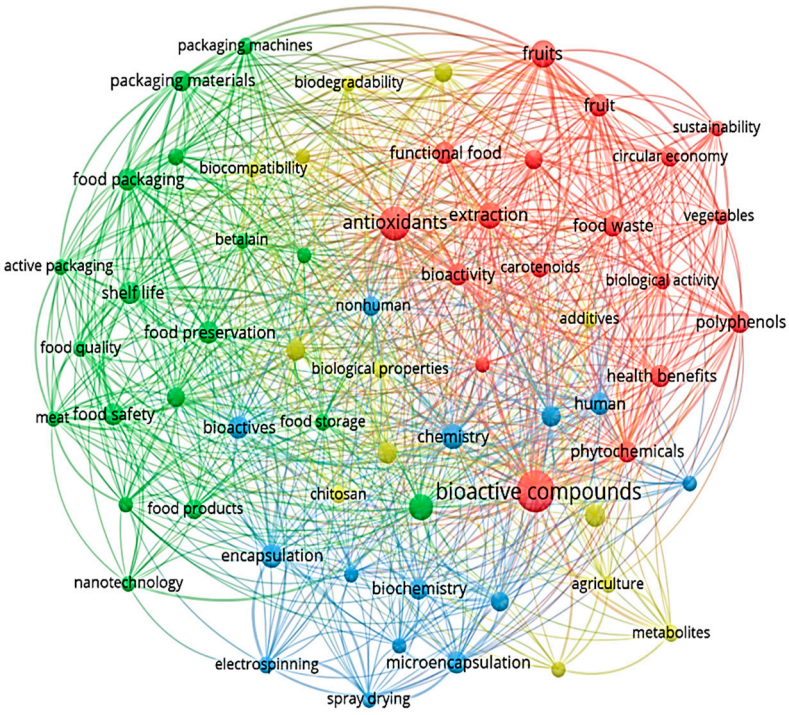


Figure 2. Network of keywords frequently co-occurring in Scopus databases regarding red fruits and edible coating.

4. Discussion

4.1. Red Fruits: Health-Promoting Properties and Benefits

The term "red fruits" refers to a collection of fruits that are either black or red in color, often in the form of berries. Examples include strawberries, cherries, red raspberries, black raspberries, blackberries, cranberries, blueberries, blackcurrants, and grapes [5]. Red fruits are widely acknowledged for their abundance of essential nutrients, such as vitamins (A, C, and E), minerals (calcium, phosphorus, iron, magnesium, potassium, sodium, manganese, and copper), as well as dietary fibers and antioxidants, particularly anthocyanins and ellagitannins [5–7,22]. Vitamin C, also known as ascorbic acid, is the predominant chemical found in red fruits and serves as a primary antioxidant in this fruit category. Blueberries have the highest concentration of ascorbic acid among fruits, whereas raspberries have a comparable amount to strawberries, and blackberries have a lesser concentration [5,23]. Cranberries have been recently classified as a novel functional food and nutraceutical, being recognized for their distinctive role in preserving urinary tract health [24].

Red fruits are rich in phenolic compounds, specifically phenolic acids (hydroxycinnamic and hydroxybenzoic acids), flavonoids (flavanols, flavonols, and anthocyanins), and stilbenes (resveratrol), which are the primary classes of phenolic compounds found in these fruits [5]. Similarities in the phenolic content can be observed among red fruits belonging to the same plant family and genus. Flavonols and hydroxycinnamic acids are commonly found in the *Ericaceae* family, specifically in the Vaccinium genus (which includes bilberries, blueberries, cranberries, and lingonberries) [5,25–29]. On the other hand, gooseberries, black currants, and red currants (which belong to the *Grossulariaceae* family, genus Ribes) are mainly characterized by the presence of flavonols [30,31]. Ellagic acid is the primary phenolic compound found in fruits belonging to the *Rosaceae* family, namely the species Fragaria and Rubus (strawberries and red raspberries) [31–33]. Although red fruits may seem identical, each species has its own characteristics. As an example, Häkkinen et al. documented that blueberries have significant amounts of quercetin and caffeic acid [34], while bilberries and lingonberries retain lower levels of quercetin [5]. Phenolic compounds possess antioxidant capabilities that hinder the spread of free radicals by stabilizing them via donating a single electron or a hydrogen atom [35,36]. Hence, consuming red fruits with antioxidant characteristics on a regular basis lowers the levels of RONS in the body, hence reducing the likelihood of developing the mentioned illnesses [3,37,38]. For instance, Huang et al. demonstrated that strawberries contain abundant anti-inflammatory phenolics, specifically anthocyanins [39]. These compounds have been proven to reduce the inflammation and oxidative stress that occur after a meal in overweight individuals who are otherwise healthy. This effect is particularly pronounced when the strawberry drink is consumed prior to the meal, as indicated by Cosme et al. [5].

Also, anthocyanins are widely recognized as the predominant and most significant category of phenolic compounds found in red fruits, responsible for their blue, purple, red, or black pigmentation [5]. Furthermore, the composition of anthocyanins in fruits and their extracts is associated with several biological characteristics, particularly in reducing the likelihood of multiple illnesses caused by oxidative damage to cells [40–44]. In addition, they possess antibacterial characteristics, as shown by Widyarman et al. [45], and antiviral activities, as shown by Figueira et al. [46]. Moreover, these chemicals play a crucial role in determining the distinct sensory characteristics of red fruits and facilitating the development of diverse industrial technologies. The efficacy of red fruits in combating metabolic illnesses has been shown via rigorous testing on both animal models and people, as shown via the findings presented in Table 1 [3]. Studies have shown that red fruits like acai and jaboticaba may effectively regulate metabolic syndrome by lowering fasting glucose, insulin, and total cholesterol levels [3,47]. Additionally, these fruits have been found to have positive effects on various health issues [42]. The regular consumption of fruits that are high in anthocyanins might potentially lower the chance of developing many forms of cancer, thanks to their antioxidant characteristics [43,44,48].

Table 1. Scientific evidence of the benefits of the health-promoting properties of red fruits.

Red Fruits	Main Nutrients /Phytochemicals	Health Benefits	Reference
 Açaí (*Euterpe oleracea* Mart.)	proteins, lipids, minerals, and vitamins; phenolics	Metabolic effects Protection against obesity, endothelial dysfunction, hypercholesterolemia, hyperglycemia, and insulin resistance. Reduction of the levels of some markers of metabolic syndrome such as insulin, glucose blood, and cholesterol. Anticancer properties Suppression of the proliferation of C-6 rat brain glioma cells. Neuroprotective properties Improvement of working memory, as tested in the Morris water Maze, observed in old rats fed only with Euterpe oleracea. Reduction of systolic blood pressure; however, no differences in co-primary electrocardiogram and diastolic blood pressure was observed.	[47–51]
 Strawberry (*Fragaria* × *ananassa*)	ascorbic acid; flavan-3-ols, flavonols, and anthocyanins	Anticancer properties Targeting the pro-inflammatory mediators and oncogenic signaling, preventing colorectal cancer in rats. Anti-inflammatory properties The presence of metabolites of berries in blood showed anti-inflammatory properties.	[52,53]
 Blackberry (*Rubus* subg. Rubus)	phenolics, especially flavonols such as quercetin glucosides	Anticancer properties Inhibition of the proliferation of colorectal carcinogenesis cells. Neuroprotective properties Digested phenolics were well transported through blood–brain barriers, showing effective neuroprotection in primary and advanced cell neurons.	[44,46]
 Red/black raspberry (*Rubus* occidentalis)	sugar and dietary fibers; lipids, proteins, and ascorbic acid; anthocyanin e.g., glucosides of delphinidins;	Anticancer properties The anthocyanin in raspberries helps in the improvement of endothelial function by its protective action on endothelial cells with less oxidative stress. Phenolics from raspberries have protective action against cancer development, especially in colon cancer and intestine cancer. The distinctive phytochemical format of raspberries has beneficial antioxidant action which helps in free radical scavenging activity. Ellagitannins and anthocyanins as a main antioxidant phytochemical of raspberries also present tumor proliferation inhibitory properties. Metabolic effects Anthocyanins in red raspberries and ellagic acid stimulates insulin secretion in animals. Red raspberry anthocyanins act as an anti-obesity agent by changing lipid metabolism as by enhancing lipolysis in adipocytes. Neuroprotective properties Raspberries are richly blessed with phenolics which help in reducing oxidative stress, inflammation, and improving insulin signaling; potential in treating Alzheimer's disease.	[54–62]

Table 1. *Cont.*

Red Fruits	Main Nutrients /Phytochemicals	Health Benefits	Reference
 Jaboticaba (*Myrciaria cauliflora*)	organic acids, sugars, vitamins, dietary fiber, minerals, and flavonoids	Metabolic effects Increasing the HDL cholesterol in the blood and the prevention of hepatic steatosis, thus preventing and controlling obesity. Activity against prostatic damage Jaboticaba peel extract is a potential prostatic lesion preventive in mice aged or fed with a high-fat diet due to the hormonal and angiogenic balance.	[41,42]
 Blueberry (*Vaccinium corymbosum*)	Polyphenols, i.e., flavonoids, procyanidins (monomeric and oligomeric form); flavonols (i.e., kaempferol, quercetin, myricetin); phenolic acids (hydroxycinnamic acids) and derivatives of stilbenes	Anticancer properties Anti-acute myeloid leukemia Antidepressant-effect Decreasing the immobility of tail mice; no observed effects on the locomotor activity with a minimum dose. Anti-inflammatory properties The presence of metabolites of berries in blood showed anti-inflammatory properties. Gastric protection Improvement of the mitochondrial dysfunction and oxidative defense, which alleviate inflammation, oxidative stress, hepatic steatosis, and, in some cases, non-alcoholic fatty liver disease. Neuroprotective properties The use of blueberries during the advances of dementia improves cognitive performance.	[40,43,53,63,64]
 Cranberry (*Vaccinium oxycoccos*)	vitamins, minerals, dietary fiber, anthocyanins, and proanthocyanidins	Effect on urinary tract Cranberries boast a rich nutritional profile, containing essential vitamins, minerals, dietary fiber, and an array of bioactive compounds such as antioxidants, anthocyanins, and proanthocyanidins. One of the standout qualities of cranberries is their impact on urinary tract health. The presence of proanthocyanidins inhibits bacterial adhesion to urinary tract walls, offering protection against urinary tract infections. Antioxidant properties Reducing the risk of chronic diseases and supporting overall well-being. Other Cranberries may have positive effects on cardiovascular health, diabetes management, oral health, and more.	[65]
 Black currant (*Ribes nigrum*)  Red currant (*Ribes rubrum*)	minerals, vitamins; phytochemicals: anthocyanins,	Cardioprotective effects Inhibited platelet formation, decreased fibrin formation, and increased anti-coagulant effects. Reduced serum inflammatory markers such as C reactive protein. Increased alpha- and gamma-tocopherol serum concentrations. Increased serum HDL-C protein and lowered triglyceride and total cholesterol in low BMI patients with hyperlipidemia. Effect on ocular system Causes the vasodilation of ocular vessels to increase blood flow into the eye and reduce fatigue.	[66–72]

Table 1. *Cont.*

Red Fruits	Main Nutrients /Phytochemicals	Health Benefits	Reference
 Grapes (*Vitis vinifera*)	vitamins, flavonoids, anthocyanins, resveratrol and carotenoids	Anticancer properties Resveratrol lowered the expressions of cyclins D1 and D2 and the multiplication of cell nuclear antigens. It also suppressed the anti-apoptotic proteins, e.g., tumor promotion markers, survivin, ornithine decarboxylase, and cyclooxygenase. Cardioprotective effects Catechin and epicatechin from grapes help in the maintenance of endothelium integrity and released nitric oxide (NO). Grape extracts contained polyphenolic complexes, which caused AKT/PI3 kinase-induced blood vessel endothelium relaxation. Antidiabetic properties Enhanced the antioxidant capability of plasma, reduced the oxidation of low-density lipoprotein concentrations, and increased high-density lipoproteins in healthy persons and patients suffering from hemodialysis. Procyanidin present in grape extracts acts as an insulinomimetic agent as it induces the phosphorylation of insulin receptors and ultimately enhanced the uptake of glucose. This induced phosphorylation pathway is different from that of insulin.	[73–77]

Research has shown that acai can prevent the growth of cancerous cells in the brain [48]. Similarly, blackberries have been found to inhibit the growth of human colorectal cells [44]. Blueberries have been shown to have a similar effect on acute myeloid leukemia (AML) [43]. Additionally, strawberries have been found to be effective against colorectal cancer [52]. Recent research showed that consuming one cup of blueberries and two cups of strawberries per day effectively decreased inflammation in human blood [3]. Hence, red fruits may serve as a viable natural option for mitigating the antecedents of several inflammatory conditions [53]. Anthocyanins and other phenolic compounds derived from red fruits, such as blackberries [46], acai [50], and blueberries, have been linked to neuroprotective benefits, including the prevention of dementia and the enhancement of cognitive function [40]. The neuroprotective properties of red fruits, particularly those rich in flavonoids, have been investigated in scientific studies. Quercetin, a flavonoid found in red fruits like berries, citrus fruits, and red wine, has demonstrated neuroprotective effects. It acts as an antioxidant and anti-inflammatory agent, contributing to the prevention of various diseases [78]. Additionally, anthocyanins, another type of flavonoid present in red fruits, can penetrate the blood-brain barrier and offer potential neuroprotective benefits [79]. Bortolini et al. found that concentrations of 20 ug/mL of blackberry, black raspberry, blueberry, cranberry, red raspberry, and strawberry extracts were effective in preserving the cellular viability of bv-2 microglia when exposed to oxidative stress [3]. These concentrations reduced the regulation of caspase 3/7 activity by 35.5%, 40.7%, 46.3%, 54.9%, and 46.9%, respectively. The study conducted by Shao et al. demonstrates the neuroprotective effects of blueberry anthocyanins [80]. These effects include protection against neural morphology changes caused by perfluorooctane sulfonate, alterations in neurotransmitter levels, changes in neural-related gene expression levels, and DNA damage. The primary association of this protective mechanism is in the capacity of anthocyanins to diminish the presence of free radicals. Nevertheless, a more comprehensive understanding of the intricate neuroprotective processes arising from phytochemicals found in red fruits is necessary [3]. Due to the numerous health benefits provided by berry fruits, red fruits can be regarded as a natural substitute for managing various chronic illnesses [3]. Additionally, they have the potential to be utilized in the development of innovative technologies for industries [81–84].

4.2. Red Fruit: Postharvest Management and Technological Applications

The handling of red fruits presents a range of difficulties. Berries are devoid of a safeguarding outer layer and are very prone to spoilage, mostly due to their vulnerability to physical harm, dehydration, and fungal deterioration [85]. In addition, berries are classified as non-climacteric fruits, meaning that they must be picked when they are fully mature or very close to it. Once separated from the plant, most berries will not continue to ripen naturally, and their eating quality will not increase after harvest [9]. Under some circumstances, fruits may undergo coloration during storage. However, if they are picked prematurely, their texture, sweetness, and acidity may not reach complete development [9,86]. The quality of fruit for the market is primarily assessed based on physicochemical factors such as size, full color, gloss, a firm and crisp texture, a lack of decay, injuries and bruises, a harmonious balance between sweetness and acidity, green sepals, and a distinctive perfume [9]. The primary factors contributing to loss and rejection include weight reduction, the appearance of bruises and cuts, signs of mildew and decay, alterations in color, juice leaking, and sepal wilt [9]. The level of fruit maturity at harvest and the way the fruit is handled are two crucial determinants of the postharvest preservation quality. The level of ripeness at harvest significantly impacts the shelf life of the berries, their storage characteristics, and the likelihood of sales [87]. Immature fruit may have a greater capacity for storage, but they are unlikely to acquire the desired sensory features. On the other hand, over-mature fruit usually has a limited shelf life due to an increased susceptibility to decay [9,88]. To achieve the highest level of quality at the time of harvest and preserve this quality during transportation and commercialization until the fruit is eaten, it is crucial to pick berries when they have reached the ideal level of maturity [9,89]. To prevent excessive handling and harm to the fruit, it is recommended to manually collect, sort, classify, and pack berries in the field straight into the final container for the purpose of selling them while fresh.

