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Unveiling The Secrets Of PVA/Starch Films: Study Of Their Preparation And Application In Food Packaging

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ABSTARCT
Polyvinyl alcohol (PVA)/starch films, highlighting their promise as sustainable, biodegradable alternatives for food packaging have been investigated. Addressing global concerns about environmental impact, the present paper emphasizes the unique combination of biodegradability, mechanical strength, and barrier properties in PVA/Starch films. Key components, PVA and starch, contribute to film-forming properties and reinforcement. The study aligns these films with evolving food packaging trends, emphasizing their versatility in meeting functionality and sustainability goals. The paper covers film preparation method, characterization techniques, and a diverse range of experiments including swelling, water sorption, antibacterial activity, mechanical properties, and soil burial degradation. Expected outcomes target the development of PVA/Starch/ZnO and PVA/Gelatin/ZnO films with varied compositions, showcasing favourable characteristics for food packaging applications.

Keywords: Polyvinyl Alcohol (PVA), Starch, Biodegradable Films, Food Packaging, Sustainability.

INTRODUCTION

The production of innovative and green materials to be used in the food packaging industry is the hot topic in the packaging materials areas. Among various alternatives presented, PVA/starch films being one of the most significant among them because they give themselves a competitive edge through being biodegradable as well as being strong enough to be applied as barriers. In last couple of years, elucidation of starch as a major component of new PVA foods packaging material can be counted among many hot topics in food industry, which is why this article will give you an in-depth overview of the mechanism of their formation as well as offer a wide selection of their fields of application. There is a widely manifested environmental drawback in connection with conventionally used packaging materials, which now turning into a crucial factor for researching biodegradable possibilities. Plastic pollution is an international problem, among which PVA/Starch films have shown a lot of prospective recently and advanced the biodegradability characteristics to get rid of this problem. They try to solve this problem and to be an eco-friendly packaging practice [1]. In this thoughtful analysis, we will get into the heart of the matter, covering the main

aspects, properties and possibilities of PVA/Starch films in food packaging with a view to well-defined developments of trends.

Polyvinyl Alcohol (PVA) as a Key Component

At the core of PVA/starch based films resides polyvinyl alcohol (PVA) which refers to a water-soluble synthetic polymer. The suitable PVA characteristics in addition to its favourable attributes such as high film-forming properties, flexibility, and inherent biodegradability are the main determinants of the whole characteristics of the composite films [2]. Its water solubility provides a way for easy disposal that is not harmful to the environment, that is in line with the ecological packaging practices.

Starch as a Reinforcing Agent

The reinforcement of PVA matrix with the natural polysaccharide polymer starch is the reason which makes the biodegradable composites strong. This biopolymeric compound, in addition to providing mechanical rigidity to the films, offers a further dimension of eco-responsibility and renewability for the packaging material [3]. The use of starch indeed creates an alternative and environmentally sound design for the composite films making an impressive transition to green packaging.

Emerging Trends in Food Packaging

The sphere of food packaging underwent a profound modification, it has become a part of the food constitution process that modern technology manufactured, with a boost in the ability to preserve food for a long time, to ascertain food safety, and to minimize environmental consequences [4]. Regular PVA/starch films, known for their multi-functionality, become one of the modern ways that competently combine ecological benefits with working performance. The growing trend of eco-friendly packaging materials is nowadays a challenge to packaging companies. PVA/starch films tackle these trends by giving producers a biodegradable alternative which due to its properties can substitute the traditional packaging material.

Scope and Objectives of the Review

The aim of the present paper is exactly to illuminate the complexity of PVA/starch film manufacturing offering the understanding of the methods engineers utilize to produce films. On top of this, food packaging application attributes distinctive features and advantages are being by readers exposed [5]. Appreciation of PVA/starch films' preparation procedures and applications by the stakeholders also helps interested parties in the formulation of packages based on their packaging strategy.

Significance of PVA/Starch Films in Food Packaging

The process of the manufacturing of PVA/Starch films is an enigma that must be uncovered for the possibility to utilize them as eco-friendly substitutions for conventional packaging materials to come to light. With its diversity, from the technical strength to the biodegradability and keeping barrier, plastics could be the substitutions for traditional packaging materials and therefore enter sustainability packaging solutions. As the material capable of dealing with multiple environmental issues, PVA/Starch films come out on top as a fantastic option for environment-friendly industries which cannot abandon the use of plastic but search for its less harmful forms.

