Application of Edible and Biodegradable Starch-Based Films in Food Packaging: A Systematic Review and Meta-Analysis

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Abstract

Background and Objective: In recent years, natural polymers such as starch have been widely considered as alternatives to plastics derived from petroleum derivatives in the production of packaging films. Currently, modified starches with new functional features are available that can be used in the production of the above mentioned films. The aim at this study is a systematic review and meta-analysis of application of edible and biodegradable starch-based films in food packaging.

Methods: At first all of the studies related to our title by using some keywords (edible and biodegradable starch-based films and food packaging) searched for English databases; Google, Google scholar, PubMed, Embase, CINAHL, PsycInfo, SCOPUS and ISI web of Science during the 2010 to 2018 was run consisting a predefined inclusion and exclusion factors. Inclusion and exclusion criteria were: papers related to edible and biodegradable starch-based films and food packaging, papers were English, types of papers were original and all the papers were free full text. As a result, related to inclusion and exclusion criteria papers were found and analyses. Data were collected based on study characteristics, edible and biodegradable starch-based films, food packaging.

Results: In the initial search, 589 articles were found that after reviewing the titles and abstract articles and removing repetitive and non-related, 33 possible related articles were examined. Of these, 24 articles were omitted from the abstract because of lack of access to the original article and lack of sufficient information. Finally, 13 papers were included in the study. Due to novel research on the application of bio-degradable biofilms...
Introduction
Today adequate and adequate food supplies have become one of the most important concerns of the authorities and community elites, in order to overcome many efforts in various areas, such as increasing production, increasing the amount of time consuming, improving Storage and storage practices, and developing methods for protecting them against destructive factors such as fungi and bacteria. The process of packing is important for keeping foods from fungi and bacteria and, finally, for long-term storage. In addition to other modern technologies that work in the food packaging industry, nanotechnology has become one of the most commonly used technologies in various fields.

Recently, biodegradable food films have vital importance in food study, according to their reception to the condition and their use in the food packaging industry. Different needs in the food packaging industry for bio-films have led to the diverse sources of starch being studied, because each source has its own specific characteristics. The properties of films obtained from starch indicated the rigidity and reduced flexibility of the films. To prevent this and the corresponding effects on the film, other polymers can be used as additive compounds.

Conclusion: Extending the use of starch structure techniques and the use of this material in combination with other materials to reduce the inherent weaknesses of this natural polymer has led to its further development in various industries, especially packaged industries. Starch is a proper substitute for polymers extracted from oil derivatives. In order to improve the characteristics of the produced films, a high number of compounds can be added to the matrix, and various variations can be applied during the processing. Optimizing conditions will produce transparent, non-odorous, non-flavored, and color-free films with improved mechanical, optical and deterrent features.

in the packaging industry of food, starch is one of the most promising and promising sources. Different needs in the food packaging industry for bio-films have led to the diverse sources of starch being studied, because each source has its own specific characteristics. The properties of films obtained from starch indicated the rigidity and reduced flexibility of the films. To prevent this and the corresponding effects on the film, other polymers can be used as additive compounds.

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Starch-based films have the appropriate physical features, so these films are odorless, taste-free, colorless and impervious to oxygen. So, there is a different limitation on the application of these films, for example, tense hydrophilic features (water sensitivity) and poor mechanical features than to customary synthetic polymers. Starch is not an innate thermoplastic, so in the existence of the softeners at above temperature and below the shear power, it can melt and flow, therefore it can be throw in extruded thermoplastic polymers. The study has revealed that starch has a proper film-making
impact; the starch source plays a vital role in film features according to the various ratio of amylose to amylopectin and the structural features of these macromolecules.9 The study is searching for different to starchy sources which have good physical, chemical and functional features.10 Ghanbarzadeh et al., (2011) has shown various samples for use of this packaging substance for various foods and so has elaborated the various types of antimicrobial factor which may be incorporated in their formulations. Most agents are consisted of designing the antimicrobial packaging system. Most agents are nearly associated with the chemical features of antimicrobial factors, the innate of the substance and target microorganisms which all will be examined in this research.11