Red fruits are used for several industrial uses, being processed into food and drinks as well as medicinal and nutraceutical items. Red fruits are highly valued for their perishability, phenolic content (particularly anthocyanins), and sensory qualities, making them desirable for both fresh consumption and industrial processing [3]. Therefore, there is a growing market for fruits that have undergone little processing, have been sterilized, peeled, and sliced, and are ready to be consumed [82]. Red fruits are utilized in the production of various fruit-based products, including juices, wines, non-alcoholic beverages, dairy products, fermented beverages like kombuchas, purees, pulps, desserts, jellies, and different types of vinegar [90–93]. Furthermore, novel technologies catering to the chemical, pharmaceutical, and food sectors have been developed, alongside their traditional uses. Red fruit growers may capitalize on this market by offering several solutions to enhance the value of the raw material [3]. The traditional method of processing fruits into juice and fermented drinks generates a significant quantity of waste or by-products, particularly fruit pomaces. These pomaces are composed of leftover pieces of fruits, such as epicarp, endocarp, mesocarp, and seeds. The majority of fruit pomace is comprised of the fruit's endocarp and seeds [3]. Consequently, this leftover material has a high concentration of carbohydrates and dietary fibers, as well as various phenolics that may be extracted for industrial purposes [94,95]. In addition, food compositions such as cookies also include fruit pomaces, sugars, and dietary fibers [96]. Consequently, the use of fruit pomaces might facilitate the creation of novel environmentally friendly products that possess the advantageous characteristics of the enhanced chemicals derived from red fruits [3].

Red fruits have a short shelf life because they contain a lot of water, have significant postharvest activity, and are prone to fruit rot and darkening [9]. The elevated respiration rates of these fruits result in modifications in texture, color, taste, and nutritional composition during storage. These alterations play a vital role in assessing fruit quality and customer satisfaction [97]. Their limited shelf life is also attributed to deterioration induced by rot-causing bacteria and rapid softening rates [98]. Ethylene in storage may enhance respiration rates and promote the formation of gray mold. Water loss is a physiological issue that may impact berries during storage. This leads to fruit shriveling, a loss of gloss,

and has a significant influence on the degradation of anthocyanin [9]. The process of fruit aging is hastened by water loss, and the fruit becomes unsuitable for sale after it has lost more than 6% of its weight [9]. To minimize water loss during the postharvest handling of berries, it is important to promptly precool them and store them in appropriate packaging at the optimal temperature and relative humidity [9,99].

Postharvest washing, immediate quick chilling, and storage at low temperatures are the primary procedures used to preserve the quality and stability of bioactive chemicals, and to prevent the deterioration of fruits and vegetables [9,100,101]. In addition, postharvest infections are often managed using synthetic fungicides [102] and by keeping the produce in controlled or modified atmospheres with elevated levels of [9,103]. Nevertheless, these approaches do have some constraints. It is not advisable to wash berries before selling them since it may easily damage the peel, and the time it takes to dry them slows the cooling process and increases the risk of infection by harmful germs [102]. In addition, chemical fungicides can have various adverse impacts on both food safety and the environment. This raises concerns among the public regarding environmental pollution, the potential contamination of berries due to fungicide residues, and the challenge of controlling fungal diseases caused by the emergence of fungicide-tolerant strains of pathogens [9,104].

4.3. Study on Red Fruits and the Implementation of Cutting-Edge Edible Coating

Pham et al. state that the primary purpose of developing edible coatings was to substitute and reduce the use of potentially hazardous chemicals and synthetic substances that might pose risks to consumers' well-being [105]. An edible coating is a thin layer made from biological or chemical components that is applied to the surface of a product. It may be constituted by a single layer or by many layers [106]. Edible coatings aid in preserving phytonutrients (such as antioxidants, phenolics, and pigments) and regulating the physicochemical properties (such as respiration rate, weight loss, total dissolved solids, and pH) of fruits over an extended period [107]. Consequently, the decay of fruit is postponed, the quality of fruit is maintained, and the duration for which fruit remains fresh is prolonged [108,109]. To be efficient, edible coatings must fulfil various functional criteria, including the following: (i) being free of toxic substances and safe for human consumption; (ii) exhibiting exceptional barrier properties with respect to water, humidity, O_2, CO_2, and C_2H_4; and (iii) enhancing the visual and textural characteristics of the coated products [110]. The application of the coating must not modify the sensory characteristics of the fruit [105,111]. Hence, it is important to meticulously develop the formulation of the edible coating throughout its creation. Moreover, the coating must regulate the gas exchange to prevent fruit fermentation and the development of unpleasant off-flavors [105,112].

4.3.1. Edible Coatings and Their Operational Principles

An edible coating is a thin layer made from edible substances and applied to food items to extend their shelf life [113,114]. Currently, there is a growing interest in edible coatings and films compared to other synthetic plastic packaging materials, largely since they are biodegradable and can be consumed. They are also compatible with food [115–117]. Edible coatings are often derived from biodegradable polymers as a substitute for nondegradable packaging materials that generate significant waste [107,118]. Edible films and coatings are a viable technological solution for preserving food quality, ensuring safety, and enhancing usefulness [10]. To be considered suitable, the materials must fulfil certain criteria, such as exhibiting favorable sensory characteristics, possessing effective barrier qualities, demonstrating sufficient mechanical resilience, maintaining biochemical, physicochemical, and microbiological stability, ensuring safety for human consumption, being environmentally friendly, and being reasonably priced [10]. Edible coatings are produced using natural raw ingredients, including polysaccharides, proteins, lipids, and their mixtures. In addition to their ability to preserve food, edible coatings are designed with chemicals, such as antioxidants, flavorings, and sweeteners, to achieve active packaging and improve the nutritional and sensory characteristics of the food [119,120].

Edible coatings and films can maintain the visual appeal, firmness, moisture content, and can extend the storage duration of fruits. This is due to their ability to act as barriers against moisture and gas transmission, prevent lipid oxidation, regulate enzymatic activities, and inhibit microbial spoilage [10,112,121]. Edible coatings alter the surrounding environment of fruits by modifying the gas composition inside the fruit, thus slowing down the respiration rate and ethylene generation. This effectively reduces the physiological degradation of fruits [4]. Moreover, it has been shown that edible coatings including antimicrobial substances, such as organic acids, plant essential oils, and polypeptides, effectively hinder the proliferation of microbes [122]. Edible coatings can decrease enzyme activity, minimize the occurrence of browning reactions, and prevent texture softening [10]. Furthermore, it has the capacity to preserve the inherent volatile flavor and color components [123]. The edible coatings shield food products from microbial contaminants, diminish the effects of deterioration [124], extend the storage duration [125,126], and minimize lipid oxidation and moisture loss in food products [10,127,128].

4.3.2. Formulation of Edible Coating for Red Fruits Application

Edible coatings are primarily categorized into three primary types. Coatings can be made from various types of materials, including polysaccharides (such as starch, chitosan, cellulose, alginate, pectin, and gums), proteins (such as zein, whey protein, wheat gluten, casein, soy protein, egg albumin, and gelatin), lipids (such as waxes and fatty acids), and composite materials. Moreover, coatings can be formed by combining multiple substances together [129,130]. Table 2 provides a summary of the several edible coatings that have been applied to red fruits, as documented in the literature.

Polysaccharides are naturally occurring polymers that are used in the production of edible coatings. Polysaccharide-based coatings for food preservation often use starch, gums, and chitosan as fundamental constituents [130]. The use of these coatings offers several benefits, such as cost-effectiveness and enhanced accessibility. Although several polysaccharides exhibit reduced water vapor barrier properties, polysaccharides like alginate and carrageenan are notably hygroscopic and possess thick film characteristics. The polysaccharide-based edible coating presents both antioxidant and antibacterial properties [130].

Protein-based edible coatings are derived from both plant and animal sources. Examples of plant-based protein coating materials include zein (derived from maize), soy protein, gluten (obtained from wheat), and other similar substances. On the other hand, animal-based protein sources encompass whey protein, milk protein casein, egg albumin, and gelatin [130]. They exhibit a significantly greater ability to create a barrier against mechanical strength, organoleptic and aroma retention, and high oxygen permeability. However, they do not possess a moisture barrier due to their hydrophilic properties, which can be enhanced by incorporating hydrophobic substances like lipids [130].

Edible coatings made from lipids, such as acetylated monoglycerides, waxes, vegetable oils, or minerals, enhance the appearance of fresh fruit by giving it a shiny and glossy appearance. Lipid coatings, being hydrophobic, may effectively mitigate the effects of oxygen, water, light, and other environmental factors on the quality of stored products. Additionally, they can reduce the rate of water evaporation from food items [130]. In addition, they provide protection against the detrimental effects that mostly occur in cold storage facilities [18,130].

In a recent study by Khalid et al. [130], there has been a significant focus on developing bilayer or composite coatings that include polysaccharides, proteins, and/or lipids. The aim was to enhance the functional quality of these coatings. Every covering substance has a unique but limited role. The combination of two different coating ingredients may enhance the functionality. The main purpose of composites is to maximize the performance of the combination while maintaining the stability of the individual components [130]. The combination of several materials may lead to the development of composite edible coatings that possess distinctive characteristics.

Table 2. Composition of edible coatings for red fruit applications with their impact on the quality attributes of berries.

Coating Composition	Types of Red Fruits	Impact on Red Fruits	Reference
Gum arabic with bergamot orange	Strawberries	✧ lower decay rate, ✧ good retention of ascorbic acid ✧ good consumer acceptability	[131]
Chitosan and sodium alginate	blueberries	Sodium alginate ✧ higher values of firmness and lightness ✧ higher total phenolic content ✧ lower values of total soluble solids content and titratable acidity ✧ promoted the growth of yeasts and molds at the end of storage period Chitosan ✧ coating delayed ripening as indicated ✧ higher total soluble solids content and titratable acidity values ✧ chitosan coating inhibited the growth of yeasts and molds	[132]
Chitosan	Raspberries	✧ reducing darkening ✧ maintaining the anthocyanin contents and attributes directly related to freshness	[133]
Milk protein and nisin	Strawberries	✧ longer shelf life ✧ better color, aroma, flavor, and acceptability	[134]
Sucrose esters of fatty acids, thyme (*Thymus zygis* L.), and cinnamon (*Cinnamomum zeylanicum*) essential oils	Raspberries	✧ minimum weight loss ✧ antifungal activity with low fungal counts ✧ highest concentration in anthocyanins	[135]
Cassava starch + chitosan	Strawberries	✧ enhanced the postharvest conservation of cold-stored strawberries ✧ provided reductions in mass loss and counts of psychrophilic microorganisms, yeasts, and molds ✧ improved the appearance of fruit after nine days of cold storage	[136]
Pectin coating containing lemon essential oil	Strawberries	✧ increase shelf life and storage time	[137]
Chitosan Paraffin Beeswax Gum arabic	Pomegranate	Chitosan ✧ significantly preserved fruit quality, firmness, visual appearance, husk color, ascorbic acid, and anthocyanin content ✧ it reduced browning, peroxidase enzyme activity, and decay incidence Paraffin and beeswax ✧ effective in maintaining fruit water content ✧ significant preservation of husk distention using paraffin at 20% Gum arabic ✧ maintained moderate rates of fruit respiration and total soluble solids content	[138]

Table 2. *Cont.*

Coating Composition	Types of Red Fruits	Impact on Red Fruits	Reference
Cassava starch	Strawberries	✧ no significant effect on soluble solids, titratable acidity, pH, and color of strawberries ✧ reducing the respiration rate ✧ efficient in delaying weight and firmness loss ✧ good conditions for consumption and good sensorial acceptance for up to 12 days of storage	[139]
Gelatin-based + cellulose nanocrystals (CNC)	Strawberries	✧ significant improvements in shelf life ✧ effective in the retention of ascorbic acid (AA) ✧ had an antimicrobial effect in the fruits	[140]
Limonene liposomes	Strawberries	✧ effective in maintaining the lesser respiration rate ✧ lower the change in pH ✧ had higher total anthyocyanin content during storage	[141]
Carboxymethyl cellulose (CMC) + propolis (complex honeybee product)	Blueberries	✧ reduced the weight loss with significant decrease in decay percentage ✧ did not affect the TSS levels, the decreasing TA, and increasing pH values ✧ did not cause a protective effect on the lowering values of total phenolic and anthocyanin contents ✧ exhibited a positive influence on the antioxidant activity in the coated blueberries ✧ reduced the bacterial, yeast, and fungal counts, visibly expressed by a reduction in decay incidence	[142]
Polyvinyl alcohol + grape pomace extract	Strawberries	✧ decreased microbial count ✧ higher firmness ✧ Improved shelf life and functional properties	[143]
Cassava starch, whey protein, beeswax, chitosan, glycerol, stearic acid, and glacial acetic acid	Blackberries	✧ had a positive effect on the physicochemical properties such as pH, acidity, soluble solids, total solids, antioxidant capacity, phenolic compounds, and anthocyanins ✧ slowed the microbial growth of the fruit ✧ conserved the sensory quality, mainly for texture, flavor, and aroma retention	[144]
Chitosan + beeswax	Strawberries	✧ prolonged the storage period ✧ slowed down their senescence process ✧ beneficial effect against fungal infection ✧ weight loss and respiration rate reduction ✧ retention of the firmness and color ✧ retention of the titratable acidity, pH, soluble solids, and sugars	[145]
Chitosan (CH) + gum ghatti (GG)	Grapes	✧ preserved nutrients and maintained quality ✧ inhibited decay incidence ✧ delayed changes in the contents of nutritional properties, phenolic compounds, and antioxidant capacity ✧ provided a significant reduction in yeast-mold growth.	[146]

Table 2. *Cont.*

Coating Composition	Types of Red Fruits	Impact on Red Fruits	Reference
Lemongrass oil	Strawberries	✧ have significant effects on the weight loss, SSC, TA, fruit firmness, microbial and chemical spoilage, and off-odor	[147]
Olive wastes polyphenols-based chitosan	Strawberries	✧ improved the bioactive substances and freshness quality ✧ maintained lower activities of cell wall deterioration and resulted in a significant delay in anthocyanins, total phenolics, flavonoids, and antioxidants	[148]
Tamarind (*Tamarindus indica* L.) seed starch	Grapes	✧ maintains the main aspects of quality ✧ providing a higher ratio of soluble solids/titratable acidity and vitamin C contents ✧ extended shelf life	[149]
Chitosan (CS) + shrimp caroteno proteins (CP)	Strawberries	✧ effective on reducing the fungal decay ✧ lower weight loss ✧ reduction phytopathogenic growth	[150]
Chitosan (CH) + Nisin (NS) + Natamycin (NT) + Pomegranate (PE) + Grape seed extract (GE)	Strawberries	✧ improved the stability of pH, total soluble solid content, and texture of fruits ✧ effective against aerobic mesophilic bacteria ✧ protective effect against yeast and mold growth on fruits ✧ improved the quality and extended the shelf life	[151]
Chitosan + Aloe vera	Blueberries	✧ successfully improved shelf life stability ✧ retard postharvest deterioration of blueberries	[152]
Chitosan and carboxymethyl cellulose (CMC)	Strawberries	✧ significantly effective in inhibiting the loss of fruit firmness and aroma volatiles of strawberries ✧ little effect on the total soluble solids and total acidity contents ✧ significantly reduced the primary metabolite contents involved in carbohydrate, fatty acids, and amino acids metabolism, as well as the secondary metabolite contents involved in terpenoid, carotenoid, phenylpropanoid, and flavonoid metabolism	[153]
Lemongrass oil + chitosan	Grape berry fruits	✧ higher efficiency in improving microbial safety against Salmonella	[154]
Alginate/Oil nanoemulsion	Sweet cherries	✧ improved quality, reduced cracking on fruits	[155]

4.3.3. Application Technique for Applying an Edible Coating on Red Fruits

Different procedures may be used to apply edible coatings onto red fruits, depending on the state of the coating ingredient, which can be a liquid, suspension, emulsion, or powder. The choice of an effective coating method influences not only the preservation effect of the coatings created on the food products, but also the manufacturing cost and process efficiency [156]. Table 3 summarizes the major different coating methods with their advantages and disadvantages. The selection of an appropriate application procedure is crucial to maximize the efficacy of the coating and produce the most promising outcomes [157].

