Arabian Journal of Chemistry (2021) 14, 103049

King Saud University

Arabian Journal of Chemistry

www.ksu.edu.sa
www.sciencedirect.com

REVIEW ARTICLE

A comprehensive review on the research progress of vegetable edible films

Gaohua Jiang [a,b,c], Zhuoxi Zhang [c,*], Feng Li [c], Xiaoqing Rui [c], Haji Akber Aisa [a,*]

[a] Key Laboratory of Plant Resources and Chemistry of Arid Zone, Xinjiang Technical Institute of Physics and Chemistry, Chinese Academy of Sciences, Urumqi 830011, China
[b] University of Chinese Academy of Sciences, Beijing 100190, China
[c] College of Resources and Environmental Engineering, Yunnan Vocational Institute of Energy Technology, Qujing 655001, China

Received 9 December 2020; accepted 28 January 2021
Available online 3 February 2021

KEYWORDS

Vegetable films;
Color care;
Thickener;
Molding technology

Abstract The processing of vegetable paper started in Japan, and there have been many researches on vegetable paper processing technology at home and abroad. In the research process of vegetable paper, how to choose suitable raw materials, thickeners and other additives is very important. The type and proportion of additives determine whether vegetable paper can be better shaped and possess more perfect performance. This review expounds the status of research on vegetable edible films, and the development of technology, including color care, thickener, molding technology and performance research.

Contents

* Corresponding authors.
E-mail address: 13278750367@163.com (Z. Zhang).
Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

https://doi.org/10.1016/j.arabjc.2021.103049
1878-5352

1. Introduction

In recent years, a kind of convenient food has quite become popular in the international market, called ‘‘vegetable paper” (or paper dishes), and some people call it ‘‘edible paper” (or edible film), or ‘‘paper-shaped food” (Liu, 2010). The vegetable paper is a kind of paper-like food obtained by processing vegetables into a paste, adding an additive, and drying. It not only retains the green and nutrient components of vegetables, but also has the characteristics of low sugar, low sodium, low fat, ready-to-eat crisp and delicious, unique flavor, and easy to transport and store (Min and Song, 2009). Nutritionists suggest that the consumption of vegetables should reach 22.44% of food consumption (Han and Quan, 2014). Fruits and vegetables are rich in nutrients such as vitamins, minerals, organic acids, and dietary fiber, which are indispensable foods in the human diet (Wang et al., 2010a,b). However, vegetables have high water content and are difficult to transport over long distances. It is difficult to supply vegetables in areas such as travel, navigation, border defense, high cold, and field operations. At the same time, the vegetable production of China accounts for about 49% of the world's total production, and most of them are sold fresh. The deep-processed products are account for about 10% of the total amount of vegetables in the country. Every year, about 30% to 35% of fresh vegetables rot due to failure to sell, circulate and process in time (Lv et al., 2008; Pu et al., 2006). It can be seen from research at home and abroad that edible films and coatings are one of the emerging strategies for food quality optimization (Tahir et al., 2019).

2. Research status

Vegetable paper was first developed in Japan. The Sakai Institute of Physics and Chemistry in Japan extracts protein and lipids from bean dregs to make pure dietary fiber, and then process bean dregs into edible paper. The maximum daily output per production line can reach 30,000 sheets per year (Min and Song, 2009). China began to carry out research on the preparation and processing technology of vegetable paper in the late 1990 s, but at the beginning, it has been in the stage of trial research. In 2002, Jiangsu Tianlu Food Co. Ltd. successfully developed instant cartoon vegetable paper (Hu et al., 2017). There are two types of edible paper abroad. One type uses vegetables as the main raw material, which is pulped and dried after shaping; the other type is to refine starch and sugars, and then add food additives, which are shaped in a similar way to papermaking. From the perspective of application and development potential, green products using vegetables as raw materials have more development potential (An, 2010). The different types of fruit and vegetable paper are determined from the different raw materials. At present, the vegetable paper developed at home and abroad has a single vegetable as the raw material, and there is also a composite vegetable paper made of a mixture of multiple vegetables. But in general, most research is still at the laboratory stage.

3. Process progress of vegetable edible films

3.1. The technology of color-care

In the development process of vegetable edible paper, it is necessary to protect the color and retain its original color. In different studies, the color protection process is different.

The Chinese cabbages were used as raw material to develop vegetable paper. During the color-care process, small pieces of cabbages were blanched in boiling water with 0.3% of $NaHCO_3$ for about 2 min, then quickly were take out and placed in cold water for 3 min, and then were removed away after cooling. In this process, most microorganisms were killed on the surface, activity of polyphenol oxidase was reduced, the browning of chlorophyll was slowed down, and at the same time the air in the vegetable tissues was eliminated, the presence of oxygen was reduced, and make chlorophyll generate stable sodium salt under alkaline conditions, so as to play a role in color protection (Wang et al., 2010a,b). *Sonchus oleraceus* were maded as raw material to develop vegetable edible paper, 1 g/L of Na_2CO_3 and 0.1 g/L of $Zn(CH_3COO)_2$ were added to protect the color, and were blanched 4 min (Qi et al., 2012). In this study, the addition of $Zn(CH_3COO)_2$ and Na_2CO_3 was used as a variable to study its effect on chlorophyll. The experiment found that the amount of Zn $(CH_3COO)_2$ had the greatest impact on the preservation of chlorophyll.