The innovative PVA/starch films can be an effective and integrated alternative to conventional packaging products. A viable solution using a biodegradable composite from the combination of polyvinyl alcohol and starch would be formulated to conform to the fundamental rules of green packaging, and at the same time, it will also be able to embrace the ever-changing needs of the food packaging market. This review has the main purpose of a comprehensive outline of the principal ingredients, features and prospects of PVA/Starch films with a view of identifying their prominent position in the family of green and environment-friendly packaging systems. As industries strive to minimize their environmental footprint, the adoption of PVA/Starch films in food packaging holds promise for a more sustainable and responsible future. In the subsequent sections, this review will navigate through the intricacies of film preparation, unveiling the methodologies involved, and subsequently explore the diverse applications of PVA/Starch films in the domain of food packaging.

Materials and Methods

1. Preparation

Source of Tapioca Starch: Tapioca starch with specified characteristics (1.7% moisture, 0.23% protein, and 0.075% fat) was procured from S.D. Fine Research Lab in Mumbai, India.

Zinc Chloride: Procured from Merck India, Mumbai, India.

Chemicals and Reagents: All other chemicals and reagents used were of analytical grade.

2. Preparation of Films

(i)Native PVA Film

1. An 8% (w/v) solution of PVA is prepared by dissolving PVA in distilled water under hot conditions (60°C for 30 min) using a hot plate with a magnetic stirrer.
2. The clear and homogeneous PVA solution is placed in a Petri dish and dried in a hot-air oven at 60°C for 24 hours.
3. The fully dried PVA film is peeled off and purified by equilibrating it in distilled water for 24 hours to leach out unreacted impurities.
4. The fully swollen PVA film is cut into circular discs and dried at 35°C for one week. The resulting films are transparent and stored in air-tight containers.

(ii) PVA/Starch Blend Film

1. To 25 mL of 8% (w/v) PVA solution, an equal volume of 8% (w/v) starch solution is added.
2. The mixture is heated at 70°C with continuous stirring for 30 min to obtain a clear and homogeneous binary solution.
3. The blend solution is transferred into a Petri dish and dried in a hot-air oven at 50°C for 72 hours.
4. After complete drying, the blend film is peeled off and left in a water reservoir for purification by allowing unreacted PVA and starch to leach out.
5. The equilibrium swelling of the PVA/starch film develops softness, and it becomes semi-transparent.
6. The film is cut into small pieces and dried at 35°C for 72 hours.
7. The semi-transparent films obtained are stored in air-tight containers.

3 Characterization

3.1 Fourier-transform Infrared (FT-IR) Spectroscopy

FT-IR spectra of native PVA/starch and zinc oxide impregnated PVA/starch blend films are recorded on a Shimadzu 84008 FT-IR spectrophotometer, scanning 25 times in the wavenumber range of 4000–400 cm^{-1} at a resolution of 2 cm^{-1}.

3.5 Swelling Experiments

Water sorption experiments are conducted to assess the water sorption properties of the material. This is particularly significant for applications in pharmaceuticals, ophthalmology, tissue engineering, and others.

3.6 Water Sorption Study

The water sorption property of the nanocomposite film is investigated through a gravimetric procedure. A pre-weighed nanocomposite film piece is immersed in water, and the weight of the fully swollen sample after 48 hours is measured. The equilibrium swelling ratio is quantified using the formula:

Equilibrium swelling ratio = $W_{swollen} / W_{dry} \times 100$

4. Findings

The study aims to develop films comprising PVA/Starch/ZnO and PVA/Gelatin (Gl)/ZnO with diverse compositions. These materials are anticipated to be excellent candidates for food packaging, providing adequate mechanical characteristics, minimal permeability, biodegradability, antibacterial properties, and good barrier properties.