Table 3. Main process parameters, benefits, and drawbacks of edible coating application techniques.

Techniques	Description	Advantages	Disadvantages	Examples	Reference
Immersion technique (Dipping method)	This entails completely immersing the food product in the coating-forming solution, resulting in the coating material being deposited onto the food product's surface. When dipping, food is simply dipped into a solution and then removed after a predetermined amount of time, typically 5 to 30 s. The solvent evaporates from the coating, leaving behind a thin layer on the product's surface.	Dipping is the most frequent lab-scale method because of its simplicity, cheap cost, good coverage on uneven food surfaces, and compatibility for very viscous biopolymers. This method works well for items that have uneven surfaces.	The dipping process has some clear drawbacks, such as the dilution of the coating solution and high leftover coating material quantities, which frequently lead to the proliferation of microorganisms in the dipping tank. Also, this method's drawbacks include the possibility of thick coating or coating solution impairing restoration, perhaps lowering food surface functioning through weakening the outer covering. Achieving appropriate adhesion quality is a challenge in the ECF implementation.	Strawberries Red grape Blueberries	[156–164]
Spraying method	In this method, the liquid solution is sprayed onto the food product. The spraying of the liquid converts the liquid solution into tiny droplets. Electrostatic spraying technology can regulate droplet size, enhance droplet coverage and deposition, provide a uniform dispersion, and minimize waste.	This technique offers uniform coating, thickness control, and the possibility of successive applications which do not contaminate the coating solution.	Highly viscous biopolymers cannot be sprayed.	Raspberries Strawberries	[156,160]
Panning method	Food products are rotated inside a big round rotating pan, and the coating-forming solution is sprayed onto the surface of the food product, while the pan keeps spinning.	Plenty of round or oval shape food products can be coated in a single batch using this method.	The primary drawback of this technology is that it takes some time to achieve, considering the necessity for water evaporation throughout the process. Moreover, the coating must be applied gradually; otherwise, it may cause the food items to cling together within the revolving container.	Small objects such as nuts and raisins Red fruits	[157,159,165]
Fluidized bed processing method	The coating solution is sprayed with the help of nozzles, and this helps to cover smaller foods with the sprayed solution. The solution starts to form a shell on the food, which slowly converts into the coating. After that, drying is performed.	This method helps apply a thin layer of coating onto the surface of very small dry food products, such as wheat or nuts. This process reduces the chances of agglomeration and helps in the reduction of the rate of the release to active compounds.	This method is costlier than other coating methods.	Apples	[159,166]

➢ Immersion (Dipping Coating Method)

The immersion technique is widely used due to its ease of implementation and cost-effectiveness. This process involves the application of a liquid, suspension, or emulsion coating. The process consists of the following three specific stages: (i) immersion and residence, (ii) deposition, and (iii) solvent evaporation [105,157,167]. To begin, submerge the food in the coating at a consistent speed, ensuring that the food contacts and retains the coating on its surface [157]. Deposition is a process used to acquire tiny layers of coating. In this process, the food is immersed and then kept still to allow the surplus coating to be eliminated via deposition [168]. The last stage, solvent evaporation, entails the removal of any surplus coating by means of either drying equipment or natural atmospheric conditions, thus allowing for the evaporation and drying of the food [157]. The immersion period might deviate from 5 to 30 s depending on the food product and edible coating purpose [169]. Prior research has demonstrated that the density and structure of the coatings formed through the process of dipping are greatly influenced by various factors. These factors include the duration of immersion, the speed at which the object is withdrawn, the number of dip-coating cycles, the properties of the coating solution, such as density, viscosity, and surface tension, the characteristics of the substrate surface, and the conditions during the drying process [105,170]. This approach has several benefits, since the whole surface of the food is consistently coated, and it may be applied to diverse surfaces. Nevertheless, the dipping approach has certain drawbacks. It may not be good for fruits with sensitive skins or membranes, since they may be harmed during immersion [171]. Dipping commonly results in a thick layer, leading to substantially reduced fruit respiration and potentially accumulate unwanted residues, and thus resulting in the development of microorganisms within the coating itself [157,160], damage food surfaces, and degraded function [105]. In addition, germs and debris from the fruit surface may contaminate the coating solution, thereby demanding industrial up-scaling. Another downside of the dipping strategy is the considerable amount of solution required for coating per unit mass of the product to assure proper dipping conditions [105,111].

➢ Spreading Technique

The spreading method is excellent for coating solutions with a high viscosity. In general, the wetness level and spreading rate are the major criteria used to characterize how the coating solution is dispersed across the food surface [105]. Several elements impact the efficacy of coating deposition via spreading, including the substrate quality, especially the drying conditions, liquid properties, and surface geometry [105,172]. This approach is employed for covering fruit with a tiny surface area, such as grapes [171,173]. The coating substance is applied to the surface of the fruits using a brush by skilled operators [171]. Thus, the human component has a substantial influence on the quality of the coating and thickness uniformity [105].

➢ Spraying Methods

The edible coating material may also be sprayed to the surface of red fruits using a spray nozzle via spraying technique [171,174]. Spraying is the procedure of utilizing a collection of nozzles to disperse tiny coating droplets over the fruit surface [105,157]. There are several types of spraying, such as air spray atomization, which involves low speed and cylindrical spray flow, air-assisted airless atomization, used for highly viscous coatings, and pressure atomization spraying, where coatings are applied using pressure instead of air [105,157,160]. The biopolymer is dissolved into a suitable solvent in order to generate a solution. The solution is then atomized into a fine mist using a spray nozzle, which is sprayed onto the surface of the fruit or vegetable [171,175]. When spraying, the pressure, viscosity, surface temperature, and coating tension are critical elements that greatly determine the final coating performance [157,160,176]. The benefit of spraying is that it is a rapid and effective approach that can be readily scaled up for commercial production [171] and to have the capacity to apply two or more distinct coatings, thus generating a multi-layered coating [160]. Additionally, the thickness of the coating layer may be adjusted with this

process [157]. Adding antibacterial agents or antioxidants to the biopolymer solution may help to increase the coated produce's shelf life [171]. The spraying method permits multi-layer applications such as interlayer solutions, as well as uniform coatings with homogenous thicknesses [177]. Additionally, the coating thickness is larger than that when using the dipping technique, owing to the low viscosity of the solution [105,160]. However, the spraying approach also has significant disadvantages [178].

➢ Pan coating technique

The pan coating process comprises putting the food products within a revolving container, where the coating is subsequently sprayed or sprinkled, thus guaranteeing a homogenous integration onto the food surface [157]. Subsequently, the coating is cured [179]. The pan coating process is used to manufacture thin or thick layers of coatings onto hard surfaces, enabling for the simultaneous coating of many food items, even with size variability, thus providing a clear, flexible, and shiny coating material [157]. The primary drawback of this technology is that it takes some time to achieve, considering the necessity for water evaporation throughout the process [157]. Moreover, the coating must be applied gradually; otherwise, it may cause the food items to cling together within the revolving container [157,165].

➢ Electro-spraying

Electro-spraying is a process in which a liquid is atomized into small droplets using an electric field. The electro-spraying method utilizes a strong electric field to produce charged droplets that have a precise and limited size distribution. These droplets are of micrometric and sub-micrometric dimensions [180]. The electro-spraying approach may modify droplet characteristics, such as size and layer thickness, by adjusting the flow velocity and solution viscosity [105,181].

➢ Vacuum Infusion

Vacuum infusion is used for fresh fruits and vegetables that have a porous structure [112,171]. The biopolymer solution is injected into the vacuum chamber, where it permeates the pores of the fruits [182]. Implementing this technique on food items like carrots has the potential to enhance their sensory properties and nutritional content, while also prolonging their shelf life and maintaining their firmness. This might be particularly advantageous for the preservation of fruits with robust skins or membranes that need a more substantial coating [183]. Vacuum infusion is not suitable for fruits with delicate structures as they may be damaged during the vacuum process [171,184].

➢ Layer by Layer (Multilayer Coating)

The layer-by-layer deposition technique relies on the electrostatic interactions between the food surface and the charged polyelectrolytes. The electrostatic interactions enhance the attachment of the coating to the food surface and may be used to produce coatings which consist of several thin layers that are chemically or physically interconnected [105]. Each layer has a distinct function, such as avoiding the infiltration of pathogenic organisms into the fruit or restricting the oxygen supply [171,185]. The efficacy of such connected multilayer coating is enhanced in comparison to typical edible coatings [105,186]. The use of a multilayer coating technique to enhance the density of coating layers during the storage of fruits after harvest has been recorded for polysaccharides and charged polyelectrolytes that can form hydrogen and covalent bonds. Polysaccharides and charged polyelectrolytes have been shown to be effective in preserving fruits when using the multi-layer coating technique to enhance the integrity of the coatings [105,187]. The efficacy of the multilayer coating technique in prolonging the storage duration of various types of fresh produce, such as strawberries, has been shown. The approach is ecologically sustainable as it minimizes the reliance on chemical preservatives and packing materials [171,188].

➢ Solution Casting Process

The process of solution casting for the application of bio-coatings entails dissolving the biopolymer in an appropriate solvent and then putting it onto the surface of the fruit [189]. Solution casting is a technique used to produce independent films inside a Petri dish or a similar container. Dipping and spraying are the predominant techniques used to apply substances to fruits, with the solvent, often water, evaporating while the fruit undergoes drying. Prudent consideration should be given to the selection of the solvent for dissolving the biopolymer, as it must exhibit compatibility with both the biopolymer itself and the fruit or vegetable intended to be coated [171]. Upon the application of the solution onto the fruit surface, the solvent undergoes evaporation, resulting in the formation of a residual thin coating. The thickness of the coating may be controlled via adjusting the concentration of the biopolymer solution or the number of coating layers applied [171,175,189]. The advantage of solution casting lies in its simplicity, cost-effectiveness, and scalability for large-scale commercial manufacturing [190]. Furthermore, the thickness and homogeneity of the coating may vary depending on the application procedure, thereby affecting its efficacy [191]. Ultimately, solution casting is a very promising technique for acquiring bio-coatings that may effectively preserve fruits. This technology has the potential to enhance food quality and minimize food waste, as shown by recent studies conducted by Moeini et al. [192] and Ungureanu et al. [171].

➢ Three-Dimensional Food Printing Method

Three-dimensional food printing is the process of using a three-dimensional printer to sequentially place materials in layers, resulting in the creation of a food item with a distinct structure, texture, and, perhaps, nutritional composition [193]. The use of 3D printing technology has the potential to fabricate accurate and consistent edible coatings on fruits and vegetables, hence improving their durability and overall quality. This has the potential to be used for incorporating natural preservatives or antimicrobials into printed food, hence prolonging the freshness of perishable goods [171]. The use of 3D printing technology may contribute to the mitigation of food waste through enabling the production of edible items from fruits and vegetables that would otherwise be rejected due to their visual flaws. While it does not specifically preserve fresh food, it may effectively enhance the use of gathered fruits and vegetables. Although still in its early stages, 3D printing shows potential in producing biodegradable packaging for fruits and vegetables, particularly red fruits [171]. This might be devised to provide safeguarding and perhaps to integrate conservation methods (e.g., modified atmosphere packing) [194].

➢ Cross-Linked Coating Method

Cross-linking refers to the act of joining polymer chains together via covalent and non-covalent connections [105]. Cross-linking is the chemical bonding process that connects polymer chains, resulting in the formation of a three-dimensional network of interlinked chains [171]. Cross-linked coatings are often formed via applying the coating solution onto the food surface with methods such as spraying, dipping, or spreading. Subsequently, a cross-linking agent is introduced to enhance the density and durability of the coating [105]. This method is employed in the development of coatings to enhance their functionality, as the cross-linked arrangement generally yields enhanced mechanical robustness, resistance to water, and stability [155]. Regarding the preservation of fresh fruits and vegetables, the cross-linked coating approach has several benefits such as enhanced mechanical characteristics, chemical and thermal durability, and improved molecular migration [105,195]. Cross-linked coatings possess denser polymer networks, resulting in decreased gas permeability (e.g., oxygen, carbon dioxide) and water vapor, hence retarding the ripening process and minimizing moisture loss in fruits and vegetables. These coatings generally exhibit enhanced mechanical strength and increased resistance to abrasion or damage, hence assuring the preservation of the protective layer during handling and transportation [171]. Cross-linked coatings exhibit enhanced resistance to dissolution and degradation, resulting in heightened stability and durability throughout extended storage periods. Cross-linked

coatings may serve as a framework for enclosing and dispensing active substances, such as antibacterial and antioxidant chemicals [171]. The cross-linked structure enables the regulated release of these substances, thereby improving the longevity and safety of the product. Chitosan, a biopolymer obtained from natural sources, is often used in edible coatings. It may undergo cross-linking via the use of agents like geminin [171,196].

Cross-linking is very efficient for biopolymer materials composed of proteins or polysaccharides [105]. Proteins are preferred over polysaccharides in this approach because proteins have a higher abundance of functional groups (Dai et al., 2020). Nevertheless, it is crucial to emphasize that a comprehensive evaluation of the safety of the cross-linking agents and the possible transfer of compounds from the coating to the food must be conducted in order to guarantee food safety. The coatings must consistently adhere to the relevant food safety norms and standards [171].

4.4. Studies That Examine the Effects of Different Sustainable and Healthy Edible Coatings on the Bioactive Compound Quality, Sensory Quality/Acceptability, Antimicrobial Properties, and Shelf Life of Red Fruits

In search of environmentally friendly substitutes, bioactive compounds derived from by-products can be employed to impart their activities in edible coatings, giving them characteristics like antimicrobial, antioxidant, and anti-enzymatic qualities, as well as therapeutic advantages for health, like being anticholesterolemic and other attributes [197]. Edible films and coatings are frequently made from many basic compounds that are then combined with other compounds to improve their functions [198]. The results of several studies on the application of edible coatings onto red fruits and its effects on the quality of the bioactive components, sensory quality and acceptability, antibacterial capabilities, and shelf life of red fruits are summarized in Table 4.

Table 4. Application of edible coatings onto red fruits and its effects on the quality of the bioactive components, sensory quality and acceptability, antibacterial capabilities, and shelf life of red fruits.