Basiak et al., (2018) in a study found that the transfer properties of starch films containing 33% of plasticizer were less effective than film comprised of 50% glycerol. Water diffusivity, oxygen permeability, and water vapor permeability at different humidity gradients, surface tension, works of surface adhesion and cohesion, and moisture sorption were tested. Glycerol content does not play a significant role on the color or mechanical properties. This work shows that glycerol can strongly affect the functional properties of starch-based coatings and films.12

Parreidt et al., (2018) reviews the most recent essential information about alginate-based edible coatings. The categorization of alginate-based coatings/film in food packaging concept is formed gradually with the explanation of the most important titles. Emphasis will be placed on active ingredients incorporated into alginate-based formulations, edible coating/film application methods, research and development studies of coated food products and mass transfer and barrier characteristics of the alginate-based coatings/films. The summarized information presented in this article will enable researchers to thoroughly understand the fundamentals of the coating process and to develop alginate-based edible films and coatings more readily.13

Materials and Methods
In this study, a systematic review and meta-analysis of all researches conducted on determining the most important application of edible and biodegradable starch-based films in food packaging according to previous studies till 2018 was used. The method of presentation of data in this work, including the determination of the problem under study, data collection, analysis and interpretation of findings based on the systematic study reporting system i.e. PRISMA was done. The above-mentioned protocol as a criterion for searching the articles was used. There was a time limit for conducting electronic searches (2010-2018). To access the information requested from the studies related to our title by using some keywords (edible starch-based films, biodegradable starch-based films, and food packaging) searched for English databases; Google, Google Scholar, PubMed, Embase, CINAHL, PsycInfo, and Cochrane Database of Systematic Reviews. Inclusion and exclusion criteria were: papers related to edible and biodegradable starch-based films or food packaging, papers were English, types of papers were original and all the papers were free full text. In order to maximize the search comprehensiveness, the list of sources for all articles related to the subject was handled in a handy manner to find other possible sources. The main inclusion criterion of articles into this structured review was papers published in English that examined the application of edible and biodegradable starch-based films in food packaging. If there were multiple reports from a study, the most complete one would be chosen. In cases where the full text of the article was not available, the information in the abstract was used, and if the abstract of the article did not provide enough information, that article was excluded from the study. To select studies and extract data, the titles of all articles obtained by two of the contributors to the study and repetitive cases were first removed, then the title and abstract of the remaining articles were carefully studied and articles with no criteria for entering this structured review were deleted. Finally, the full text of the probably related articles was examined; eligible articles were selected and removed from the non-relevant items. As a result, related to inclusion and exclusion criteria 13 papers were found and analyses. Data were collected based on study characteristics, measures of edible and biodegradable starch-based films, and factors associated with food packaging. The PRISMA guidelines were followed in performing this systematic review.
To avoid subversion, extraction, and evaluation of the quality of articles was done by two independent researchers. If the articles were not submitted, the reasons for refusing it were mentioned. In cases where there was a controversy between the two researchers, the review was done by a third person. In the next step, the information about the selected articles includes the name of the first author, the year and place of the study, the year of the publication, the sample size, general characteristics of the samples, edible and biodegradable starch-based films, and the reported results in the study. The form has been pre-registered. For quantitative and qualitative evaluation of articles, a systematic review of the choice bias (random sequence generation and allocation concealment) implementation (blindness of participants and evaluators), diagnosis (statistical analysis blindness), sample loss out of the study after randomization, and reporting (selective outcomes report). For this purpose, the risk of bias tool of the Cochrane collaboration group was used.

![Flowchart](image_url)

**Fig. 1: The selection process of studies included in this study**

We excluded studies according to inclusion criteria such as papers related to edible starch-based films, biodegradable starch-based films, and food packaging, papers were English, types of papers were original and all the papers were free full text that the information depicts on the Fig. 1.