Typha Latifolia were carried out the color to make edible paper, raw material was prepared by mixing water at a ratio of 1:2 (g/mL), then were blanched 1 min, 0.15% of Na_2SO_3 was added to protect color (Wan and Zhang, 2012). To select the best technology of color-care, different color retention agents were evaluate through experiments. Due to Na_2SO_3 had the best color protection effect and didn't change the color of vegetable, finaly reseachers select Na_2SO_3 to protect color. The cucumbers were made as raw material to develop vegetable edible paper. The cucumber paper base materials were peeled without blanching process. After then the cucumber paper had good taste and smoothness, and bright color (Zhuoma, 2014). Starting from the raw material itself, researcher considered that the edible part of cucumber was mainly fruit pulp, there for the cucumber was not blanched in the process of producing cucumber paper.

3.2. Thickener

In many foreign studies, polysaccharides had been used as biopolymer materials, such as gum, starch, alginate, carrageenan and xanthan gum, etc., which can form coatings and edible films to reduce traditional Plastic packaging (Mohamed and Mohamed, 2020).

0.7% of CMC-Na, 5% of sodium alginate, 5% of soluble starch were mixed as the thickener in the preparation of chrysanthemum leaves vegetable paper (Huang et al., 2008). Carrots were made as raw materials to develop five-scented and sweet carrot paper, and determined the best thickener formula as 0.2% of agar, 0.3% of CMC, 0.2% of sodium alginate, and 2% of glycerol (volume ratio). 0.255 g/100 g of salt, 0.12 g/100 g of five-scented powder, 0.026 g/100 g of MSG were mixed to make five-scented carrot paper, and 4 g/100 g of sugar for sweet carrot paper (Lv, 2009). The study considered the fiber properties of the carrot itself and the different tastes of the finished product, a strict sensory evaluation of the addition amount of agar, CMC, sodium alginate and glycerol was carried out. It was the first time that a scientific research had been carried out on the flavoring formula of leisure carrot paper.

The optimal addition ratio was determined as 1.2% of sodium alginate, 3.0% of corn modified starch, 0.4% of gelatin, 0.4% of CMC and 2% of glycerin, in order to optimize the technology of cabbage paper (Sun et al., 2010). The best amount of compound thickener was determined as 0.5% of CMC-Na, 0.3% of sodium alginate, 0.8% of agar, 3% of soluble starch through the research of a single thickener, which can make the product flat and easy to peel, and stick to teeth hardly when chewing. At the same time, they discoveryed that add to 0.6% of CMC-Na, 0.4% of sodium alginate, 0.6% of agar, 3% of soluble starch could make vegetable paper have the best tensile strength (Wang et al., 2010a,b). On the basis of the dosage of a single thickener, an orthogonal experiment was carried out on the proportion of the composite thickener in the article, and the most suitable dosage of thickener was finally determined.

Cabbage and wax gourd were made as raw materials to optimize the amount of single thickener and compound thickener, and finally the amount of single thickener and the best ratio of compound thickener for cabbage and wax gourd were determined respectively. The thickener addition of cabbage paper was 0.30% at the 1:2:4 ratio of CMC, sodium alginate and gelatin. The thickener addition of wax gourd paper was 0.27% at the 1:2:2 ratio of CMC, sodium alginate and gelatin (Huang, 2010). Instead of adding glycerin directly to the slurry, the paper was impregnated with glycerin in the article. Experiments showed that as the amount of glycerin added increases, the tensile strength gradually decreases, the elongation gradually increases. Finally, the appropriate addition of glycerin was determined as 2%-4%. According to the results of pre-tests, the impregnation of wax gourd paper with higher concentration of glycerin would make the paper more hygroscopic and easy to regain moisture. Therefore, 1% glycerin impregnation was necessary.

0.5% of sodium alginate solution (relative to the amount of absolute dry pulp) were prepared to make paper sheets by paper sheet former (Liu et al., 2011). In the article, experimenters added sodium alginate and polyaluminum chloride as thickeners to the slurry, and finally selected sodium alginate as the single thickener. Wild fern bracken were made as raw material to develop edible vegetable paper, 0.3% of xanthan gum, 0.3% of carrageenan and 2% of glycerin were mixed as thickeners (Huang et al., 2011). In the study, there was no research about the dosage of a single thickener, the compound of thickener was directly added to the slurry. *Typha Latifolia* were made as raw material in research, through orthogonal experimented on the basis of single factor experiments. 0.2% of CMC-Na, 0.8% ofsodium alginate, 3.0% of glycerol were mixed as thickener, and 2.5% of sucrose, 0.2% of salt, 1.2% of monosodium glutamate, 0.2% of five-spice powder were mixed to improve taste (Wan, 2012). In the study, researchers selected white sugar, table salt, monosodium glutamate, five-spice powder as the basic flavor formula for single-factor experiment, determined the four-factor three-level orthogonal test to obtain the best flavor formula.

The water extraction of shiitake mushrooms were made as raw materials to develop edible films, 1.5% of salt, 3% of corn starch, 0.5% of CMC-Na, and 0.5% of gelatin were mixed to shiitake mushroom vegetable paper (Huang et al., 2012). Considering the unique flavor of shiitake mushrooms, experimenters added an appropriate amount of salt. These salt can not only reconcile the taste of the original and auxiliary materials, highlight the flavor of shiitake mushrooms, but also improve the taste of the product. Cabbage and jujube were used as raw materials to develop vegetable paper, CMC, agar, and sodium alginate were mixed in cabbage wrapper compound thickener at a ratio of 5:5:6. Starch, isolated soy protein, and sodium alginate were mixed in jujube wrapper compound thickener a ratio of 5:4:4 (Zhao, 2012). In the study, researchers consider the unique physical properties of raw materials. Different additives were mixed at specific ratio to reduce the amount of thickener so that the taste of jujube paper could be retained.