Membrane Type	Red Fruits	Effects	Reference
Bergamot pomace, bergamot essential oil, and butylated hydroxytoluene	Strawberries	• extended shelf life over a period of fourteen days • lower rates of decay and good consumer acceptability score • retention of a significant amount of ascorbic acid	[131]
Chitosan and sodium alginate	Blueberries	Sodium alginate-coated samples exhibited • increased firmness and lightness • decreased levels of total soluble solids content and titratable acidity and a greater amount of total phenolic content • the proliferation of yeasts and molds Chitosan coating resulted in • a delay in the ripening process • an increase in the total soluble solids content and higher levels of titratable acidity • effectively suppressed the proliferation of yeasts and molds	[132]
Chitosan	Raspberries.	• reduced darkening • preserved the anthocyanin contents	[133]
Milk protein and Nisin-based edible coating.	Strawberries	• extended shelf life with higher acceptability scores	[134]
Biopolymer-based coatings	Raspberries	Coated fruits exhibited • a lower degree of weight loss • the greatest concentration of anthocyanins • decrease in the fungal counts after four days	[135]

Table 4. *Cont.*

Membrane Type	Red Fruits	Effects	Reference
Cassava starch and chitosan	Organic strawberries	• reduced mass loss • decreased presence of psychrophilic microorganisms, yeasts, and molds • enhanced fruit appearance after nine days of cold storage	[136]
Pectin coating containing lemon essential oil	Strawberries	• proved to be a more successful method for extending the shelf life and storage period of strawberries	[137]
Antimicrobial starch edible coating: cassava starch and potassium sorbate	Strawberries	• no impact on the levels of soluble solids, titratable acidity, pH, and color of strawberries. • cassava starch coatings proved effective in prolonging the storage life of strawberries through delaying weight and firmness loss • potassium sorbate did not have any inhibitory effect on the development of microorganisms and did not contribute to extending the shelf life of strawberries	[139]
Several coatings: chitosan; paraffin; arabic gum; beeswax	Pomegranate fruits (*Punica granatum* L., cv. *Wonderful*)	Chitosan, at 2%, effectively maintained the quality of fruits by • preserving their firmness, visual appearance, husk color, ascorbic acid, and anthocyanin content • decreased browning, peroxidase enzyme activity, and the occurrence of decay • paraffin at 10% and beeswax at 10% were successful in preserving the water content of the fruit • paraffin at 20% significantly preserved the expansion of the husk • arabic gum at 5% maintained moderate rates of fruit respiration and the content of total soluble solids	[138]
Gelatin-based edible coating—cellulose nanocrystals (CNC))	Strawberries	• enhancement of shelf life • preserving the ascorbic acid • exhibited antibacterial properties on the fruits	[140]
Plant-based edible coatings—*limonene liposomes*	Chandler' strawberries	*limonene liposomes* coatings were very successful in • reducing the respiration rate • minimizing pH changes • increasing the total anthocyanin content during storage	[141]
Propolis, (a complex substance derived from honeybees), and CMC (carboxymethyl cellulose)	Blueberries	The CMC (Carboxymethyl cellulose) and CMC + P coatings • resulted in a reduction in weight loss, accompanied by a considerable drop in the decay percentage • no impact on the total soluble solids (TSS) levels • resulted in a decrease in titratable acidity (TA) and an increase in pH values • did not provide protection against the decrease in total phenolic and anthocyanin contents • had a good impact on the antioxidant activity • a decrease in the number of bacteria, yeasts, and fungi	[142]

Table 4. *Cont.*

Membrane Type	Red Fruits	Effects	Reference
Polyvinyl alcohol containing grape pomace extract (PVA/GPE)	Strawberries	• higher quality of ascorbic acid concentration, total phenolic content, total anthocyanin content, and antioxidants • exhibited reduced microbial growth during storage • exhibited markedly greater firmness in comparison to the untreated fruit • enhanced strawberry shelf life and increased functional qualities	[143]
Cassava starch, whey protein, beeswax, chitosan, glycerol, stearic acid, and glacial acetic acid	Andean blackberries	• resulted in beneficial improvements in physicochemical characteristics, including pH, acidity, soluble solids, total solids, antioxidant capacity, phenolic compounds, and anthocyanins • inhibited the proliferation of microorganisms on the fruit • preserved its sensory attributes, particularly its texture, taste, and flavor, for a duration of 10 days at 4 °C	[144]
Chitosan—beeswax	Strawberries	The use of chitosan-based coatings • extended the storage duration by 7 days at 20 °C and 53% relative humidity • retarded their senescence process • the incorporation of beeswax, either as a distinct layer or as a constituent in the composite coating, exhibited advantageous outcomes • there was a negative opinion towards the sensory characteristics of the three-layer waxy coatings	[145]
Chitosan and gum ghatti	R'ishbaba' grape (*Vitis vinifera* L.).	• effectively retained nutrients and maintained quality for a period of 60 days at 0 ± 1 °C and 85%RH • effectively reduced decay occurrence • delayed alterations in nutritional characteristics, phenolic components, and antioxidant capacity • decrease in yeast-mold formation.	[146]
Lemongrass oil and modified atmosphere packaging (MAP)	Strawberries	Reduction in • weight, soluble solid content (SSC), total acidity (TA), fruit hardness • microbiological and chemical deterioration • the presence of off-flavors in strawberry fruits	[147]
Chitosan	Strawberries	• enhanced the bioactive compounds and freshness quality • effectively reduced the degradation of cell walls and therefore led to a notable postponement in the decline of anthocyanins, total phenolics, flavonoids, and antioxidants	[148]
Tamarind (*Tamarindus indica* L.) seed starch	I'sabel' grapes	• extended the shelf life to 12 days at 12 ± 2 °C and a relative humidity of 85 ± 5% • preserved the key quality attributes of the grapes, resulting in a greater ratio of soluble solids to titratable acidity, as well as maintaining the vitamin C content	[149]

Table 4. *Cont.*

Membrane Type	Red Fruits	Effects	Reference
Chitosan (CS) + shrimp carotenoproteins (CP) + glycerol and polyvinyl alcohol (PVA)	Strawberries	• significantly reduced fungal decay by 45–50% • considerably reduced weight loss • effectively suppressed the development of plant-disease-causing microorganisms on the surface of cold-stored fruits • longer shelf life of the strawberries during storage	[150]
Chitosan (CH) + nisin (NS), natamycin (NT), pomegranate (PE), and grape seed extract (GE)	Strawberries	• enhanced the stability of the pH, total soluble solid content, and texture of fruits • shown efficacy against aerobic mesophilic bacteria • exhibited a protective effect against yeast and mold development on fruits • prolonged the shelf life of fresh strawberries for up to 30 days	[151]
Chitosan + Aloe vera	Blueberries	• effectively enhances the stability of blueberries during storage and slows down their degradation after harvest	[152]
Chitosan + carboxymethyl cellulose (CMC)	Strawberries (*Fragaria* × *ananassa* Duch.)	• successful in preventing decreases in firmness and fragrance volatiles • little impact on the levels of total soluble solids and total acidity • decreased the levels of primary metabolites related to glucose, fatty acids, and amino acid metabolism • decreases in secondary metabolites involved in terpenoid, carotenoid, phenylpropanoid, and flavonoid metabolism during an eight-day storage period	[153]
Lemongrass oil + chitosan nanoemulsion coating	Grape	• effective in enhancing microbiological safety against Salmonella • maintained the quality of grapes throughout a 28-day storage period at 4 °C	[154]

4.5. Constraints, Safety Considerations, Legal Regulations, and Future Developments of Edible Coatings for Red Fruits

In Duguma's work [10], it is noted that, although edible coatings have many benefits, there are several obstacles that hinder their widespread use in industrial settings. Tahir et al. determined that a high concentration of gum in the edible coating might have a detrimental impact on the sensory perceptions of coated vegetables [199]. In addition to the negative impact on the sensory quality of some edible coatings, the instability of bioactive chemicals, as well as the weak film-forming characteristics and surface adherence, provide additional challenges that restrict the commercial use of Aloe vera gel as an edible coating [200]. The use of essential oil to enhance the antimicrobial characteristics of edible coatings leads to drawbacks such as a limited solubility in water, strong odor, and high tendency to evaporate [201]. Furthermore, the absence of suitable materials possessing the necessary functions, as well as the financial burden associated with acquiring and installing the coating equipment, are additional obstacles that impede the implementation of edible coatings. The hydrophobic properties of most edible packing materials, together with the inadequate control over the temperature and relative humidity, provide obstacles that hamper the widespread use of edible coatings in the industry [10]. Furthermore, the lack of approved standards for the application of diverse edible coatings poses difficulties in terms of regulatory and safety concerns. The use of appropriate edible coatings, the optimization of edible coating concentration, the integration of edible coatings with flavor

enhancers, and nanoencapsulation techniques may effectively mitigate some drawbacks associated with edible coatings [10]. Additionally, conducting a washing process at the conclusion of storage has the potential to enhance the taste of the edible coating [202]. Nayak et al. proposed that incorporating nanotechnologies such as nanoencapsulation and multilayer systems into edible coatings might address the current limitations of these coatings [203]. This involves the creation of next generation edible coatings that can release active substances. In a similar vein, Bakhy and Zidan found that incorporating nanoelements into edible coatings effectively extended the shelf life of goods by mitigating the development of pathogens and enhancing the quality of fruits and vegetables [204].

Food safety and regulations differ among nations. As per EU and US standards, edible films and coating might be classified as food components, additives, contact materials, or packaging materials [205]. Matloob et al. [162] stressed in their review that edible coatings should adhere to the necessary requirements for food components, as these rules are essential for ensuring the quality of the edible product [206]. To ensure the quality and safety of edible coatings, it is necessary to use constituents that have been generally recognized as safe (GRAS) according to the regulations set by the Food and Drug Administration (FDA) [18,205]. This is important for maintaining the safety of the product and ensuring that it can be consumed without any concerns [162]. However, it is possible for edible coatings to undergo a metamorphosis into poisonous compounds because of the changes that take place during the process of film development [207]. The use of various cross-linking agents to improve the film characteristics and interactions with gastrointestinal contents may also induce the generation of harmful compounds [208]. The research conducted by Roșu et al. examined the impact of graphene oxide and its derivatives on the cytotoxicity of a methylcellulose-based film on human lungs [209]. The findings revealed that reduced graphene oxide exhibited a lesser toxicity when compared to graphene oxide. Despite the impact of the modification methods and ingredient selection being crucial for ensuring the safety of edible films, it is seldom addressed in research concerning edible films [205]. Certain edible films may include substances that have the potential to induce hypersensitivity reactions. Hence, irrespective of the little quantity used, it is essential to inform the client about the presence of a substantial toxin in edible coating films and provide an appropriate warning [162,210]). Users should evaluate and accept each component used in the coatings based on their sensory perception [211]. Furthermore, it is crucial to consider the toxicity and genotoxicity of edible coatings as a significant issue during assembly, as highlighted by Matloob et al. [162]. Under these conditions, organic oils often used in edible coatings as a germicidal compound, although being GRAS (generally recognized as safe) by the European Commission and the United States, might potentially cause hypersensitivity reactions [212]. Specific guidelines exist for including antioxidants and antimicrobials in food compositions [162,213].

Therefore, as evident from the previous section, although edible coatings have the potential to enhance the quality, shelf life, and safety of fresh and minimally processed fruits, their commercial use remains relatively restricted [205]. There are several factors contributing to this phenomenon as follows: the increased expenses; the challenge of consistently producing consistent coatings that adhere well to the fruit; the subpar mechanical, barrier, and optical characteristics of many edible coatings; the potential for allergenic reactions with protein-based coating materials; undesirable sensory qualities; and the challenges of scaling up to mass production [205]. There are some regions that are expected to see growth soon. Nanotechnology may be used to produce edible coatings that possess enhanced functional characteristics through the integration of organic or inorganic nanoparticles into biopolymer films [205]. The addition of these nanoparticles can be utilized to control and adjust the optical, mechanical, and barrier characteristics of coatings. Furthermore, it can aid in the integration of functional components such as colors, flavors, antimicrobials, antioxidants, vitamins, and nutraceuticals ([205]. Furthermore, layer-by-layer techniques may be used to easily fabricate multilayer coatings with improved functional characteristics. The process of microencapsulation may enhance the long-term viability and safety

of probiotic strains, thus allowing them to be integrated into edible coatings [214]. Nevertheless, further investigation is necessary to ensure the economic feasibility of several emerging technologies.

Edible films and coatings extend the shelf life and enhance food quality through protecting against physical and mechanical damage, producing a regulated environment, and functioning as a semipermeable barrier for gases, vapors, and water. Guimarães et al. describe edible coatings [215], as carriers of living microorganisms, as a new strategy for biopreservation and healthier foods. However, improper handling and storage can cause microbial degradation and spoilage. Despite their ability to contain antimicrobial chemicals, coatings that are incorrectly formulated or applied may generate an environment that is conducive to bacterial development. Overall, well-coated fruits exhibited less microbial deterioration [216]. Furthermore, aerobic mesophilic bacteria were dramatically decreased, entirely suppressing mold and yeast development on food surfaces without negatively influencing consumer approval [217].

5. Conclusions

Red fruits contain abundant bioactive components, which have been shown to have significant beneficial impacts on human nutrition and health. These benefits may be attributed to the presence of many health-promoting substances, such as organic acids, phenolics, and sugars. Multiple research projects have been undertaken to examine the efficacy of edible coatings in maintaining the quality and extending the shelf life of red fruits. This review has shown that an edible coating may act as a protective layer on the surface of the fruit, alter the interior gas composition, reduce water loss, and postpone fruit ripening. The primary hurdles in edible coating methods lie in finding materials that may effectively prolong the shelf life of red fruits while preserving their sensory and nutritional qualities. This needs additional study and attention. Additionally, the functional efficacy and nutritional quality of these coatings may be improved via integrating additives such as pigments, tastes, substances that prevent oxidation, substances that inhibit the growth of microorganisms, devices that detect changes, essential nutrients, and substances that provide health benefits. Nevertheless, more investigation is necessary to ascertain novel and more efficient compositions, as well as to develop edible coatings that can be inexpensively manufactured in huge quantities. It is important to consider the potential allergenicity of the coating materials.