**Table 1: A summary of papers performed on the application of edible and biodegradable starch-based films in food packaging**

<table>
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<th>No</th>
<th>Authors</th>
<th>Objectives</th>
<th>Materials and Methods:</th>
<th>Results</th>
<th>Conclusion</th>
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<td>1</td>
<td>Molaee Aghae et al., (2015)</td>
<td>Surveying the impact of packaging with chitosan film containing garlic basic oil on the chemical chicken filet amid capacity at refrigeration temperature.</td>
<td>Diverse levels of garlic basic oil (0, 0.5, 1 and 2%) were utilized in chitosan film arrangement. Chemical examination carried out in days 0, 2, 4, 7, 10, and 14 on chicken filets</td>
<td>Tests secured with distinctive films appeared lower values for pH, add up to unstable nitrogen (TVN), Thiobarbituric acid-reactive substances (TBArs), and peroxide list (P.V) compared with controls amid the think about (p ≤ 0.05). By and</td>
<td>Chicken packaging with chitosan film particularly by particularly including different levels of garlic basic oil seem had a preventive impact on major chemical deterioration components. Considering the generally comparative preventive impact of 1 and 2 % basic oil levels conjointly financial angles, ideal dosage</td>
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secured with distinctive films and put away at 4 °C. Factual investigation was carried out utilizing SPSS program.

2 Ghasemlou By including antimicrobial-antioxidants compounds, the plausibility of avoidance of pathogenic microorganisms will be given. Composite eatable films based on corn starch distinctive concentrations of Zataria multiflora Boiss and Mentha pulegium (1,2,3%) were arranged by emulsification with the point of progressing obstruction and microbial properties. Data were examined utilizing the SAS for Windows program. The mechanical features were impacted by using essential oils as tensile strength decreased and elongation enhanced mainly. SEM observation accepted the existence of essential oil in both the internal and surface parts of the films that elaborated food-technology uses reducing water barrier features of films covering lipidic compounds. Discoveries appear that fundamental oil can have critical part in use of this film for nourishment innovation. In this manner, basic oil might be consolidated into these films for a few food-technology uses which require a moo fondness toward water.

3 Soukoulis et al., (2016) The effect of the compositional, physicochemical and auxiliary properties of double starch-protein consumable films on Lactobacillus rhamnosus GG practicality and steadiness was assessed. Local rice and corn starch, as well as bovine skin gelatine, sodium caseinate and soy protein concentrate were utilized for the creation of the probiotic eatable films. Starch and protein sort both affected the auxiliary, mechanical, optical and warm properties of the films, and the method misfortune of L. rhamnosus GG amid evaporation-dehydration was altogether lower within the nearness of proteins (0.91–1.07 log CFU/g) compared to exclusively starch based frameworks (1.71 log CFU/g). In specific, a 3- to 7-fold increment within the practicality of L. rhamnosus GG was watched within the nearness of proteins, with sodium caseinate – rice starch based films advertising the foremost improved steadiness. The film’s shelf-life (as calculated utilizing the FAO/WHO (2011) premise of 6 log practical CFU/g) extended between 27-96 and 15–24 days for frameworks put away at ice chest or room temperature conditions individually.
Examine the relationship between main physical features of eatable films based on a blend of chitosan and altered starches. Films were arranged by the casting strategy utilizing chitosan (CT), waxy (WS), oxidized (OS) and acetylated (AS) corn starches and their blends. The CT-starch films appeared progressed boundary and mechanical properties as compared with those made from person components, CT-OS film displayed the least thickness (74 ± 7 µm), water substance (11.53% ± 0.85%, w/w), dissolvability (26.77% ± 1.40%, w/v) and water vapor penetrability ((1.18 ± 0.48) × 10−9 g•s−1•m−1•Pa−1). This film appeared moo hardness (2.30 ± 0.19 MPa), moo surface harshness (Rq = 3.20 ± 0.41 nm) and was the foremost versatile (Young's modulus = 0.11 ± 0.06 GPa).