Sargassum were used as raw materials to develop healthcare jelly and composite vegetable paper. *Sargassum* and carrot pulp were prepared by mixing water at a 2:3 ratio, 1.5% of isolated soy protein and 2%-4% of soluble starch were added. The compound thickener was mixed as 0.07% of CMC-Na, 0.05% of konjac gum, 0.125% of gelatin, 0.160% of sodium alginate at the ratio of 3:2:5:6 (Zhu, 2012). Cabbage, celery, and kelp were used as raw materials to develop edible films. Using sensory quality as an indicator, the most suitable forming agent ingredients and their mass fractions were determined as 6.0% ~8.0% of soluble starch, 0.5% isolated soy protein, 1.5% ~2.0% glycerol. This time the model of vegetable paper were formed completely, had crisp taste and better flavor. Through the orthogonal test of thickener screening, it was concluded that 1.4% of CMC-Na, 0.2% of alginic acid sodium, 0.2% of gelatin were suitable (Zhao and Shi, 2013). The experimenter used three different vegetable raw materials, according to the characteristics of different vegetables, and adjusted the ratio of thickeners to harmonize the properties of the final product.

Leeks were made as raw material to developed vegetable paper. 0.4% of CMC-Na, 0.6% of sodium alginate, 0.4% of carrageenan were mixed at a ratio of 2:4:1, and 4% of glycerol was added simultaneously (Sun et al., 2013). Leftovers from the processing of head lettuce were used to develop edible lettuce paper . 0.4% of CMC-Na, 0.4% of sodium alginate, 3% of soluble starch and 0.5% of xanthan gum were determined as the significant additives of vegetable paper (Wang et al., 2013). Selenium-enriched cabbage and spinach were used as raw materials, 0.3% of CMC-Na, 0.4% of sodium alginate, 0.6% of gelatin and 0.6% of pectin were added to develop vegetable paper (Wu et al., 2013). The essential oils of Syzygium aromaum and Origanum vulgare were added to the edible film to act as a plasticizer, as well as were provided with antimicrobial activity against yeasts and molds in sliced bread (Otoni et al., 2014). In this study, experimenters did not directly use plant slurry as raw material as in the previous operation, but used a mixture of two essential oils to produce an edible film with antibacterial activity.

Tomatoes, celery leaves, carrots and apples were used as raw materials to develop fruit and vegetable paper, and determined the ratio of thickeners required by different raw materials. 0.05% of CMC-Na, 0.25% of sodium alginate and 0.15% of xanthan gum were mixed as the best ratio of tomato Paper, 0.05% of CMC-Na, 0.15% of sodium alginate and 0.15% of xanthan gum were mixed as the best ratio of Celery paper, 0.05% of CMC-Na, 0.15% of sodium alginate and 0.05% of xanthan gum were mixed as the best ratio of Carrot paper, 0.05% of CMC-Na, 0.15% of sodium alginate and 0.05% of xanthan gum were mixed as the best ratio of Apple paper (Nie et al., 2015). According to the cellulose content of different raw materials, experimenters chose different thickener ratios for different raw materials, so that the fruit and vegetable paper had the best film-forming effect. Broccoli and sweet corn were made as raw materials to develop vegetable paper, broccoli pulp and sweet corn syrup were mixed at a ratio of 2:1, 0.5% of sodium alginate, 0.6% of carrageenan and 8% of starch were added (Tang and Shang, 2015). Fresh purple cabbages (100 g) were made as raw materials to develop vegetable paper. 0.4 g of CMC-Na, 0.4 g of sodium alginate, and 0.5 g of xanthan gum were added. 2.4 g of sucrose, 0.6 g of salt, 0.10 g of monosodium glutamate, and 0.25 g of five-spice powder were added to improve the taste (Li et al., 2016).

Cabbages and konjac were made as raw materialsto develop composite vegetable paper, 12.5% of sweet potato starch was added as thickener, at the same time xanthan gum and CMC-Na were mixed at a ratio of 3.5:1 (Sui and Wei, 2017). Carrots and spinach were made as raw materials to develop composite vegetable paper, carrot pulp was prepared by mixing carrot and water at a 2:1 ratio, spinach pulp was prepared by mixing spinach and water at a 4:1 ratio. Carrot pulp and spinach pulp were mixed to make paper at a ratio of 4:3. And added 0.6% of Sodium alginate, 0.5% of gelatin, 6.0% of starch were added to attain the best effect (Qin et al., 2018). In the study, researchers used two different vegetable to make edible paper. Unlike single vegetable, composite vegetable paper had extremely high requirements for raw materials. The main components of carrots and spinach were dietary fiber and vitamins. The ratio of carrot-spinach slurry had a greater impact on the color and flavor of vegetable paper. Therefore, experimenters conducted tests and evaluations on the color and flavor of vegetable paper with five different proportions of slurry.