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References

1. Cheung, J.T.H.; Lok, J.; Gietel-Basten, S.; Koh, K. The Food Environments of Fruit and Vegetable Consumption in East and Southeast Asia: A Systematic Review. *Nutrients* **2021**, *13*, 148. [CrossRef] [PubMed]
2. Figueira, J.A.; Porto-Figueira, P.; Berenguer, C.; Pereira, J.A.M.; Câmara, J.S. Evaluation of the Health-Promoting Properties of Selected Fruits. *Molecules* **2021**, *26*, 4202. [CrossRef] [PubMed]
3. Bortolini, D.G.; Maciel, G.M.; Fernandes ID, A.A.; Rossetto, R.; Brugnari, T.; Ribeiro, V.R.; Haminiuk, C.W.I. Biological potential and technological applications of red fruits: An overview. *Food Chem. Adv.* **2022**, *1*, 100014. [CrossRef]
4. Maringgal, B.; Hashim, N.; Mohamed Amin Tawakkal, I.S.; Muda Mohamed, M.T. Recent advance in edible coating and its effect on fresh/fresh-cut fruits quality. *Trends Food Sci. Technol.* **2020**, *96*, 253–267. [CrossRef]

5. Cosme, F.; Pinto, T.; Aires, A.; Morais, M.C.; Bacelar, E.; Anjos, R.; Ferreira-Cardoso, J.; Oliveira, I.; Vilela, A.; Gonçalves, B. Red Fruits Composition and Their Health Benefits—A Review. *Foods* **2022**, *11*, 644. [CrossRef] [PubMed]
6. Skrovankova, S.; Sumczynski, D.; Mlcek, J.; Jurikova, T.; Sochor, J. Bioactive Compounds and Antioxidant Activity in Different Types of Berries. *Int. J. Mol. Sci.* **2015**, *16*, 24673–24706. [CrossRef] [PubMed]
7. De Souza, V.R.; Pereira, P.A.P.; Da Silva, T.L.T.; De Oliveira Lima, L.C.; Pio, R.; Queiroz, F. Determination of the bioactive compounds, antioxidant activity and chemical composition of Brazilian blackberry, red raspberry, strawberry, blueberry and sweet cherry fruits. *Food Chem.* **2014**, *156*, 362–368. [CrossRef] [PubMed]
8. Zhang, X.; Li, G.; Wu, D.; Li, X.; Hu, N.; Chen, J.; Chen, G.; Wu, Y. Recent progress in the design fabrication of metal-organic frameworks-based nanozymes and their applications to sensing and cancer therapy. *Biosens. Bioelectron.* **2019**, *137*, 178–198. [CrossRef]
9. Horvitz, S. Postharvest Handling of Berries. In *Postharvest Handling*; Kahramanoglu, I., Ed.; InTech: London, UK, 2017. [CrossRef]
10. Duguma, H.T. Potential applications and limitations of edible coatings for maintaining tomato quality and shelf life. *Int. J. Food Sci. Technol.* **2022**, *57*, 1353–1366. [CrossRef]
11. Swathi, V.; Gladvin, G.; Babitha, B. Physico-chemical characteristics and applications of edible films for fruit preserva tion. *Int. Res. J. Eng. Technol.* **2017**, *4*, 1954–1958.
12. Aguirre-Joya, J.; de Leon, M.; Alvarez-perez, O.B.; Torres-Leon, C.; Oropeza, D.; Rojas, R.; Ramos, M.; Ventura-sobrevilla, J.; Aguilar, M.; Ruelas, X. Basic and applied concepts of edible packaging for foods. In *Food Packaging and Preservation*; Academic Press Inc.: London, UK, 2018.
13. Abebe, Z.; Yetenayet, B.T.; Ali, M. Effects of edible coating materials and stages of maturity at harvest on storage life and quality of tomato (*Lycopersicon esculentum* Mill.) fruits. *Afr. J. Agric. Res.* **2017**, *12*, 550–565. [CrossRef]
14. Cazón, P.; Velazquez, G.; Ramírez, J.A.; Vázquez, M. Polysaccharide-based films and coatings for food packaging: A review. *Food Hydrocoll.* **2017**, *68*, 136–148. [CrossRef]
15. Aayush, K.; McClements, D.J.; Sharma, S.; Sharma, R.; Singh, G.P.; Sharma, K.; Oberoi, K. Innovations in the development and application of edible coatings for fresh and minimally processed Apple. *Food Control* **2022**, *141*, 109188. [CrossRef]
16. Hassan, B.; Chatha, S.A.S.; Hussain, A.I.; Zia, K.M.; Akhtar, N. Recent advances on polysaccharides, lipids and protein based edible films and coatings: A review. *Int. J. Biol. Macromol.* **2018**, *109*, 1095–1107. [CrossRef]
17. Fazio, A.; Caroleo, M.C.; Cione, E.; Plastina, P. Novel acrylic polymers for food packaging: Synthesis and antioxidant properties. *Food Packag. Shelf Life* **2017**, *11*, 84–90. [CrossRef]
18. Dhall, R.K. Advances in Edible Coatings for Fresh Fruits and Vegetables: A Review. *Crit. Rev. Food Sci. Nutr.* **2013**, *53*, 435–450. [CrossRef] [PubMed]
19. Galus, S.; Kadzińska, J. Food applications of emulsion-based edible films and coatings. *Trends Food Sci. Technol.* **2015**, *45*, 273–283. [CrossRef]
20. McHugh, T.H.; Senesi, E. Apple Wraps: A Novel Method to Improve the Quality and Extend the Shelf Life of Fresh-Cut Apples. *J. Food Sci.* **2000**, *65*, 480–485. [CrossRef]
21. van Eck, N.; Waltman, L. Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics* **2009**, *84*, 523–538. [CrossRef]
22. Gomes-Rochette, N.F.; Da Silveira Vasconcelos, M.; Nabavi, S.M.; Mota, E.F.; Nunes-Pinheiro, D.C.S.; Daglia, M.; De Melo, D.F. Fruit as Potent Natural Antioxidants and Their Biological Effects. *Curr. Pharm. Biotechnol.* **2016**, *17*, 986–993. [CrossRef]
23. Jabłońska-Ryś, E.; Zalewska-Korona, M.; Kalbarczyk, J. Antioxidant Capacity, Ascorbic Acid and Phenolics Content in Wild Edible Fruits. *J. Fruit Ornam. Plant Res.* **2009**, *17*, 115–120.
24. Maki, K.C.; Kaspar, K.L.; Khoo, C.; Derrig, L.H.; Schild, A.L.; Gupta, K. Consumption of a cranberry juice beverage lowered the number of clinical urinary tract infection episodes in women with a recent history of urinary tract infection. *Am. J. Clin. Nutr.* **2016**, *103*, 1434–1442. [CrossRef] [PubMed]
25. Colak, N.; Primetta, A.K.; Riihinen, K.R.; Jaakola, L.; Grúz, J.; Strnad, M.; Torun, H.; Ayaz, F.A. Phenolic compounds and antioxidant capacity in different-colored and non-pigmented berries of bilberry (*Vaccinium myrtillus* L.). *Food Biosci.* **2017**, *20*, 67–78. [CrossRef]
26. Wang, L.-J.; Wu, J.; Wang, H.-X.; Li, S.-S.; Zheng, X.-C.; Du, H.; Xu, Y.-J.; Wang, L.-S. Composition of phenolic compounds and antioxidant activity in the leaves of blueberry cultivars. *J. Funct. Foods* **2015**, *16*, 295–304. [CrossRef]
27. Brown, P.N.; Shipley, P.R. Determination of anthocyanins in cranberry fruit and cranberry fruit products by high-performance liquid chromatography with ultraviolet detection: Single-laboratory validation. *J. AOAC Int.* **2011**, *94*, 459–466. [CrossRef] [PubMed]
28. Biswas, N.; Balac, P.; Narlakanti, S.K.; Haque, M.E.; Hassan, M.M. Identification of Phenolic Compounds in Processed Cranberries by HPLC Method. *J. Nutr. Food Sci.* **2013**, *3*, 181. [CrossRef]
29. Ek, S.; Kartimo, H.; Mattila, S.; Tolonen, A. Characterization of Phenolic Compounds from Lingonberry (*Vaccinium vitis-idaea*). *J. Agric. Food Chem.* **2006**, *54*, 9834–9842. [CrossRef] [PubMed]
30. Vagiri, M.; Ekholm, A.; Johansson, E.; Andersson, S.C.; Rumpunen, K. Major phenolic compounds in black currant (*Ribes nigrum* L.) buds: Variation due to genotype, ontogenetic stage and location. *LWT—Food Sci. Technol.* **2015**, *63*, 1274–1280. [CrossRef]
31. Adina, F.; Cecilia, G.; Fel icia, G.; Carmen, D.; Ovidiu, T. Identification and quantification of phenolic compounds from red currant (*Ribes rubrum* L.) and raspberries (*Rubus idaeus* L.). *Int. J. Pharm. Phytochem. Ethnomed.* **2017**, *6*, 30–37.

32. Guiné, R.P.F.; Soutinho SM, A.; Gonçalves, F.J. Phenolic compounds and antioxidant activity in red fruits produced in organic farming. *Croat. J. Food Sci. Technol* **2014**, *6*, 15–26.
33. Aaby, K.; Mazur, S.; Nes, A.; Skrede, G. Phenolic compounds in strawberry (*Fragaria* x *ananassa* Duch.) fruits: Composition in 27 cultivars and changes during ripening. *Food Chem.* **2012**, *132*, 86–97. [CrossRef] [PubMed]
34. Häkkinen, S.; Heinonen, M.; Kärenlampi, S.; Mykkänen, H.; Ruuskanen, J.; Törrönen, R. Screening of selected flavonoids and phenolic acids in 19 berries. *Food Res. Int.* **1999**, *32*, 345–353. [CrossRef]
35. Apak, R.; Özyürek, M.; Güçlü, K.; Çapanoğlu, E. Antioxidant Activity/Capacity Measurement. 1. Classification, Physicochemical Principles, Mechanisms, and Electron Transfer (ET)-Based Assays. *J. Agric. Food Chem.* **2016**, *64*, 997–1027. [CrossRef] [PubMed]
36. Apak, R.; Özyürek, M.; Güçlü, K.; Çapanoğlu, E. Antioxidant Activity/Capacity Measurement. 2. Hydrogen Atom Transfer (HAT)-Based, Mixed-Mode (Electron Transfer (ET)/HAT), and Lipid Peroxidation Assays. *J. Agric. Food Chem.* **2016**, *64*, 1028–1045. [CrossRef] [PubMed]
37. Dantas, A.M.; Mafaldo, I.M.; Oliveira PM, D.L.; Lima MD, S.; Magnani, M.; Borges, G.D.S.C. Bioaccessibility of phenolic compounds in native and exotic frozen pulps explored in Brazil using a digestion model coupled with a simulated intestinal barrier. *Food Chem.* **2019**, *274*, 202–214. [CrossRef] [PubMed]
38. Veberic, R.; Slatnar, A.; Bizjak, J.; Stampar, F.; Mikulic-Petkovsek, M. Anthocyanin composition of different wild and cultivated berry species. *LWT—Food Sci. Technol.* **2015**, *60*, 509–517. [CrossRef]
39. Huang, Y.; Park, E.; Edirisinghe, I.; Burton-Freeman, B.M. Maximizing the health effects of strawberry anthocyanins: Understanding the influence of the consumption timing variable. *Food Funct.* **2016**, *7*, 4745–4752. [CrossRef] [PubMed]
40. Krikorian, R.; Kalt, W.; McDonald, J.E.; Shidler, M.D.; Summer, S.S.; Stein, A.L. Cognitive performance in relation to urinary anthocyanins and their flavonoid-based products following blueberry supplementation in older adults at risk for dementia. *J. Funct. Foods* **2020**, *64*, 103667. [CrossRef]
41. Lamas, C.A.; Lenquiste, S.A.; Baseggio, A.M.; Cuquetto-Leite, L.; Kido, L.A.; Aguiar, A.C.; Erbelin, M.N.; Collares-Buzato, C.B.; Maróstica, M.R.; Cagnon, V.H.A. Jaboticaba extract prevents prediabetes and liver steatosis in high-fat-fed aging mice. *J. Funct. Foods* **2018**, *47*, 434–446. [CrossRef]
42. Lenquiste, S.A.; De Almeida Lamas, C.; Da Silva Marineli, R.; Moraes, É.A.; Borck, P.C.; Camargo, R.L.; Quitete, V.H.A.C.; Carneiro, E.M.; Junior, M.R.M. Jaboticaba peel powder and jaboticaba peel aqueous extract reduces obesity, insulin resistance and hepatic fat accumulation in rats. *Food Res. Int.* **2019**, *120*, 880–887. [CrossRef]
43. McGill, C.M.; Brown, T.J.; Cheng, Y.-Y.; Fisher, L.N.; Shanmugavelandy, S.S.; Gustafson, S.J.; Dunlap, K.L.; Lila, M.A.; Kester, M.; Toran, P.T.; et al. Therapeutic Effect of Blueberry Extracts for Acute Myeloid Leukemia. *Int. J. Biopharm. Sci.* **2018**, *1*, 102.
44. Tatar, M.; Bagheri, Z.; Varedi, M.; Naghibalhossaini, F. Blackberry Extract Inhibits Telomerase Activity in Human Colorectal Cancer Cells. *Nutr. Cancer* **2019**, *71*, 461–471. [CrossRef] [PubMed]
45. Widyarman, A.S.; Widjaja, S.B.; Idrus, E. Strawberry Extract's Effects on *Enterococcus faecalis* and *Porphyromonas gingivalis* Biofilms in vitro. *Sci. Dent. J.* **2017**, *1*, 1. [CrossRef]
46. Figueira, I.; Tavares, L.; Jardim, C.; Costa, I.; Terrasso, A.P.; Almeida, A.F.; Govers, C.; Mes, J.J.; Gardner, R.; Becker, J.D.; et al. Blood–brain barrier transport and neuroprotective potential of blackberry-digested polyphenols: An in vitro study. *Eur. J. Nutr.* **2019**, *58*, 113–130. [CrossRef] [PubMed]
47. Udani, J.K.; Singh, B.B.; Singh, V.J.; Barrett, M.L. Effects of Açai (*Euterpe oleracea* Mart.) berry preparation on metabolic parameters in a healthy overweight population: A pilot study. *Nutr. J.* **2011**, *10*, 45. [CrossRef] [PubMed]
48. Hogan, S.; Chung, H.; Zhang, L.; Li, J.; Lee, Y.; Dai, Y.; Zhou, K. Antiproliferative and antioxidant properties of anthocyanin-rich extract from açai. *Food Chem.* **2010**, *118*, 208–214. [CrossRef]
49. De Oliveira, A.L.M.S.; Maciel, G.M.; Rossetto, R.; De Liz, M.V.; Rampazzo Ribeiro, V.; Haminiuk, C.W.I. Saccharomyces cerevisiae biosorbed with grape pomace flavonoids: Adsorption studies and in vitro simulated gastrointestinal digestion. *Int. J. Food Sci. Technol.* **2019**, *54*, 1413–1422. [CrossRef]
50. Carey, A.N.; Miller, M.G.; Fisher, D.R.; Bielinski, D.F.; Gilman, C.K.; Poulose, S.M.; Shukitt-Hale, B. Dietary supplementation with the polyphenol-rich açaí pulps (*Euterpe oleracea* Mart. And *Euterpe precatoria* Mart.) improves cognition in aged rats and attenuates inflammatory signaling in BV-2 microglial cells. *Nutr. Neurosci.* **2017**, *20*, 238–245. [CrossRef] [PubMed]
51. Gale, A.M.; Kaur, R.; Baker, W.L. Hemodynamic and electrocardiographic effects of açaí berry in healthy volunteers: A randomized controlled trial. *Int. J. Cardiol.* **2014**, *174*, 421–423. [CrossRef]
52. Shi, N.; Clinton, S.; Liu, Z.; Wang, Y.; Riedl, K.; Schwartz, S.; Zhang, X.; Pan, Z.; Chen, T. Strawberry Phytochemicals Inhibit Azoxymethane/Dextran Sodium Sulfate-Induced Colorectal Carcinogenesis in Crj: CD-1 Mice. *Nutrients* **2015**, *7*, 1696–1715. [CrossRef]
53. Rutledge, G.A.; Fisher, D.R.; Miller, M.G.; Kelly, M.E.; Bielinski, D.F.; Shukitt-Hale, B. The effects of blueberry and strawberry serum metabolites on age-related oxidative and inflammatory signaling in vitro. *Food Funct.* **2019**, *10*, 7707–7713. [CrossRef] [PubMed]
54. Youdim, K.; Martin, A.; Joseph, J. Incorporation ofthe elderberry anthocyanins by endothelial cells increasesprotection against oxidative stress. *Free Radic. Biol. Med.* **2000**, *29*, 51–60. [CrossRef]
55. Mullen, W.; Stewart, A.J.; Lean, M.E.J.; Gardner, P.; Duthie, G.G.; Crozier, A. Effect of freezing and storage on the phenolics, ellagitannins, flavonoids, and antioxidant capacity of redraspberries. *J. Agric. Food Chem.* **2002**, *50*, 5197–5201. [CrossRef] [PubMed]