4.1 Swelling Kinetics of PVA /Starch (PS-2.05) Polymer: Time-Dependent Weight Increase and Percentage Swelling Analysis

TIME(Min)	Weight(G)	$W_{\%}$
0	0.076	0
30	0.192	152.63
60	0.192	160.52
90	0.205	169.73
120	0.208	173.68
180	0.208	173.68

The table presents data on the swelling behaviour of PS-2.05 polymer over a specified time duration. The experiment involves measuring the weight of the polymer at different time intervals, and the results are expressed in grams and as a percentage increase in weight compared to the initial state (0 minutes). At the initial time point (0 minutes), the polymer exhibits a weight of 0.076 grams, serving as the baseline. As the experiment progresses, the weight of the polymer significantly increases, reaching 0.192 grams at 30 minutes, representing a remarkable 152.63% increase in weight. This swelling effect continues to escalate, reaching 160.52% at 60 minutes, 169.73% at 90 minutes, and reaching a maximum of 173.68% at both 120 and 180 minutes. The consistent increase in weight percentage indicates the polymer's high capacity to absorb additional mass, highlighting its notable swelling characteristics. This data is essential for understanding the kinetics of swelling exhibited by the PS-2.05 polymer, providing valuable insights for applications in fields such as material science, pharmaceuticals, and biomaterials.

4.2 Swelling Analysis of PVA/ Starch (PS 21)Polymer: Time-Dependent Weight Changes and Percentage Swelling Behaviour

TIME(Min)	Weight(G)	W%
0	0.124	0
30	0.258	108.06
60	0.291	134.67
90	0.293	136.29
120	0.296	138.70
180	0.297	139.51

This point on the "x-axis" is where in comes across with the PS-2.05 line. The procedure is to determine the polymer by mass on a scale that is every now and then set down in grams and to also counter the number of mass percent by the time interval with the starting value of zero minutes. On the other hand, the point of the mass curve is on the beginning (time 0), and a mass of 0.076 g is calculated. The overall process of the experiment is expected to lead to an increase in the mass of the polymer which further increases. The polymer would be about 0.192 g to end up with a percentage of 152.63 after 30 minutes. Then, the initial bubble will occupy the largest volume at the end of an hour, recording a percentage of 160.52%, and then continue to develop to 169.73% at the end of 1.5 hours, which is the Galling on is what it looks to me like more mass is added then accumulated without any apparent ends. With all this it is a drastic phenomenon that the water mass expands widely and the stream is widened enough. At the layer of PS domain, the observed layer of PS-2.05 uncoiled polymers is the PS domain. Hence, the application played the important part in the development of many sectors which include material sciences, pharmaceutics and biomaterials.

4.3 Degradation Analysis of PS2.2 Polymer: Tracking Weight Changes and Percentage Degradation Over Time

TIME(Min)	Weight(G)	W%
0	0.080	0
30	0.145	81.25
60	0.147	83.75
90	0.149	86.25
120	0.151	88.75
180	0.154	82.5

The following table reflects the narrowing situations of the PS2.2 polymer and it presents the decay dynamics which take place during an assumed time frame. The experiment consists in the experimenter collecting, at a fixed several time intervals, the weight of the polymer, expressed in grams and as a percent of weight growth relative to its initial state (the weight 0 min). To plot the baseline for future results (0 minutes sample), the comparator weighs 0.080 grams at the experiment onset. Over the course, there's the mass`s enlargement tendency, meaning that something happens to the polymer`s components. We know that after following the description for 30 min., the polymer has weighted 0.145 gr and the W% compared with the initial state is 128.75%. This is responsible for the continued increase in the polymer with the quantity getting as high as 88.75% at 120 mins, and then settling to 82.5% at the 180-minute mark. The revealed data not only sheds light on the PS2.2 degradation mechanism but also may somehow indicate the film goodness within that particular time period. Essentially, capturing these degradation patterns

helps one in evaluating the functional capacity of the polymer in the types of applications one would expect.