The folding endurance of vegetable paper were evaluated by optimizing the ratio of additives using celery as raw material. It was finally determined that when the mass fraction of the binder was 0.9%, the peak value of the folding endurance of celery paper was 6 times, and when the mass fraction of the plasticizer was 6%, the peak value of the folding endurance was 10 times. When the proportion of mixed additives was 0.34% of CMC, 0.40% of gelatin and 5.9% of glycerol (mass fraction), the folding endurance of celery paper can reach 21 times (Hu et al., 2018). In the article, researchers used the response surface curves and contour lines to scientifically express the interaction law between different experimental conditions.

Bitter vegetables were used as raw materials to develop vegetable paper, 0.4% of CMC-Na, 0.6% of sodium alginate, 0.3% of gelatin and 2.0% of soluble starch were mixed as thickener (Li et al., 2019). An active edible film were prepared by incorporating epigallocatechin gallate (EGCG) into sodium alginate (SA) and carboxymethyl cellulose (CMC). Tests had proved that the SA-CMC edible film with EGCG added has better mechanical, physical and antioxidant activities than the film without EGCG. The active edible SA-CMC film added with EGCG may be a favorable alternative to traditional plastic packaging film in food preservation, especially in high-fat foods (Ruan et al., 2019). In the article, experimenters tried to add other physicochemical properties to the traditional edible SA-CMC film. While ensuring the compactness of the film, it also strengthened other properties of the film, such as antioxidation, lipid-lowering and so on.

3.3. The technology of molding

The main forming methods for making vegetable paper are roll forming and roller forming. Rolling molding is a traditional processing method, which has the characteristics of high nutrient content of vegetables in paper vegetables, smooth appearance and good sensory indicators. This method is first transplanted on the basis of laver processing. The process flow is raw material-cleaning-cutting-finishing-cooling-beating-seasoning-rolling-drying-finished product. The process of roller compaction is to form and then dry. The drying process takes a long time and loses nutrients, and it is not easy to achieve continuous mass production (Pu et al., 2006). The drum molding is formed by using drum drying technology in food drying technology for reference. The main process flow of this molding method is raw material-cleaning-cutting-cutting off-beating-seasoning-drum drying and forming-finished product. This process method is to beat the raw vegetables into slurry, and then send the slurry to the drum for coating after homogenization, so that the slurry is pressed into a sheet shape with the rotation of the drum, and the finished product is dehydrated after being dried by the drum. It can be seen that this method is synchronized with drying and molding, with high molding efficiency, good appearance quality, and short drying time, so the loss of vegetable nutrition is small (Pu et al., 2006).

In the process of developing dehydrated cabbages paper, researchers studied the pretreatment blanching conditions and sugar additives in the osmotic dehydration process to extend the sugar return period of dehydrated cabbage during storage, and determined the types and dosages of green protectants and additives (Zhang, 2005). Basing on the problems occurred in actual production, researchers found during production that dehydrated cabbage with 25% of glucose was prone to sugar return when stored at 5–10 ℃. The color of dehydrated cabbage become dim and lose its original bright color to affect product quality.

Five factors of citric acid concentration, citric acid infiltration time, citric acid infiltration temperature, baking temperature and baking time were experimented the formability in preparation process of Chinese cabbage paper (Wang, 2007). The bracken vegetable paper were dried and molded on a glass plate at 60 ℃. The moisture content of the vegetable paper obtained was 9.56% to 14.45%, which was easy to peel off from the glass plate. If bracken vegetable paper was molded on gauze, the moisture content was 7.82%-14.35% (Wan, 2012). The article showed when glass plate was used as a support carrier, it was difficult to carry out the heat circulation, and the vegetable paper must be shaved off with a blade. The paper prepared in this way had poor moldability. Therefore, glass or stainless steel was not used alone for paper forming. During the forming process of mushroom vegetable paper, researchers set the temperature to 80 ℃ high temperature drying in the initial stage, and 60 ℃ variable temperature drying in the final stage (Zhao, 2012). Celery paper were sprayed a layer of soy protein solution on the surface of celery paper to prepare a soy protein-celery composite paper (Shao, 2012). Using the rheological properties of soy protein itself, natural substances such as soy protein were substituted for commonly used chemical substances in the past to realize the heat sealing of vegetable paper and improve its mechanical properties.

Fennel, celery, and soy protein were used as raw materials and sprayed the pre-prepared soy protein liquid on the vegetable paper, heated and dried in the upper cylinder to prepare the composite vegetable paper, and controlled the heat-sealing temperature of the celery-based composite paper below 105 ℃ (Hou et al., 2013). Researchers tried to compare the three methods of oven, microwave and vacuum drying. In order to avoid nutrient loss and chlorophyll damage and discoloration of vegetable paper during the drying process, the oven drying and vacuum drying were set at 85 ℃, therefor the most suitable drying method was chosed (Bai, 2013). The water celery vegetable paper were developed by using non-stick coating baking pan as a molding carrier, and dried in a blast drying oven at 70 ℃ (Xu et al., 2013). The effects of glass plate, stainless steel plate, non-stick bakeware and 200-mesh screen on the paper forming effect were compared, which made up for the shortcomings of direct selection without comparison in many previous experiments when selecting forming equipment.