56. Mullen, W.; McGinn, J.; Lean, M.E.J.; MacLean, M.R.; Gardner, P.; Duthie, G.G.; Yokota, T.; Crozier, A. Ellagitannins, flavonoids, and other phenolics inred raspberries and their contribution to antioxidant capacityand vasorelaxation properties. *J. Agric. Food Chem.* **2002**, *50*, 5191–5196. [CrossRef] [PubMed]
57. Singh, S.; Virmani, T.; Kohli, K. Phytochemicals and Medicinal Uses of Red Raspberry: A Review. *J. Pharm. Res.* **2020**, *5*, 48–52.
58. Benetou, V.; Orfanos, P.; Lagiou, P.; Trichopoulos, D.; Boffetta, P.; Trichopoulou, A. Vegetables and fruits in relation to cancerrisk: Evidence from the Greek EPIC cohort study. *Cancer Epidemiol. Biomark. Prev.* **2008**, *92*, 1812–1823.
59. Bowen-Forbes, C.; Zhang, Y.; Nair, M. Anthocyanincontent, antioxidant, anti-inflammatory and anti-cancerproperties of blackberry and raspberry fruits. *J. Food Compos. Anal.* **2010**, *23*, 554–560. [CrossRef]
60. Jayaprakasam, B.; Vareed, S.; Olson, L.; Nair, M. Insulin secretion by bioactive anthocyanins and anthocyanidinspresent in fruits. *J. Agric. Food Chem.* **2005**, *53*, 28–31. [CrossRef] [PubMed]
61. Park, K. Raspberry ketone, a naturally occurringphenolic compound, inhibits adipogenic and lipogenic geneexpression in 3T3-L 1 adipocytes. *Pharm. Biol.* **2015**, *53*, 870–875. [CrossRef]
62. Park, K. Raspberry ketone increases both lipolysis andfatty acid oxidation in 3T3-L 1 adipocytes. *Planta Med.* **2010**, *76*, 1654–1658. [CrossRef]
63. Gapski, A.; Gomes, T.M.; Bredun, M.A.; Ferreira-Lima, N.E.; Ludka, F.K.; Bordignon-Luiz, M.T.; Burin, V.M. Digestion behavior and antidepressant-like effect promoted by acute administration of blueberry extract on mice. *Food Res. Int.* **2019**, *125*, 108618. [CrossRef] [PubMed]
64. Li, Z.; Zhang, H.; Li, Y.; Chen, H.; Wang, C.; Wong, V.K.W.; Jiang, Z.; Zhang, W. Phytotherapy using blueberry leaf polyphenols to alleviate non-alcoholic fatty liver disease through improving mitochondrial function and oxidative defense. *Phytomedicine* **2020**, *69*, 153209. [CrossRef] [PubMed]
65. Tiwari, S.; Talreja, S. Health Benefits of Cranberries: An In-DepthOverview. *Health Sci. J.* **2023**, *17*, 1057.
66. Gopalan, A.; Reuben, S.C.; Ahmed, S.; Darvesh, A.S.; Hohmann, J.; Bishayee, A. The health benefits of blackcurrants. *Food Funct.* **2012**, *3*, 795. [CrossRef] [PubMed]
67. Stone, D.A.; Hawke, M.W.; LaMonte, M.; Kittner, S.J.; Acosta, J.; Corretti, M.; Sample, C.; Price, T.R.; Plotnick, G.D. Ulcerated atherosclerotic plaques in the thoracic aorta are associated with cryptogenic stroke: A multiplane transesophageal echocardiographic study. *Am. Heart J.* **1995**, *130*, 105–108. [CrossRef] [PubMed]
68. Dalgård, C.; Nielsen, F.; Morrow, J.D.; Enghusen-Poulsen, H.; Jonung, T.; Hørder, M.; De Maat, M.P.M. Supplementation with orange and blackcurrant juice, but not vitamin E, improves inflammatory markers in patients with peripheral arterial disease. *Br. J. Nutr.* **2008**, *101*, 263–269. [CrossRef] [PubMed]
69. Helbig, D.; Wagner, A.; Glei, M.; Basu, S.; Schubert, R.; Jahreis, G. Blackcurrant seed press residue increases tocopherol concentrations in serum and stool whilst biomarkers in stool and urine indicate increased oxidative stress in human subjects. *Br. J. Nutr.* **2009**, *102*, 554. [CrossRef] [PubMed]
70. Zhao, F.; Wu, Z.; Hou, Y.; Zhang, T.; Li, K. Efficacy of blackcurrant oil soft capsule, a Chinese herbal drug, in hyperlipidemia treatment. *Phytother. Res.* **2010**, *24*, S209–S213. [CrossRef] [PubMed]
71. Nakaishi, H.; Matsumoto, H.; Tominaga, S.; Hirayama, M. Effects of black current anthocyanoside intake on dark adaptation and VDT work-induced transient refractive alteration in healthy humans. *Altern. Med. Rev. A J. Clin. Ther.* **2000**, *5*, 553–562.
72. Matsumoto, H.; Nakamura, Y.; Tachibanaki, S.; Kawamura, S.; Hirayama, M. Stimulatory Effect of Cyanidin 3-Glycosides on the Regeneration of Rhodopsin. *J. Agric. Food Chem.* **2003**, *51*, 3560–3563. [CrossRef]
73. Imran, M.; Rauf, A.; Imran, A.; Nadeem, M.; Ahmad, Z.; Atif, M.; Awais, M.; Sami, M.; Imran, M.; Fatima, Z.; et al. Health Benefits of Grapes Polyphenols. *J. Environ. Agric. Sci.* **2017**, *10*, 40–51.
74. Aziz, M.H.; Reagan-Shaw, S.; Wu, J.; Longley, B.J.; Ahmad, N. Chemoprevention of skin cancer by grape constituent resveratrol: Relevance to human disease? *FASEB J.* **2005**, *19*, 1193–1195. [CrossRef] [PubMed]
75. Mendes, A.; Desgranges, C.; Chèze, C.; Vercauteren, J.; Freslon, J.L. Vasorelaxant effects of grape polyphenols in rat isolated aorta. Possible involvement of a purinergic pathway. *Fundam. Clin. Pharmacol.* **2003**, *17*, 673–681. [CrossRef] [PubMed]
76. Edirisinghe, I.; Burton-Freeman, B.; Tissa Kappagoda, C. Mechanism of the endothelium-dependent relaxation evoked by a grape seed extract. *Clin. Sci.* **2008**, *114*, 331–337. [CrossRef] [PubMed]
77. Pinent, M.; Blay, M.; Bladé, M.C.; Salvadó, M.J.; Arola, L.; Ardévol, A. Grape seed-derived procyanidins have an antihyperglycemic effect in streptozotocin-induced diabetic rats and insulinomimetic activity in insulin-sensitive cell lines. *Endocrinology* **2004**, *145*, 4985–4990. [CrossRef] [PubMed]
78. Fideles, S.O.M.; de Cássia Ortiz, A.; Buchaim, D.V.; de Souza Bastos Mazuqueli Pereira, E.; Parreira, M.J.B.M.; de Oliveira Rossi, J.; da Cunha, M.R.; de Souza, A.T.; Soares, W.C.; Buchaim, R.L. Influence of the Neuroprotective Properties of Quercetin on Regeneration and Functional Recovery of the Nervous System. *Antioxidants* **2023**, *12*, 149. [CrossRef] [PubMed]
79. Zaa, C.A.; Marcelo, Á.J.; An, Z.; Medina-Franco, J.L.; Velasco-Velázquez, M.A. Anthocyanins: Molecular Aspects on Their Neuroprotective Activity. *Biomolecules* **2023**, *13*, 1598. [CrossRef] [PubMed]
80. Shao, X.; Zhao, B.; Wang, B.; Zhao, B.; Zhu, Y.; Yuan, Z.; Zhang, J. Neuroprotective effects of blueberry anthocyanins against perfluorooctanoic sulfonate on planarian *Dugesia japonica*. *Ecotoxicol. Environ. Saf.* **2019**, *175*, 39–47. [CrossRef] [PubMed]
81. Gutiérrez, T.J. Active and Intelligent Films Made from Starchy Sources/Blackberry Pulp. *J. Polym. Environ.* **2018**, *26*, 2374–2391. [CrossRef]

82. Oliveira, M.; Rodrigues, C.M.; Teixeira, P. Microbiological quality of raw berries and their products: A focus on foodborne pathogens. *Heliyon* **2019**, *5*, e02992. [CrossRef]
83. Ribeiro, V.R.; Fernandes, I.D.A.A.; Mari, I.P.; Stafussa, A.P.; Rossetto, R.; Maciel, G.M.; Haminiuk, C.W.I. Bringing together Saccharomyces cerevisiae and bioactive compounds from plants: A new function for a well-known biosorbent. *J. Funct. Foods* **2019**, *60*, 103433. [CrossRef]
84. Santos, S.S.; Rodrigues, L.M.; Costa, S.C.; Madrona, G.S. Antioxidant compounds from blackberry (*Rubus fruticosus*) pomace: Microencapsulation by spray-dryer and pH stability evaluation. *Food Packag. Shelf Life* **2019**, *20*, 100177. [CrossRef]
85. Sánchez, M.; Haba, M.; Benítez-López, M.; Fernández-Novales, J.; Garrido-Varo, A.; Pérez-Marín, D. Non-destructive characterization and quality control of intact strawberies based on NIR spectral data. *J. Food Eng.* **2012**, *110*, 102–108. [CrossRef]
86. Kalt, W.; Prange, R.; Lidster, P. Postharvest color development of strawberries: Influence of maturity, temperature and light. *Can. J. Plant Sci.* **1993**, *73*, 541–548. [CrossRef]
87. Krüger, E.; Schöpplein, E.; Rasim, S.; Cocca, G.; Fischer, H. Effects of ripening stage and storage time on quality parameters of red raspberry fruit. *Eur. J. Hortic. Sci.* **2003**, *68*, 176–182.
88. García, M. La agroindustria de la mora. Alternativas viables para los fruticultores. *Tecnol. Para Agro* **2001**, *1*, 15–17.
89. Sturm, K.; Koron, D.; Stampar, F. The composition of fruit of different strawberry varieties depending on maturity stage. *Food Chem.* **2003**, *83*, 417–422. [CrossRef]
90. Abuduaibifu, A.; Tamer, C.E. Evaluation of physicochemical and bioaccessibility properties of goji berry kombucha. *J. Food Process. Preserv.* **2019**, *43*, e14077. [CrossRef]
91. De Sá, L.Z.C.M.; Castro, P.F.S.; Lino, F.M.A.; Bernardes, M.J.C.; Viegas, J.C.J.; Dinis, T.C.P.; Santana, M.J.; Romao, W.; Vaz, B.G.; Lião, L.M.; et al. Antioxidant potential and vasodilatory activity of fermented beverages of jabuticaba berry (*Myrciaria jaboticaba*). *J. Funct. Foods* **2014**, *8*, 169–179. [CrossRef]
92. Hornedo-Ortega, R.; Álvarez-Fernández, M.A.; Cerezo, A.B.; Garcia-Garcia, I.; Troncoso, A.M.; Garcia-Parrilla, M.C. Influence of Fermentation Process on the Anthocyanin Composition of Wine and Vinegar Elaborated from Strawberry. *J. Food Sci.* **2017**, *82*, 364–372. [CrossRef]
93. Silva, V.L.M.; Silva, A.C.O.; Costa-Lima, B.R.C.; Carneiro, C.S.; Conte-Junior, C.A. Stability of polyphenols from blueberry (*Vaccinium corymbosum* L.) in fermented dairy beverage. *J. Food Process. Preserv.* **2017**, *41*, e13305. [CrossRef]
94. Albuquerque, B.R.; Pinela, J.; Barros, L.; Oliveira MB, P.P.; Ferreira, I.C.F.R. Anthocyanin-rich extract of jabuticaba epicarp as a natural colorant: Optimization of heat- and ultrasound-assisted extractions and application in a bakery product. *Food Chem.* **2020**, *316*, 126364. [CrossRef] [PubMed]
95. José Jara-Palacios, M.; Gonçalves, S.; Hernanz, D.; Heredia, F.J.; Romano, A. Effects of in vitro gastrointestinal digestion on phenolic compounds and antioxidant activity of different white winemaking byproducts extracts. *Food Res. Int.* **2018**, *109*, 433–439. [CrossRef] [PubMed]
96. Šarić, B.; Mišan, A.; Mandić, A.; Nedeljković, N.; Pojić, M.; Pestorić, M.; Đilas, S. Valorisation of raspberry and blueberry pomace through the formulation of value-added gluten-free cookies. *J. Food Sci. Technol.* **2016**, *53*, 1140–1150. [CrossRef] [PubMed]
97. Goulas, V.; Manganaris, G. The effect of postharvest ripening on strawberry bioactive composition and antioxidant potential. *J. Sci. Food Agric.* **2011**, *91*, 1907–1914. [CrossRef] [PubMed]
98. Jing, W.; Tu, K.; Shao, X.; Su, Z.; Zhao, Y.; Wang, S.; Tang, J. Effect of postharvest short hot-water rinsing and brushing treatment on decay and quality of strawberry fruit. *J. Food Qual.* **2010**, *33*, 262–272. [CrossRef]
99. Nunes, M.; Brecht, J.; Morais, A.; Sargent, S. Possible influences of water loss and polyphenol oxidase activity on anthocyanin content and discoloration in fresh ripe strawberry (cv. Oso Grande) during storage at 1 °C. *J. Food Sci.* **2005**, *70*, S79–S84. [CrossRef]
100. Han, C.; Zhao, Y.; Leonard, S.; Trabe, M. Edible coatings to improve storability and enhance nutritional value of fresh and frozen strawberries (*Fragaria* × *ananassa*) and raspberries (*Rubus ideaus*). *Postharvest Biol. Technol.* **2004**, *33*, 67–78. [CrossRef]
101. Hernández-Muñoz, P.; Almenar, E.; Ocio, M.; Gavara, R. Effect of calcium dips and chitosan coatings on postharvest life of strawberries (*Fragaria* × *ananassa*). *Postharvest Biol. Technol.* **2006**, *39*, 247–253. [CrossRef]
102. Vardar, C.; Ilhan, K.; Karabulut, O. The application of various disinfectants by fogging for decreasing postharvest diseases of strawberry. *Postharvest Biol. Technol.* **2012**, *66*, 30–34. [CrossRef]
103. Holcroft, D.; Kader, A. Controlled atmosphere induced changes in pH and organic acid metabolism may affect color of stored strawberry fruit. *Postharvest Biol. Technol.* **1999**, *17*, 19–32. [CrossRef]
104. Leroux, P. Chemical control of botrytis and its resistance to chemical fungicides. In *Botrytis: Biology, Pathology and Control*; Elad, Y., Williamson, B., Tudzynski, P., Delen, N., Eds.; Springer: Berlin/Heidelberg, Germany, 2007; pp. 195–222.
105. Pham, T.T.; Nguyen, L.L.P.; Dam, M.S.; Baranyai, L. Application of Edible Coating in Extension of Fruit Shelf Life: Review. *Agriengineering* **2023**, *5*, 520–536. [CrossRef]
106. Paidari, S.; Zamindar, N.; Tahergorabi, R.; Kargar, M.; Ezzati, S.; Shirani, N.; Musavi, S.H. Edible coating and films as promising packaging: A mini review. *J. Food Meas. Charact.* **2021**, *15*, 4205–4214. [CrossRef]
107. Sharma, P.; Shehin, V.P.; Kaur, N.; Vyas, P. Application of edible coatings on fresh and minimally processed vegetables: A review. *Int. J. Veget. Sci.* **2019**, *25*, 295–314. [CrossRef]