Create a bioindicator eatable films (BEF) from tapioca starch (TS), agar, and ruddy cabbage juice (RC), and to assess its execution on wiener weakening discovery. The explore had a 3x3 randomized factorial experimental plan (agar: 3, 5, 7% by weight of TS; RC: 10, 15, 20% v/v based on 100% of suspension). Glycerol was utilized as the plasticizer. The comes about appeared that the expansion of agar into the film solution expanded the thickness, stretching, and ductile quality, and diminished water vapor transmission rate (WVTR). Whereas the expansion of RC expanded the thickness, but diminished stretching, pliable quality, and WVTR. BEF comprising of 2% custard starch, 7% (w/w) agar and 10% (v/v)

It was shown that the sort of starch adjustment affected intelligent with chitosan, driving to diverse films features.
<table>
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<th>Page</th>
<th>Author(s) and Year</th>
<th>Method/Results</th>
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<tr>
<td>6</td>
<td>Brandelero et al., 2016</td>
<td>RC was chosen to apply on frankfurter. Multivariate investigation appeared that the lettuce misplaced quality after 2 days of capacity in PVC films, speaking to a diverse result from the other medicines. Lettuce put away in biodegradable-le movies for 2 and 4 days appeared a more noteworthy likeness with recently collected lettuce.</td>
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<td>7</td>
<td>Javanmard, 2010</td>
<td>The films with or without the adding of essential oil revealed same features. Bio-degradable films were created viable for the saved of minimally processed lettuce.</td>
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Gomes et al., (2016) developed and characterized edible films based on the starch phosphates of the seeds of S. burchelli, with the specific aim to apply these starches to cherry tomatoes for post-harvest conservation. The films were measured for thickness, permeability to water vapor and solubility in water. The concentrations of cherry tomatoes with and without coverage were studied over 8 evaluation times (up to 21 days) at 10±2 °C and 80±5% relative humidity. The edible films presented with an acceptable appearance and without the development of cracks. The concentration of glycerol and the type of starch influenced the characteristics of the films, increasing the permeability and reducing the water solubility of the various edible films. The best result obtained regarding the conservation of cherry tomatoes was observed for fruits with edible coatings of greater permeability to water vapor; such fruits exhibited only a slight decline in firmness during storage compared with the control.

Tabari Biodegradable Sago starch films were arranged and plasticized with sorbitol/glycerol by the casting strategy. Nano Carboxymethyl Cellulose with 0%, 1%, 2%, 3%, 4% and 5% (w/w) was included to the films some time recently casting them. The impacts of the expansion of nanoparticles were measured on mechanical features, water retention capacity, thickness and warm sealability. In mechanical test of the combined films, by expanding of CMC nanoparticles concentration altogether (P<0.05) expanded malleable quality and Youthful Modulus and prolongation parameter appeared noteworthy (P<0.05) diminishment from 17.69 to 15.39. The seal quality for the sago film was expanded by consolidating a moo rate of nano Carboxymethyl Cellulose nanoparticles expanded can found a position among packaging materials.
-noparticles.

**10 Adjouman et al., (2017)**

Investigations the impact of glycerol, shelled nut oil and soybean lecithin on the water vapor porosity (WVP) of eatable films based on moved forward cassava (Manihot esculenta Crantz) local starches from Côte d'Ivoire. The films were arranged utilizing 4 g cassava starch, 25% and 30% glycerol (w/w), 5% and 10% shelled nut oil (w/w) and 0% to 5% soybean lecithin (w/w oil) in Petri dishes. The WVP of the films was decided at 25°C and 75% relative mugginess. The dampness substance of the films was decided in an stove at 105°C and the film thickness was decided physically employing a micrometer.

Cellulose and upgraded the physicochemical properties and warm sealability of sago films. The coming about films was homoge- nous, straight forward and crack-free. WVP, dampness substance and thick-ness of the films expanded with expan-ding glycerol concentra- tion. The combina- tion of glycerol and shelled nut oil expanded the WVP of the films, while expansion of soybean lecithin had no impact. The least WVP values were gotten utilizing 25% glycerol, 5% shelled nut oil and 5% soybean lecithin.

**11 Rejak et al., (2014)**

Assessing Permeability Tests findings Lower permeability of water vapor take place in starch film with 20% of glycerol and 4% of poly (vinyl) alcohol processed at 80 rpm.

Permeability examinations were carried out for different material of raw substitute and processed at various screw speeds during film blowing.