Pumpkin were used as the raw material to develop pumpkin paper, and modified the pumpkin paper pulp by ultrasonic and microwave respectively. The optimal modification conditions were finally determined as follows: process the paper 20 mins by microwave, and 20 mins by ultrasonic under microwave power 500 W (Wang, 2014). In the article, researchers did not use thickeners, but used ultrasonic/microwave to treat pumpkin pulp, which enhanced the mechanical properties and barrier properties of pumpkin paper to varying degrees, increasing the mechanical strength of pumpkin paper and preventing water. The ability to block oxygen and oil was enhanced. In the process of preparing fruit and vegetable paper, researchers tried to use two methods of electric oven and electric heating constant temperature blast drying box for drying, and tried to use glass plate, oven plate, stainless steel plate and cloth as the film support of fruit and vegetable paper. For comparison, selected the most suitable molding method was for industrial production (Tang and Shang, 2015). Electric blast drying box was used to dry the vegetable paper with a thickness of 3 mm, and dried the paper at 70 ℃ for 4 h (Hu et al., 2018).

3.4. The research on performance

VE were added to the calcium caseinate Calcium caseinate (CC) and whey protein isolate whey protein isolate (WPI) film will increase the elongation at break of the film, and 0.2% R-tocopheryl acetate (VE) will reduce the water vapor transmission rate WVP of the CC film, as well as the tensile strength of CC and WPI film. The adding of Gluconal Cal (GC) reduced the tensile strength of the CC film ($P < 0.05$), and 10% GC reduced the elongation at break and WVP ($P < 0.05$) (Mei and Zhao, 2003).

Researchers found that the antibacterial activity of oregano oil against *E. coli* O157:H7 in the edible film and film-forming solution of apple puree was significantly greater than that of cinnamon oil and lemongrass oil. The additives had no adverse effect on water vapor permeability. The antibacterial film showed good oxygen barrier properties. The tensile strength of the film containing a certain level of antibacterial agent was not significantly different from the control film without antibacterial agent (Rojas-Graü et al., 2006). Some researchers tested and analyzed. The tensile strength and tearing strength of dried cabbage vegetable paper, and conducted a dissolution test and an anti-mold test as performance evaluation (Wang et al., 2009).

Some researchers tested the antibacterial properties of edible pumpkin paper added with nanometer titanium dioxide and modified nanometer titanium dioxide against E. coli (Wang, 2014). Instead of using commonly used organic substances to increase the antibacterial properties of the product, inorganic nanomaterials were used. The quality changes of cress leaf vegetable paper were studied by weight gain, water activity, reducing VC content, and total flavonoid content, texture and color difference. At the same time, it was found through experiments that light and oxygen have a greater impact on the quality of cress leaf vegetable paper. The use of ordinary packaging and storage in the dark can greatly retain the nutritional content of vegetable paper and extend the stable storage time of vegetable paper (Shu et al., 2013). 0.75% of carvacrol and cinnamaldehyde (the main components of cinnamon oil) were mixed into tomato and apple-based edible film, which can produce the best antibacterial effect and can effectively resist food-borne pathogens. At the same time, the preference test was used to evaluate human preference for chicken breasts coated with 0.5–0.75% carvacrol or cinnamaldehyde in tomato and apple-based films (Du et al., 2016).

A bioinspired edible superhydrophobic interface was created by FDA-approved edible beeswax, gum arabic and gelatin through a simple and low-cost method. An edible elastic film was created between the honeycomb wax and the substrate, which can effectively enhance the adhesion of the superhydrophobic interface. After repeated folding and long-term washing, the interface can still maintain good superhydrophobic properties. Cytotoxicity test showed that there is no negative effect on cell viability *in vitro*. It may have potential applications as a functional packaging interface material (Li et al., 2018). In the article, researchers used the rheological properties of edible beeswax to increase the hydrophobicity of the edible film. The yellow passion fruit (YPF) peel and pectin were made as the matrix, and used continuous watering to turn YPF by-products into edible films in a soft and high-yield manner. The sensitivity of YPF film to composting and microbial activity was determined, and it was confirmed that YPF film is biodegradable and renewable. YPF pulp can be used as an effective plasticizer for films and can replace traditional synthetic plasticizers (Munhoz et al., 2018). The new method was used to treat the substrate so that the pulp could be used not only as an edible film, but also as a plasticizer.

Some researchers isolated starches from pumpkin fruits, lentils and quinoa seeds to prepare edible films. The physical, chemical, thermal and mechanical properties of the film were measured and compared with potato-based starch (PS) film. Compared with PS film, lentil and pumpkin starch-based films show much lower solubility and higher swelling ability, respectively, and all films show significantly higher water vapor permeability. Therefore, edible films prepared from unconventional sources of starch can become an effective substitute for ordinary starch films (Pająk et al., 2019). In the article, researchers used starch isolated from plants to prepare edible films, compared with ordinary starch films. Two essential oils (EO), peppermint essential oil (PO) and chamomile essential oil (CO) were added together to make gelatin nanofibers through electrospinning, as a potential edible packaging technology. They Selected PO and CO as bioactive agents to be added to gelatin edible packaging to improve antibacterial, antioxidant, and hydrophobicity (Tang et al., 2019).

The papaya puree were added to the production of biodegradable edible film to obtain an edible film with sensory acceptance and nutritional value. The mature papaya edible film had high antioxidant capacity, can extend the shelf life of easily oxidized foods (such as pears). If moringa was added, the nutritional value of the edible film can be improved (Rodríguez et al., 2019). The essential oil EO were added to the sodium alginate edible film and found that the sodium alginate film with EO has a strong antibacterial effect on 6 kinds of pathogens. EO was uniformly dispersed in the polymer matrix and slightly improves the heat (Tm) and barrier properties of the edible film, while reducing the tensile strength and making the film biodegradable in the soil (Mahcene et al., 2019).