108. Irimia, A.; Stoleru, E.; Vasile, C.; Bele, A.; Brebu, M. Application of Vegetal Oils in Developing Bioactive Paper-Based Materials for Food Packaging. *Coatings* **2021**, *11*, 1211. [CrossRef]
109. Blancas-Benitez, F.J.; Montaño-Leyva, B.; Aguirre-Güitrón, L.; Moreno-Hernández, C.L.; Fonseca-Cantabrana, Á.; Romero-Islas, L.D.C.; González-Estrada, R.R. Impact of edible coatings on quality of fruits: A review. *Food Control* **2022**, *139*, 109063. [CrossRef]
110. Otoni, C.G.; Avena-Bustillos, R.J.; Azeredo HM, C.; Lorevice, M.V.; Moura, M.R.; Mattoso LH, C.; McHugh, T.H. Recent Advances on Edible Films Based on Fruits and Vegetables—A Review. *Compr. Rev. Food Sci. Food Saf.* **2017**, *16*, 1151–1169. [CrossRef] [PubMed]
111. Lin, D.; Zhao, Y. Innovations in the Development and Application of Edible Coatings for Fresh and Minimally Processed Fruits and Vegetables. *Compr. Rev. Food Sci. Food Saf.* **2007**, *6*, 60–75. [CrossRef]
112. Senturk Parreidt, T.; Müller, K.; Schmid, M. Alginate-Based Edible Films and Coatings for Food Packaging Applications. *Foods* **2018**, *7*, 170. [CrossRef]
113. Yuan, G.; Chen, X.; Li, D. Chitosan films and coatings containing essential oils: The antioxidant and antimicrobial activity, and application in food systems. *Food Res. Int.* **2016**, *89*, 117–128. [CrossRef]
114. Salama, H.E.; Abdel Aziz, M.S.; Alsehli, M. Carboxymethyl cellulose/sodium alginate/chitosan biguanidine hydrochloride ternary system for edible coatings. *Int. J. Biol. Macromol.* **2019**, *139*, 614–620. [CrossRef] [PubMed]
115. Abdel Aziz, M.S.; Salama, H.E.; Sabaa, M.W. Biobased alginate/castor oil edible films for active food packaging. *LWT* **2018**, *96*, 455–460. [CrossRef]
116. Salama, H.E.; Abdel Aziz, M.S.; Sabaa, M.W. Novel biodegradable and antibacterial edible films based on alginate and chitosan biguanidine hydrochloride. *Int. J. Biol. Macromol.* **2018**, *116*, 443–450. [CrossRef] [PubMed]
117. Moghadam, M.; Salami, M.; Mohammadian, M.; Khodadadi, M.; Emam-Djomeh, Z. Development of antioxidant edible films based on mung bean protein enriched with pomegranate peel. *Food Hydrocoll.* **2020**, *104*, 105735. [CrossRef]
118. Bashir, K.; Jan, K.; Aggarwal, M. Thermo-rheological and functional properties of gamma-irradiated wholewheat flour. *Int. J. Food Sci. Technol.* **2017**, *52*, 927–935. [CrossRef]
119. Tiwari, A.; Galanis, A.; Soucek, M.D. *Biobased and Environmental Benign Coatings*; Scrivener Publishing: Beverly, MA, USA, 2016.
120. Rambabu, K.; Bharath, G.; Banat, F.; Show, P.L.; Cocoletzi, H.H. Mango leaf extract incorporated chitosan antioxidant film for active food packaging. *Int. J. Biol. Macromol.* **2019**, *126*, 1234–1243. [CrossRef]
121. Brown, S.R.B.; Kozak, S.M.; D'Amico, D.J. Applications of Edible Coatings Formulated with Antimicrobials Inhibit Listeria monocytogenes Growth on Queso Fresco. *Front. Sustain. Food Syst.* **2018**, *2*, 1. [CrossRef]
122. Nandane, A.S.; Dave, R.K.; Rao, T.V.R. Optimization of edible coating formulations for improving postharvest quality and shelf life of pear fruit using response surface methodology. *J. Food Sci. Technol.* **2017**, *54*, 1–8. [CrossRef]
123. Sapper, M.; Chiralt, A. Starch-Based Coatings for Preservation of Fruits and Vegetables. *Coatings* **2018**, *8*, 152. [CrossRef]
124. Dong, C.; Wang, B.; Li, F.; Zhong, Q.; Xia, X.; Kong, B. Effects of edible chitosan coating on Harbin red sausage storage stability at room temperature. *Meat Sci.* **2020**, *159*, 107919. [CrossRef]
125. Grosso, A.L.; Asensio, C.M.; Grosso, N.R.; Nepote, V. Increase of walnuts' shelf life using a walnut flour protein-based edible coating. *LWT* **2020**, *118*, 108712. [CrossRef]
126. Hasan, S.M.K.; Ferrentino, G.; Scampicchio, M. Nanoemulsion as advanced edible coatings to preserve the quality of fresh-cut fruits and vegetables: A review. *Int. J. Food Sci. Technol.* **2020**, *55*, 1–10. [CrossRef]
127. De Pilli, T. Development of a vegetable oil and egg proteins edible film to replace preservatives and primary packaging of sweet baked goods. *Food Control* **2020**, *114*, 107273. [CrossRef]
128. Kazemian-Bazkiaee, F.; Ebrahimi, A.; Hosseini, S.M.; Shojaee-Aliabadi, S.; Farhoodi, M.; Rahmatzadeh, B.; Sheikhi, Z. Evaluating the protective effect of edible coatings on lipid oxidation, fatty acid composition, aflatoxins levels of roasted peanut kernels. *J. Food Meas. Charact.* **2020**, *14*, 1025–1038. [CrossRef]
129. Kurek, M.; Ščetar, M.; Galić, K. Edible coatings minimize fat uptake in deep fat fried products: A review. *Food Hydrocoll.* **2017**, *71*, 225–235. [CrossRef]
130. Khalid, M.A.; Niaz, B.; Saeed, F.; Afzaal, M.; Islam, F.; Hussain, M.; Mahwish; Khalid, H.M.S.; Siddeeg, A.; Al-Farga, A. Edible coatings for enhancing safety and quality attributes of fresh produce: A comprehensive review. *Int. J. Food Prop.* **2022**, *25*, 1817–1847. [CrossRef]
131. De Bruno, A.; Gattuso, A.; Ritorto, D.; Piscopo, A.; Poiana, M. Effect of Edible Coating Enriched with Natural Antioxidant Extract and Bergamot Essential Oil on the Shelf Life of Strawberries. *Foods* **2023**, *12*, 488. [CrossRef] [PubMed]
132. Chiabrando, V.; Giacalone, G. Quality evaluation of blueberries coated with chitosan and sodium alginate during postharvest storage. *Int. Food Res. J.* **2017**, *24*, 1553–1561.
133. Tezotto-Uliana, J.V.; Fargoni, G.P.; Geerdink, G.M.; Kluge, R.A. Chitosan applications pre- or postharvest prolong raspberry shelf-life quality. *Postharvest Biol. Technol.* **2014**, *91*, 72–77. [CrossRef]
134. Guapi Álava, G.; Guerrón Troya, V.; Oña Cundulle, T.; Revilla Escobar, K.; Aldas Morejon, J.; Caicedo Álvarez, E. Effect of milk protein coating and Nisin on the postharvest quality of strawberries (*Fragaria ananassa*). *Bionatura* **2023**, *8*, 49. [CrossRef]

135. Pereira, J.O.; Soares, J.; Sousa, S.; Madureira, A.R.; Gomes, A.; Pintado, M. Edible films as carrier for lactic acid bacteria. *LWT-Food Sci. Technol.* **2016**, *73*, 543–550. [CrossRef]
136. Campos, C.A.; Gerschenson, L.N.; Flores, S.K. Development of Edible Films and Coatings with Antimicrobial Activity. *Food Bioprocess Technol.* **2011**, *4*, 849–875. [CrossRef]
137. Abdi, S.; Roein, Z.; Erfanimoghadam, J.; Aziznia, S. Application of pectin coating containing essential oil for increasing quality of strawberry fruit. *J. Postharvest Technol.* **2017**, *5*, 83–94.
138. Khedr, E.H. Application of different coating treatments to enhance storability and fruit quality of pomegranate (*Punica granatum* L., cv. Wonderful) during prolonged storage. *Rev. Bras. Frutic.* **2022**, *44*, e-855. [CrossRef]
139. Garcia, L.C.; Pereira, L.M.; De Luca Sarantópoulos, C.I.G.; Hubinger, M.D. Effect of Antimicrobial Starch Edible Coating on Shelf-Life of Fresh Strawberries. *Packag. Technol. Sci.* **2012**, *25*, 413–425. [CrossRef]
140. Fakhouri, F.M.; Casari, A.C.A.; Mariano, M.; Yamashita, F.; Mei, L.H.I.; Soldi, V.; Martelli, S.M. Effect of a gelatin-based edible coating containing cellulose nanocrystals (CNC) on the quality and nutrient retention of fresh strawberries during storage. *IOP Conf. Ser. Mater. Sci. Eng.* **2014**, *64*, 012024. [CrossRef]
141. Dhital, R. Application of Plant Based Edible Coatings for Maintaining Post Harvest Quality and Extending Shelf Life of Strawberries [Internet] [Theses. 2468]. [USA]: Southern Illinois University Carbondale. 2018. Available online: https://opensiuc.lib.siu.edu/theses/2468 (accessed on 15 May 2024).
142. Tumbarski, Y.D.; Todorova, M.M.; Topuzova, M.G.; Georgieva, P.I.; Petkova, N.T.; Ivanov, I.G. Postharvest Biopreservation of Fresh Blueberries by Propolis-Containing Edible Coatings Under Refrigerated Conditions. *Curr. Res. Nutr. Food Sci. J.* **2022**, *10*, 99–112. [CrossRef]
143. Kaynarca, G.B.; Kamer, D.D.A.; Yucel, E.; Gümüş, T. Proposed Use of a Polyvinyl Alcohol with Grape Pomace Extract as an Edible Coating for Strawberries. *Pol. J. Food Nutr. Sci.* **2023**, *73*, 151–162. [CrossRef]
144. Rodríguez, M.D.; García-Cordero, J.; Suárez-Coca, D.; Ruiz Del Castillo, M.L.; Blanch, G.P.; De Pascual-Teresa, S. Varietal Effect on Composition and Digestibility of Seedless Table Grapes (*Vitis vinifera* L.) under In Vitro Conditions. *Foods* **2022**, *11*, 3984. [CrossRef]
145. Velickova, E.; Winkelhausen, E.; Kuzmanova, S.; Alves, V.D.; Moldão-Martins, M. Impact of chitosan-beeswax edible coatings on the quality of fresh strawberries (*Fragaria ananassa* cv Camarosa) under commercial storage conditions. *LWT—Food Sci. Technol.* **2013**, *52*, 80–92. [CrossRef]
146. Eshghi, S.; Karimi, R.; Shiri, A.; Karami, M.; Moradi, M. Effects of polysaccharide-based coatings on postharvest storage life of grape: Measuring the changes in nutritional, antioxidant and phenolic compounds. *J. Food Meas. Charact.* **2022**, *16*, 1159–1170. [CrossRef]
147. Kahramanoğlu, İ. Effects of lemongrass oil application and modified atmosphere packaging on the postharvest life and quality of strawberry fruits. *Sci. Hortic.* **2019**, *256*, 108527. [CrossRef]
148. Khalifa, I.; Barakat, H.; El-Mansy, H.A.; Soliman, S.A. Enhancing the keeping quality of fresh strawberry using chitosan-incorporated olive processing wastes. *Food Biosci.* **2016**, *13*, 69–75. [CrossRef]
149. Santos, B.G.F.L.; de Medeiros Teodosio, A.E.M.; Araújo, R.H.C.R.; Onias, E.A.; de Oliveira, A.M.F.; da Nóbrega Santos, E.; da Silva Marcelino, R.M.O.; Santos, J.G.F.L. Application of tamarind seed starch as edible coating in the post-harvest quality of grapes 'Isabel' (*Vitis labrusca* × *Vitis vinifera* L.). *Aust. J. Crop Sci.* **2020**, *14*, 953–958. [CrossRef]
150. Hajji, S.; Younes, I.; Affes, S.; Boufi, S.; Nasri, M. Optimization of the formulation of chitosan edible coatings supplemented with carotenoproteins and their use for extending strawberries postharvest life. *Food Hydrocoll.* **2018**, *83*, 375–392. [CrossRef]
151. Duran, M.; Aday, M.S.; Zorba, N.N.D.; Temizkan, R.; Büyükcan, M.B.; Caner, C. Potential of antimicrobial active packaging 'containing natamycin, nisin, pomegranate and grape seed extract in chitosan coating' to extend shelf life of fresh strawberry. *Food Bioprod. Process.* **2016**, *98*, 354–363. [CrossRef]
152. Vieira, J.M.M. Development of Chitosan-Based Edible Coatings Containing Aloe Vera for Blueberries Application. Ph.D. Thesis, Universidade de Coimbra, Coimbra, Portugal, 2014.
153. Yan, J.; Luo, Z.; Ban, Z.; Lu, H.; Li, D.; Yang, D.; Aghdam, M.S.; Li, L. The effect of the layer-by-layer (LBL) edible coating on strawberry quality and metabolites during storage. *Postharvest Biol. Technol.* **2019**, *147*, 29–38. [CrossRef]
154. Oh, Y.A.; Oh, Y.J.; Song, A.Y.; Won, J.S.; Song, K.B.; Min, S.C. Comparison of effectiveness of edible coatings using emulsions containing lemongrass oil of different size droplets on grape berry safety and preservation. *LWT—Food Sci. Technol.* **2017**, *75*, 742–750. [CrossRef]
155. Gutiérrez-Jara, C.; Bilbao-Sainz, C.; McHugh, T.; Chiou, B.-S.; Williams, T.; Villalobos-Carvajal, R. Effect of Cross-Linked Alginate/Oil Nanoemulsion Coating on Cracking and Quality Parameters of Sweet Cherries. *Foods* **2021**, *10*, 449. [CrossRef]
156. Zhong, Y.; Cavender, G.; Zhao, Y. Investigation of different coating application methods on the performance of edible coatings on Mozzarella cheese. *LWT—Food Sci. Technol.* **2014**, *56*, 1–8. [CrossRef]
157. Nunes, C.; Silva, M.; Farinha, D.; Sales, H.; Pontes, R.; Nunes, J. Edible Coatings and Future Trends in Active Food Packaging–Fruits' and Traditional Sausages' Shelf Life Increasing. *Foods* **2023**, *12*, 3308. [CrossRef] [PubMed]
158. Guerreiro, A.C.; Gago, C.M.L.; Faleiro, M.L.; Miguel, M.G.C.; Antunes, M.D.C. The use of pol-ysaccharide-based edible coatings enriched with essential oilsto improve shelf-life of strawberries. *Postharvest Biol. Technol.* **2015**, *110*, 51–60. [CrossRef]
159. Kumar, L.; Ramakanth, D.; Akhila, K.; Gaikwad, K.K. Edible films and coatings for food packaging applications: A review. *Environ. Chem. Lett.* **2022**, *20*, 875–900. [CrossRef]