Tests findings revealed that water vapor permeability amount extended from 2, 63.10-9 to 0, 65.10-9 g/ (m∙s∙Pa) rely on recipe of granulate and processing situation.

**12 Xiaoyong et al., (2018)**

Consumable Lemon fundamental Findings appeared The iron yam/maize starch helpful nourishment films with great physical and antibacterial properties can be considered as helpful nourishment flavoring packaging materials.

Lemon fundamental oil was utilized as plasticizers to get ready iron yam/maize starch consumable films. Changes of physical, microcosmic and antimicrobial features of films were examined.

Findings appeared that the expansion of lemon fundamental oil driven to diminish of dampness substance, straightforwardness, whiteness record, water vapor porousness, vapor porousness, solvency and malleable quality and the increment of b*, stretching and cloudiness values. With the increment of lemon...
Doles et al., (2014) created a starch-based film bundling fabric with antimicrobial movement. The foundation for the film is made of starch determined from custard. As a plasticizer we joined glycerol. The antimicrobial action was accomplished by including restorative plant extricates. The extricates of common restorative plants such as neem, betel leaves, guava leaves, rhizomes of lotus and turmeric, and blooms of hibiscus were utilized. The extricates were arranged utilizing ethanol extraction strategy. The viability of extricates were tried by utilizing agar dissemination strategy. Five diverse bacterial strains such as E. coli, Pseudomonas, S. aureus, B. cereus and Klebsiella were utilized for the ponder. Least inhibitory concentration and least bactericidal concentration values of extricates were too found out. We moreover conducted show nourishment considers for the film utilizing crude carrot and chicken.

Findings
In the initial search, 589 articles were found that after reviewing the titles and abstracts articles and removing repetitive and non-related, 33 possible related articles were examined. Of these, 24 articles were omitted from the abstract because of lack of access to the original article and lack of sufficient information. Finally, 13 papers were included in the study (Figure 1).

Edible and Biodegradable Films
These packages in the food industry can control or prevent the occurrence of reactions occurring within the package. Biodegradable packaging according to edible films has more importance due to the innate ingredients, the application of reincarnated and the deficiency of environmental pollution of the day to day. In this regard, the ability of such films as cover of antimicrobial and antioxidant factors and other active factors to increase quality, enhance the shelf-life, monitor of pathogens and increase the organoleptic features of the materials have different use for them in the food packaging industry.27

Application of Edible Films
Including applications of edible films, delaying the moisture content of food and the environment, controlling the amount of food breathing by reducing the amount of oxygen absorbed and selective blocking of CO₂ and vapor, reducing the migration of fats, maintaining the structure of food, including food additives, preventing the migration of aroma and flavoring and colored food products to the environment and between heterogeneous food components, preventing microbial corruption during long-term storage, increasing the nutritional value of the product, protecting the product against mechanical and physical damage, reducing the amount of packaging material and the complexity of packaging.28
**Discussion**