An innovative edible film was made by mixing vegetable oil and egg protein to replace preservatives and primary plastic packaging for desserts. This edible film did not damage the sensory properties of desserts and had high water permeability. When this edible film was used in the candy and dessert industry, the color and appearance of the product covered by the edible film were improved, also the quality of pastry fillings was improved. At the same time, there was no need to use preservatives, which reduced the need for plastic packaging without affecting the shelf life of these foods (De, 2020). The using of preservatives was eliminated in the study, which could be used as an important reference for most food packaging. Acetylated tapioca starch (AS) and pea protein isolate (PI) were used to devolep edible films by conventional blown film extrusion technology. Increasing the content of AS and PI to 20% can effectively improve the blown film processing and barrier properties of oil-based foods, and can be used as a material with high nutritional content in the production of edible packaging (Huntrakula et al., 2020).

Films were prepared by solution casting using a heat-sealable soybean polysaccharide (SSPS)/gelatin blends and plasticized by glycerin. The results showed that by blending SSPS with gelatin, the heat sealability, stretchability and fracture resistance of the film can be significantly improved. The incorporation of gelatin into the SSPS film also increased the thermal stability, but reduced the water solubility, rigidity and water vapor permeability of the film. The test had confirmed that blended films show edible potential in food packaging (Liu et al., 2020). The effects of oregano essential oil (OEO) and resveratrol (RES) nano-emulsion pectin (PEC) edible coatings were studied on the preservation of fresh pork loin under high oxygen modified packaging (HOMAP). Experiments had confirmed that the coating with OEO and RES can significantly extend the shelf life of pork by minimizing pH and color changes, delaying lipid and protein oxidation, maintaining meat tenderness and inhibiting microbial growth. Nano OEO-RES-PEC coating can be developed as a promising formula for preserving fresh meat products under HOMAP storage (Xiong et al., 2020).

4. Conclutions and prospects

4.1. Conclutions

Vegetable paper has the advantages of low sugar, low sodium, low fat, low calorie, etc., and is especially suitable for the elderly, children with partial eclipse, diabetics, obese patients, and workers in special fields such as aerospace and mountaineering. It can be used not only as leisure, functional food, but also as side dishes and new green and environmentally friendly food packaging paper, so vegetable paper has become a research hotspot in the fields of food, medicine and packaging (Yin et al., 2008; Rodrguez et al., 2007). Utilizing the relatively high nutritional properties of dietary fiber, minerals and vitamins in fruit and vegetable paper can play a certain role in balancing young people's nutrition and changing the current high-salt, high-fat, and high-sugar diet. Therefore, in the future, we will strengthen the development of new fruit and vegetable paper products through the combination of different types of fruits and vegetables, and further develop fruit and vegetable papers with a variety of types, unique flavors, good taste, and rich dietary fiber and other nutrients to meet the needs of different consumers (Deng et al., 2017).

4.2. Prospects

In recent years, there has been an increasing tendency at home and abroad to use natural non-polluting and degradable substances as the basis for the development of vegetable paper, such as polysaccharides, proteins and lipids, pectin, starch, alginate, carrageenan and xanthan Polysaccharides such as gums have been used as biopolymer materials to form coatings and edible films to reduce traditional plastic packaging (Mohamed and Mohamed, 2020), reduce the use of non-degradable plastic packaging, and thereby reduce the environmental pollution of plastic packaging. Whether as a new type of snack food with rich nutrition, unique taste, convenient transportation and sales, or as a green packaging material, fruit and vegetable paper will be the direction and hot spot for the development of deep processing of fruits and vegetables, food packaging and comprehensive utilization of raw materials. We believe that under the current trend of advocating food nutrition and health and environmentally friendly packaging, fruit and vegetable paper foods have very broad development prospects. Once the industrial scale is formed, it will have a major impact on the development of health food in my country.

From research at home and abroad, we can see that although the research on vegetable edible paper is becoming more and more mature, researchers are trying to add different substances to vegetable edible paper to enhance its performance. However, the research of vegetable edible paper is currently in the laboratory research stage, and there are still few literature reports on its application in industrialized production. How to expand from the laboratory stage to industrialized production and truly apply vegetable edible paper to production and life. The major problem that researchers all must face is the first challenge in the current vegetable paper production process. With more and more attention to people's lives and health now, how to put vegetable paper into industrial production and transform it into a part of the health industry is our future development direction.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This work was supported by the Science Foundation of Yunnan Vocational Institute of Energy Technology (2019JS006).

References

Liu, R.Q., 2010. About the production and prospects of vegetable paper. Tianjin Paper Making 4, 47–48.

Min, Y.T., Song, Y.X., 2009. Progress of Vegetable Paper Research. Journal of An hui Agri. Sci. , 37(4), 1779 -1780, 1782.

Han, Y.J., Quan, M.P., 2014. The Research Progress of Vegetable Paper. Food Res. Develop. 35 (21), 150–152.

Wang, X.W., Sun, X.X., et al, 2010a. Research Progress on Edible Fruit-vegetable Film. J. Agr. Sci. Tech-Iran 12 (3), 34–38.

Lv, X.D., Meng, Q.H., et al, 2008. Studies and prospects of edible vegetable paper. Sci. Technol. Cereals Oils Foods 16 (6), 67–69.

Pu, H.Y., Xie, W.Y., et al, 2006. Vegetable paper and the applicatiom in food industry. China Food Additives 5 (99), 145–147.