160. Andrade, R.D.; Skurtys, O.; Osorio, F.A. Atomizing Spray Systems for Application of Edible Coatings. *Compr. Rev. Food Sci. Food Saf.* **2012**, *11*, 323–337. [CrossRef]
161. Hirlekar, R.; Patel, M.; Jain, S.; Kadam, V. Drug Eluting Coronary Artery Stents. *Curr. Drug Deliv.* **2010**, *7*, 421–427. [CrossRef] [PubMed]
162. Matloob, A.; Ayub, H.; Mohsin, M.; Ambreen, S.; Khan, F.A.; Oranab, S.; Rahim, M.A.; Khalid, W.; Nayik, G.A.; Ramniwas, S.; et al. A Review on Edible Coatings and Films: Advances, Composition, Production Methods, and Safety Concerns. *ACS Omega* **2023**, *8*, 28932–28944. [CrossRef] [PubMed]
163. Costa, M.J.; Maciel, L.C.; Teixeira, J.A.; Vicente, A.A.; Cerqueira, M.A. Use of edible films and coatings in cheese preservation: Opportunities and challenges. *Food Res. Int.* **2018**, *107*, 84–92. [CrossRef] [PubMed]
164. Ju, J.; Xie, Y.; Guo, Y.; Cheng, Y.; Qian, H.; Yao, W. Application of edible coating with essential oil in food preservation. *Crit. Rev. Food Sci. Nutr.* **2019**, *59*, 2467–2480. [CrossRef] [PubMed]
165. Akita, K.; Associates, J.P.; Building, D. Patent Application Publication (10) Pub. No.: US 2008/0283851 A1 Patent Application Publication. U.S. Patent US 2008/0280 138 A1, 2 October 2008.
166. Lipin, A.A.; Lipin, A.G. Prediction of coating uniformity in batchfluidized-bed coating process. *Particuology* **2021**, *61*, 41–46. [CrossRef]
167. Tavassoli-Kafrani, E.; Shekarchizadeh, H.; Masoudpour-Behabadi, M. Development of edible films and coatings from alginates and carrageenans. *Carbohydr. Polym.* **2016**, *137*, 360–374. [CrossRef]
168. Costa, C.; Conte, A.; Del Nobile, M.A. Effective preservation techniques to prolong the shelf life of ready-to-eat oysters: Prolonging the shelf life of ready-to-eat oysters. *J. Sci. Food Agric.* **2014**, *94*, 2661–2667. [CrossRef] [PubMed]
169. Raghav, P.K.; Agarwal, N.; Saini, M. Edible Coating of Fruits and Vegetables: A Review. *Int. J. Sci. Res. Modern Ed.* **2016**, *1*, 188–204.
170. Tang, X.; Yan, X. Dip-coating for fibrous materials: Mechanism, methods and applications. *J. Sol-Gel Sci. Technol.* **2017**, *81*, 378–404. [CrossRef]
171. Ungureanu, C.; Tihan, G.; Zgârian, R.; Pandelea (Voicu), G. Bio-Coatings for Preservation of Fresh Fruits and Vegetables. *Coatings* **2023**, *13*, 1420. [CrossRef]
172. Kumar, G.; Prabhu, K.N. Review of non-reactive and reactive wetting of liquids on surfaces. *Adv. Colloid Interface Sci.* **2007**, *133*, 61–89. [CrossRef] [PubMed]
173. Shiekh, K.A.; Ngiwngam, K.; Tongdeesoontorn, W. Polysaccharide-Based Active Coatings Incorporated with Bioactive Compounds for Reducing Postharvest Losses of Fresh Fruits. *Coatings* **2021**, *12*, 8. [CrossRef]
174. Giray Tufan, E.; Akpi Nar Borazan, A.; Koçkar, Ö.M. A Review on Edible Film and Coating Applications for Fresh and Dried Fruits and Vegetables. *Bilecik Şeyh Edebali Üniv. Fen Bilim. Derg.* **2021**, *8*, 1073–1085. [CrossRef]
175. Moncayo Martinez, D.C.; Buitrago Hurtado, G.; Algecira Enciso, N.A. The surface properties of biopolymer-coated fruit: A review. *Ing. Investig.* **2013**, *33*, 11–16. [CrossRef]
176. Debeaufort, F.; Voilley, A. Lipid-Based Edible Films and Coatings. In *Edible Films and Coatings for Food Applications*; Kahramanoglu, I., Huber, K.C., Embuscado, M.E., Eds.; Springer: Berlin/Heidelberg, Germany, 2009; pp. 135–168.
177. Martín-Belloso, O.; Rojas-Graü, M.A.; Soliva-Fortuny, R. Delivery of Flavor and Active Ingredients Using Edible Films and Coatings. In *Edible Films and Coatings for Food Applications*; Kahramanoglu, I., Huber, K.C., Embuscado, M.E., Eds.; Springer: Berlin/Heidelberg, Germany, 2009; pp. 295–313.
178. Ghosh, M.; Singh, A.K. Potential of engineered nanostructured biopolymer based coatings for perishable fruits with Coronavirus safety perspectives. *Prog. Org. Coat.* **2022**, *163*, 106632. [CrossRef]
179. Dangaran, K.; Tomasula, P.M.; Qi, P. Structure and Function of Protein-Based Edible Films and Coatings. In *Edible Films and Coatings for Food Applications*; Kahramanoglu, I., Huber, K.C., Embuscado, M.E., Eds.; Springer: Berlin/Heidelberg, Germany, 2009; pp. 25–56.
180. Khan, M.K.I.; Schutyser, M.; Schroën, K.; Boom, R. Barrier properties and storage stability of edible coatings prepared with electrospraying. *Innov. Food Sci. Emerg. Technol.* **2014**, *23*, 182–187. [CrossRef]
181. Jaworek, A.; Sobczyk, A.T. Electrospraying route to nanotechnology: An overview. *J. Electrost.* **2008**, *66*, 197–219. [CrossRef]
182. Dilucia, F.; Lacivita, V.; Conte, A.; Del Nobile, M.A. Sustainable Use of Fruit and Vegetable By-Products to Enhance Food Packaging Performance. *Foods* **2020**, *9*, 857. [CrossRef] [PubMed]
183. Phianmongkol, A.; Rongkom, P.; Wirjantoro, T.I. Effect of Fruit Size and Processing Time on Vacuum Impregnation Parameters of Cantaloupe and Apple. *Chiang Mai Univ. J. Nat. Sci.* **2015**, *14*, 125–132. [CrossRef]
184. Radziejewska-Kubzdela, E.; Biegańska-Marecik, R.; Kidoń, M. Applicability of vacuum impregnation to modify physico-chemical, sensory and nutritive characteristics of plant origin products—A review. *Int. J. Mol. Sci.* **2014**, *15*, 16577–16610. [CrossRef] [PubMed]
185. Arnon-Rips, H.; Poverenov, E. Improving food products' quality and storability by using Layer by Layer edible coatings. *Trends Food Sci. Technol.* **2018**, *75*, 81–92. [CrossRef]
186. Skurtys, O.; Acevedo, C.; Pedreschi, F.; Enrione, J.; Osorio, F.; Aguilera, J.M. *Food Hydrocolloids: Characteristics, Properties and Structures*; Hollingworth, C.S., Ed.; Nova Science Publishers: Hauppauge, NY, USA, 2010.
187. Kocira, A.; Kozłowicz, K.; Panasiewicz, K.; Staniak, M.; Szpunar-Krok, E.; Hortyńska, P. Polysaccharides as Edible Films and Coatings: Characteristics and Influence on Fruit and Vegetable Quality—A Review. *Agronomy* **2021**, *11*, 813. [CrossRef]

188. Andriani, V.; Abyor Handayani, N. Recent technology of edible coating production: A review. *Mater. Today Proc.* **2023**, *87*, 200–206. [CrossRef]
189. Nain, N.; Katoch, G.K.; Kaur, S.; Rasane, P. Recent Developments in Edible Coatings for Fresh Fruits and Vegetables. *J. Hortic. Res.* **2021**, *29*, 127–140. [CrossRef]
190. Chawla, R.; Sivakumar, S.; Kaur, H. Antimicrobial edible films in food packaging: Current scenario and recent nanotechnological advancements—A review. *Carbohydr. Polym. Technol. Appl.* **2021**, *2*, 100024. [CrossRef]
191. Abdullah Cai, J.; Hafeez, M.A.; Wang, Q.; Farooq, S.; Huang, Q.; Tian, W.; Xiao, J. Biopolymer-based functional films for packaging applications: A review. *Front. Nutr.* **2022**, *9*, 1000116. [CrossRef]
192. Moeini, A.; Pedram, P.; Fattahi, E.; Cerruti, P.; Santagata, G. Edible Polymers and Secondary Bioactive Compounds for Food Packaging Applications: Antimicrobial, Mechanical, and Gas Barrier Properties. *Polymers* **2022**, *14*, 2395. [CrossRef]
193. Cheng, Y.; Fu, Y.; Ma, L.; Yap, P.L.; Losic, D.; Wang, H.; Zhang, Y. Rheology of edible food inks from 2D/3D/4D printing, and its role in future 5D/6D printing. *Food Hydrocoll.* **2022**, *132*, 107855. [CrossRef]
194. Qiu, L.; Zhang, M.; Bhandari, B.; Chitrakar, B.; Chang, L. Investigation of 3D printing of apple and edible rose blends as a dysphagia food. *Food Hydrocoll.* **2023**, *135*, 108184. [CrossRef]
195. Guo, Q.; Paliy, M.; Kobe, B.; Trebicky, T.; Suhan, N.; Arsenault, G.; Ferrari, L.; Yang, J. Characterization of cross-linking depth for thin polymeric films using atomic force microscopy. *J. Appl. Polym. Sci.* **2015**, *132*, 41493. [CrossRef]
196. Tihan, G.; Zgarian, R.; Berteanu, E.; Ionita, D.; Totea, G.; Iordachel, C.; Tatia, R.; Prodana, M.; Demetrescu, I. Alkaline Phosphatase Immobilization on New Chitosan Membranes with Mg^{2+} for Biomedical Applications. *Mar. Drugs* **2018**, *16*, 287. [CrossRef]
197. Bangar, S.P.; Chaudhary, V.; Thakur, N.; Kajla, P.; Kumar, M.; Trif, M. Natural Antimicrobials as Additives for Edible Food Packaging Applications: A Review. *Foods* **2021**, *10*, 2282. [CrossRef]
198. Martins, V.F.R.; Pintado, M.E.; Morais, R.M.S.C.; Morais, A.M.M.B. Recent Highlights in Sustainable Bio-Based Edible Films and Coatings for Fruit and Vegetable Applications. *Foods* **2024**, *13*, 318. [CrossRef]
199. Tahir, H.E.; Xiaobo, Z.; Mahunu, G.K.; Arslan, M.; Abdalhai, M.; Zhihua, L. Recent developments in gum edible coating applications for fruits and vegetables preservation: A review. *Carbohydr. Polym.* **2019**, *224*, 115141. [CrossRef] [PubMed]
200. Sarker, A.; Grift, T.E. Bioactive properties and potential applications of Aloe vera gel edible coating on fresh and minimally processed fruits and vegetables: A review. *J. Food Meas. Charact.* **2021**, *15*, 2119–2134. [CrossRef]
201. Yousuf, B.; Wu, S.; Siddiqui, M.W. Incorporating essential oils or compounds derived thereof into edible coatings: Effect on quality and shelf life of fresh/fresh-cut produce. *Trends Food Sci. Technol.* **2021**, *108*, 245–257. [CrossRef]
202. Ruiz-Martínez, J.; Aguirre-Joya, J.A.; Rojas, R.; Vicente, A.; Aguilar-González, M.A.; Rodríguez-Herrera, R.; Alvarez-Perez, O.B.; Torres-León, C.; Aguilar, C.N. Candelilla Wax Edible Coating with Flourensia cernua Bioactives to Prolong the Quality of Tomato Fruits. *Foods* **2020**, *9*, 1303. [CrossRef] [PubMed]
203. Nayak, S.L.; Sethi, S.; Sharma, R.R.; Prajapati, U. Active Edible Coatings for Fresh Fruits and Vegetables. In *Polymers for Agri-Food Applications*; Gutiérrez, T.J., Ed.; Springer International Publishing: Berlin/Heidelberg, Germany, 2019; pp. 417–432. [CrossRef]
204. Bakhy, E.A.; Zidan, N.S.; Aboul-Anean HE, D. The effect of nano materials on edible coating and films' improvement. *Int. J. Pharm. Res. Allied Sci.* **2018**, *7*, 20–41.
205. Ajesh, K.V.; Hasan, M.; Mangaraj, S.M.P.; Verma, D.K.; Srivastav, P.P. Trends in Edible Packaging Films and its Prospective Future in Food: A Review. *Appl. Food Res.* **2022**, *2*, 100118. [CrossRef]
206. Ackermann, P.; Jägerstad, M.; Ohlsson, T. Foods and Packaging Materials—Chemical Interactions. Herausgegeben von P. Ackermann, M. Jägerstad und Th. Ohlsson. 231 Seiten, zahlr. Abbildungen und Tabellen. The Royal Society of Chemistry, Cambridge 1995. Preis: 45,—£. *Food/Nahrung* **1995**, *39*, 337. [CrossRef]
207. Giteru, S.G.; Cridge, B.; Oey, I.; Ali, A.; Altermann, E. In-vitro degradation and toxicological assessment of pulsed electric fields crosslinked zein-chitosan-poly(vinyl alcohol) biopolymeric films. *Food Chem. Toxicol.* **2020**, *135*, 111048. [CrossRef] [PubMed]
208. Chiralt, A.; González-Martínez, C.; Vargas, M.; Atarés, L. Edible films and coatings from proteins. In *Proteins in Food Processing*; Elsevier: Amsterdam, The Netherlands, 2018; pp. 477–500. [CrossRef]
209. Roșu, M.-C.; Páll, E.; Socaci, C.; Măgeruşan, L.; Pogăcean, F.; Coroş, M.; Turza, A.; Pruneanu, S. Cytotoxicity of methylcellulose-based films containing graphenes and curcumin on human lung fibroblasts. *Process Biochem.* **2017**, *52*, 243–249. [CrossRef]
210. Franssen, L.R.; Krochta, J.M. Edible coatings containing natural antimicrobials for processed foods. In *Natural Antimicrobials for the Minimal Processing of Foods*; Elsevier: Amsterdam, The Netherlands, 2003; pp. 250–262. [CrossRef]
211. Wan, V.C.; Lee, C.M.; Lee, S. Understanding Consumer Attitudes On Edible Films and Coatings: Focus Group Findings. *J. Sens. Stud.* **2007**, *22*, 353–366. [CrossRef]
212. Ribeiro-Santos, R.; Andrade, M.; Melo, N.R.D.; Sanches-Silva, A. Use of essential oils in active food packaging: Recent advances and future trends. *Trends Food Sci. Technol.* **2017**, *61*, 132–140. [CrossRef]
213. Kraśniewska, K.; Gniewosz, M. Substances with Antibacterial Activity in Edible Films—A Review. *Pol. J. Food Nutr. Sci.* **2012**, *62*, 199–206. [CrossRef]
214. Oberoi, K.; Tolun, A.; Sharma, K.; Sharma, S. Microencapsulation: An overview for the survival of probiotic bacteria. *J. Microbiol. Biotechnol. Food Sci.* **2019**, *9*, 280–287. [CrossRef]
215. Guimarães, A.; Abrunhosa, L.; Pastrana, L.M.; Cerqueira, M.A. Edible Films and Coatings as Carriers of Living Microorganisms: A New Strategy Towards Biopreservation and Healthier Foods. *Compr. Rev. Food Sci. Food Saf.* **2018**, *17*, 594–614. [CrossRef]

216. Adetunji, C.O.; Williams, J.; Olayemi, F.; Omojowo, F.S. Microbiological evaluation of an edible antimicrobial coatings on mangoes fruit stored under ev aporative coolant system (ecs). *Asian J. Agric. Biol.* **2014**, *2*, 20–27.
217. Peralta-Ruiz, Y.; Tovar, C.D.G.; Sinning-Mangonez, A.; Coronell, E.A.; Marino, M.F.; Chaves-Lopez, C. Reduction of Postharvest Quality Loss and Microbiological Decay of Tomato "Chonto" (*Solanum lycopersicum* L.) Using Chitosan-E Essential Oil-Based Edible Coatings under Low-Temperature Storage. *Polymers* **2020**, *12*, 1822. [CrossRef]

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