Food packaging is one of the important things that are done by different materials. Plastics over the last two decades, with annual growth of 5%, are the second most widely used materials for packaging food, paper, and paperboard. Oil-based plastic materials such as polyethylene, polypropylene, polyyamide, despite the environmental problems, are used extensively for packaging due to its flexibility, transparency, and stability. However, despite good properties, their use and accumulation cause serious problems. Starch is a good alternative to petroleum-derived polymers due to its easy availability, food contact, low cost, and digestibility. However, the use of starch in packaging also has problems. For example, highly water-starch and its film properties are heavily dependent on moisture content and also have relatively poor mechanical properties. Its films are very fragile and resistant to oxygen permeation. In a study, the combination of PLA and starch with appropriate properties with suitable packaging properties was obtained and the results showed that different proportions of PLA-starch, (20-80 or 30-70) with epoxy soybean oil or malic a hydric, mechanical resistance, provides a very good prevention of water vapor and gases as well as good flexibility. Khan et al., used thermoplastic material due to their intermolecular forces and hydrogen bonding starches, called thermoplastic starches (TPS), which increases the flexibility of starch, causing the stability of starch is below its degradation temperature. TPS is a very promising product for biodegradable plastics than biodegradable plastics. Corn starch was applied as a polymer matrix for the increment of antimicrobial packaging applying the way of casting and applies of Pittides Nisin or Pediocin to preserve food. Halloysite nanoparticles were selected to enhance the film. The results showed that the adding of Nisin and Piodosine peptides in starch films to the creation of active packaging substances with antimicrobial activity against L. Monocytogenes and C. Perforation. Biodegradable starch/clay nanocomposite films were also used to pack foods. Montmorillonite nanomaterials (homogeneously distributed in various starch-based substances) were obtained by polymer melt processing methods. The structural and mechanical features of nanocomposite films were examined and the findings of the clay particle increase impact on the modulus and the starch strength revealed starch. Starch and starch derivatives, Polyhydroxylbutyrate (polylactic glycolide), have high properties that are compatible with antimicrobial agents for packaging. PHB, starch, and PLGA have unique properties in the fields of food, cosmetics, pharmaceuticals as well as various composites. Starchy films were mixed with chitosan and potassium sorbate compounds and active films used to inhibit E. coli growth and S. Aureus, as well as the deterrence properties of the films. An environmentally friendly biodegradable nanocomposite was made using potato starch and pineapple leaves. Due to the fiber structure and the dispersion of nanofibers on the starch field, the properties of nanocomposites increase after reinforcement to 3% by weight of cellulosic nanofibers, but in loading more filler, these properties are likely to decrease due to the density of nanofiber. The permeability of water vapor, water absorption and absorption of moisture nanocomposites were investigated and it was found that the inhibitory properties increased significantly. The good dispersion and good adhesion of nanofibers to starch is the same structure of polysaccharides in both phases. Jang et al., (2017) prepared silver and starch nanoparticles for one-stage coating using ultrasound and a mixture of starch, silver nitrate and distilled water, which used starch as an environmentally friendly and inexpensive agent. Ultraviolet-neomorphic and transient electron microscopy showed that the single-phase process was effective for the synthesis of starch-coated coatings with silver nanoparticles. Jang et al., (2018) used synthetic zirconium and silver nanoparticles and starch (chitosan: starch-silver nanoparticle) for antimicrobial coating applications. Besides, the effects of different ratios of chitosan and silver nanoparticles and starches were studied on different study features such as mechanical features, water and oil opposition, and antimicrobial function. The findings revealed which the study covering features rely severely on the compound of these three substances, and then covering with a ratio of 1 to 9 shown good mechanical features and excellent resistance features to water and oil.

**Conclusion**

Contaminants from petroleum-based polymer materials have focused on the production of biodegradable polymers. The global trend of
research and industry development is towards the
use of biomass and renewable and environmentally
friendly materials. Starch is one of the most abundant
and cheapest substitutes for petroleum products
and is now considered by researchers. Extending
the use of starch structure techniques and the use
of this material in combination with other materials
to reduce the inherent weaknesses of this natural
polymer has led to its further development in
various industries, specially packaged industries.
It is expected that in Iran, taking advantage of
global experience, the production and use of starch
will be developed as an important raw material in
various industrial sectors. Due to novel research
on the application of bio-degradable biofilms in the
packaging industry of food, starch is one of the most
promising and promising sources. Different needs
in the food packaging industry for bio-films have
led to the diverse sources of starch being studied
because each source has its specific characteristics.
While various starch components themselves
are effective on the characteristics of the film,
they produce different behavioral characteristics.
To adapt the starch to create an interesting film,
it can be revised by applying different substances.
It creates films with interesting features, is free from
improper chemicals during the film. Another new
approach to improving the mechanical features and
starch permeability is the application of different
polymers with starch in film process that has the
main impact on the improvement of the features of
starch-based films; it may also have other features,
such as antimicrobial features. The many novel
studies on starch composite films are the use of
bio-nano-composites that can have a good impact
on the features of these films.

Acknowledgement
The authors would like to thank all of the people and
persons for helping this study.

Funding
Given that our country is developing, the authors do
not have the financial means to pay for it, and it is
apparent that this article will be published for free.

Conflict of Interest
The authors declared that there is no conflict of
interest.

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