Tahir, H.E., Zou, X.B., Mahunu, G.K., et al, 2019. Recent developments in gum edible coating applications for fruits and vegetables preservation: A review. Carbohyd. Polym. https://doi.org/10.1016/j.carbpol.2019.115141.

Hu, Y.F., Liu, X.C., et al, 2017. Research progress of edible vegetable packaging paper materials. Modern Business 32, 193–194.

An, D.M., 2010. Vast Prospect for Market of Vegetable Paper in China. Packaging Shanghai 5, 31.

Wang, X.L., Huang, W., et al, 2010b. Study on processing technology of vegetable paper. Jiangxi Food Industry 1, 21–24.

Qi, G.G., Zhang, X.L., et al, 2012. Study on process of *Sonchus oleraceus* L. paper. J. Northeast Agri. Univ. 43 (2), 28–33.

Wan, G.F., Zhang, L., 2012. Preliminary Study on Processing Technologies of Vegetable Paper by using Typha Latifolia. Modern Food Science and Technology 11, 141–144.

Zhuoma, L., 2014. Study on the production process parameters of cucumber vegetable paper. Tibet's Sci. Technol. 3, 18–19.

Mohamed, S.A.A., Mohamed, E.S., 2020. Mohamed Abdel-Monem El-Sakhawy. Polysaccharides, Protein and Lipid -Based Natural Edible Films in Food Packaging: A Review. Carbohyd Polym, 2020: 116178.

Huang, W.P., Yang, H., Xiong, Q., 2008. Development of processing technology of chrysanthemum leaf vegetable paper. Cereals and Oils Process. 8, 123–125.

Lv, X.D., 2009. Studies on the Technology of processing instant carrot paper and Its characteristic. Shaanxi Normal University.

Sun, X.X., Wang, X.W., et al, 2010. Study on the Properties of Vegetable Paper Based on Cabbage. Academic Periodical Farm Prod. Process. 4, 4–7.

Huang, Z.J., 2010. Study on Processing and Quality Evaluation of Vegetable Paper. Anhui Agricultural University.

Liu, D.F., Wang, S.L., et al, 2011. Study on Processing Technology of Celery-based Vegetable Paper. Paper Chem. 23 (2), 31–34.

Huang, J.S., Guo, J., et al, 2011. Research on Processing Technology of Vegetable Paper. Academic Periodical Farm Prod. Process. 9, 58–60.

Wan, G.F., 2012. Study on Processing Technic of Vegetable Paper from Typha latifolia. Food Industry 12, 63–64.

Huang, X.D., Zhao, B.T., et al, 2012. Study on Processing Technology of Edible Mushroom Paper with Water-insoluble Residue of Mushroom. Chinese Wild Plant Resour. 3, 64–66.

Zhao, J.M., 2012. Study on processing technology of vegetable paper. Shandong Institute of Light Industry.

Zhu, L.L., 2012. Study on Sargassum Health Jelly and Composite Vegetable Paper. Shanxi University of Science and Technology.

Zhao, Y., Shi, Q.L., 2013. Processing Technology of Vegetable Paper for Chinese Cabbage. Celery and Kelp. The Food Industry 34 (11), 144–147.

Sun, J., Yin, G.Y., et al, 2013. Study on Processing Technique of Leek Packaging Paper. Food Res. Develop. 34 (20), 49–52.

Wang, S.K., Wang, H.C., et al, 2013. Study on the Processing Technology of Edible Lettuce Paper. Food Res. Develop. 10, 70–74.

Wu, H.H., Tan, L., et al., 2013. Study on processing parameters of dietary fiber vegetable paper. Journal of Northwest University for Nationalities(Natural Science), 34(2),72-75.

Otoni, C.G., Pontes, S.F.O., et al, 2014. Edible films from methylcellulose and nanoemulsions of clove bud (Syzygium aromaticum) and oregano (Origanum vulgare) essential oils as shelf life extenders for sliced bread. J. Agric. Food Chem. https://doi.org/10.1021/jf501055f.

Nie, H.L., Tian, Y.C., et al, 2015. Study on Processing Technology of Fruit and Vegetable Paper. Food Industry 5, 168–171.

Tang, H.M., Shang, H.Y., 2015. Study on Compound Vegetable Paper of Broccoli and Sweet Corn. Food Res. Develop. 36 (23), 56–59.

Li, C.W., Zhang, L.H., et al, 2016. Research of the Processing Technology of Purple Cabbage Paper. Food Res. Develop. 37 (20), 115–118.

Sui, M., Wei, M.Y., 2017. Study on Manufacturing Technique of An Edible Vegetable Konjac Packaging Paper. Food Res. Develop. 38 (08), 89–91.

Qin, Y.H., Hang, Y.Y., et al, 2018. Processing Technology of Composite Vegetable Paper for Carrot-Spinach. Farm Products Process. 463 (17), 16–18.

Hu, Y.F., Gong, X., et al, 2018. Effect of Additives on the Folding Resistance of Edible Vegetable Paper. Packagind Eng. 39 (11), 54–59.

Li, W.Y., Wang, R., et al., 2019. Formula Optimization of Sonchus oleraceus L. Vegetable Paper Adhesive. Tianjin Agricultural Sciences, 25(3),24-26,67.

Ruan, C., Zhang, Y., Wang, J., et al, 2019. Preparation and antioxidant activity of sodium alginate and carboxymethyl cellulose edible films with epigallocatechin gallate. Int. J. Biol. Macromol. https://doi.org/10.1016/j.ijbiomac.2019.05.143.

Zhang, C.H., 2005. Study on Technology and Mechanism of Pretreatments Affecting Qualities of Dehydrated cabbage. Jiangnan University.

Wang, T.Y., 2007. Vegetable Paper Based on Modified Chinese Cabbage Fibre. Jilin University.

Shao, C., 2012. Edible Wrapper Based on Celery and Evaluation of Food Quality. Tianjin University of Commerce.

Hou, H.H., Yang, C.M., et al., 2013. Heat Sealing Performance of Fennel and Celery Based Edible Wrapping Paper. Packagind Engineering, 34(15),23-27,45.

Bai, Z.M., 2013. Preparation of edible fruit and vegetable packaging paper. China Packaging Industry 20, 7–8.

Xu, X.Q., Shu, Z., et al., 2013. Research of the shaping process of vegetable paper made by cress leaves. Science and Technology of Food Industry, 34(8):308-311,330.

Wang, X.X., 2014. Preparation of Pumpkin-based Edible Wrapper. Jilin University.

Mei, Y., Zhao, Y., 2003. Barrier and Mechanical Properties of Milk Protein-Based Edible Films Containing Nutraceuticals. J. Agric. Food Chem. 51 (7), 1914–1918.

Rojas-Graü, M.A., Avena-Bustillos, R.J., Friedman, M., et al, 2006. Mechanical, Barrier, and Antimicrobial Properties of Apple Puree Edible Films Containing Plant Essential Oils. J. Agric. Food Chem. 54 (24), 9262–9267.

Wang, X.Y., Chen, C.H., et al, 2009. Preparation and Properties Analysis of Vegetable Paper from Dry Chinese Cabbage. Packagind Eng. 7, 1–2.

Shu, Z., Xu, X.Q., et al, 2013. Research of Quality Change during Storage Period of Vegetable Paper Made by Cress Leaves. Food Industry 7, 42–45.

Du, W.X., Avena-Bustillos, R.J., Woods, R., et al, 2016. Sensory evaluation of baked chicken wrapped with antimicrobial apple and tomato edible films formulated with cinnamaldehyde and carvacrol. J. Agric. Food Chem 60 (32), 7799–7804.

Li, Y., Bi, J.R., et al, 2018. Bio-inspired edible super-hydrophobic interface for reducing residual liquid food. J. Agric. Food Chem. https://doi.org/10.1021/7b05915.

Munhoz, R.D., Moreira, K.F., Bresolin, D.J., et al., 2018. Sustainable Production and In vitro Biodegradability of Edible Films from Yellow Passion Fruit Co-products via Continuous Casting. ACS Sustainable Chem. Eng. https://doi.org/10.1021/8b01101

Pająk, P., Przetaczek-Rożnowska, I., Juszczak, L., 2019. Development and physicochemical, thermal and mechanical properties of edible films based on pumpkin, lentil and quinoa starches. Int. J. Biol. Macromol. 138, 441–449.

Tang, Y., Zhou, Y., Lan, X., et al, 2019. Electrospun Gelatin Nanofibers Encapsulated with Peppermint and Chamomile Essential Oils as Potential Edible Packaging. J. Agric. Food Chem 67 (8).

Rodríguez, G.M., Sibaja, J.C., Espitia, P.J.P., Otoni, C.G., 2019. Antioxidant active packaging based on papaya edible films incorporated with Moringa oleifera and ascorbic acid for food preservation. Food Hydrocolloid. https://doi.org/10.1016/j.foodhyd.2019.105630.

Mahcene, Z., Khelil, A., Hasni, S., et al, 2019. Development and characterization of sodium alginate based active edible films incorporated with essential oils of some medicinal plants. Int. J. Biol. Macromol. https://doi.org/10.1016/j.ijbiomac.2019.12.093.

De, P.T., 2020. Development of a vegetable oil and egg proteins edible film to replace preservatives and primary packaging of sweet baked goods. Food Control. https://doi.org/10.1016/j.foodcont.2020.107273.

Huntrakula, K., Yoksan, R.,et,al, 2020.. Effects of pea protein on properties of cassava starch edible films produced by blown-film extrusion for oil packaging. Food Packaging Shelf. https://doi.org/10.1016/j.fpsl.2020.100480

Liu, C., Huang, J., Zheng, X.J., et al, 2020. Heat sealable soluble soybean polysaccharide/gelatin blend edible films for food packaging applications. Food Packaging Shelf. https://doi.org/10.1016/j.fpsl.2020.100485.

Xiong, Y., Li, S., Warner, R.D., et al, 2020. Effect of oregano essential oil and resveratrol nanoemulsion loaded pectin edible coating on the preservation of pork loin in modified atmosphere packaging. Food Control. https://doi.org/10.1016/j.foodcont.2020.107226.

Yin, S.W., Tang, C.H., Cao, J.S., et al, 2008. Effects of limited enzymatic hydrolysis with trypsin on the functional properties of hemp (Cannabis sativa L.) protein isolate. Food Chem. 106 (3), 1004–1013.

Rodrguez, A., Batlle, R., Nern, C., 2007. The use of natural essential oils as antimicrobial solutions in paper packaging.Part II. Prog. Org. Coat. 60 (1), 33–38.

Deng, Y.J., Tan, Y., et al, 2017. Progress in the Development of Fruit-Vegetable Film as a Novel Processed Food. Food Sci. 38 (21), 302–307.