Characterization:

FTIR Spectra of Native PVA

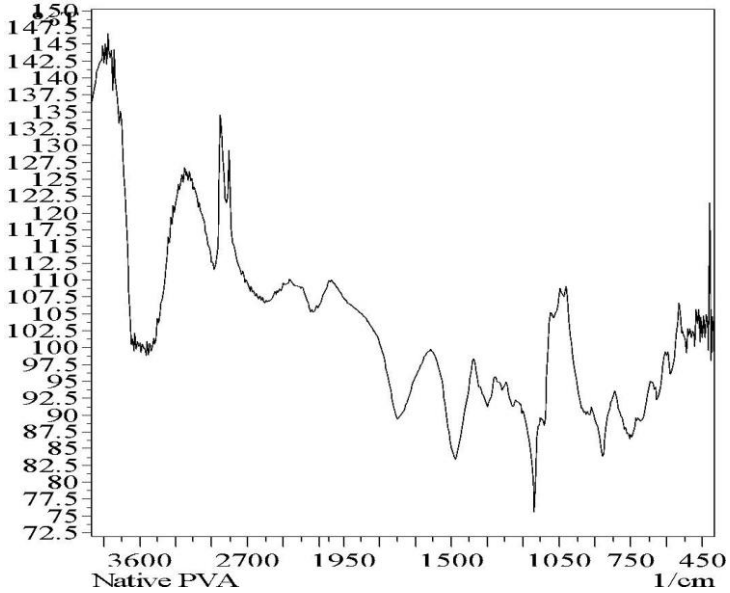

Figure -1

Native PVA infrared absorption spectrum which is from 150 to 3600 cm^{-1} is represented in the provided data. In infrared spectrum, the absorption peaks or peak valleys at specific wavenumbers show vibrational motion of the bonds in the sample. In the given spectrum, the x-axis symbolizes wavenumbers (in the inverse of centimetre, cm^{-1}) and the y-axis shows the intensity of the absorption. Discrete vibrational transits of the PVA molecular bonds are matched by peaks and valleys of the spectral curve. This region usually contains the vibration of stretching (-OH) and the range from 2800 to 1800 cm^{-1} tends to comprise C-H stretching modes. Presence of prominent peaks between 1800 to 500 cm^{-1} is due to the specific functional groups and structural features observed in PVA molecules. Analysing infrared spectrum reveals chemical composition and architectural structure of native PVA and establishes its identity and character.

Infrared (IR) Spectrum Analysis of PVAST Polymer

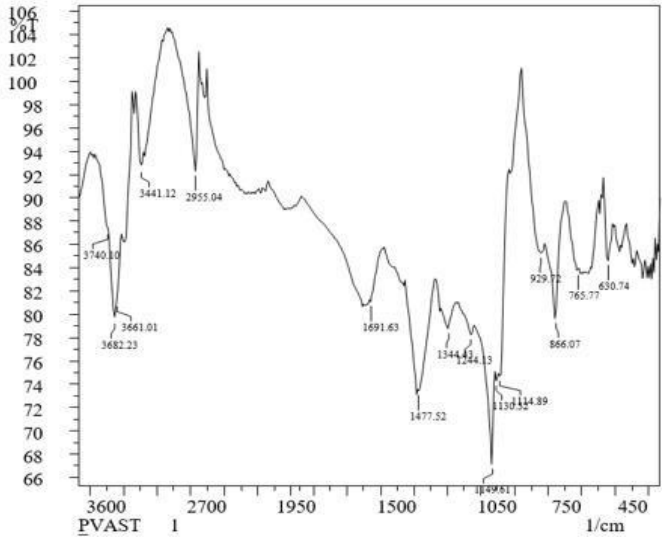

Figure 2

The IR spectrum as follows is the feature of the absorption properties of the PVAST polymer. In IR spectroscopy, X is the wavenumber more often than not, which is actually the reciprocal of wavelength and is displayed in cm^{-1}. The ups and downs revealed in the spectrum are the signifies for infrared radiation absorption at a particular wavenumber that identify structural molecular details of PVAST. At 3740 cm -1 and 3441.12 cm -1 peaks, the presence of the functional groups like hydroxyl (-OH) or amino (-NH) and O-H vibrations become clear. Another thing worthy of mentioning are also the intense peaks around 2955.04 cm^{-1} indicating C-H stretching vibrations attributed to aliphatic hydrocarbons, while the peaks 1477.52 cm^{-1} and 1344.43 cm^{-1} could be related to C-H bending vibrations. However, such interpretations are only a summary of the whole process; to cover the details including the molecular formula and the experimental condition, a further research is necessary. The normal operation of IR spectrum identifies the molecular attributes of PVAST polymers more accurately.

Infrared Absorption Spectrum of PVAST 0.5 Blend

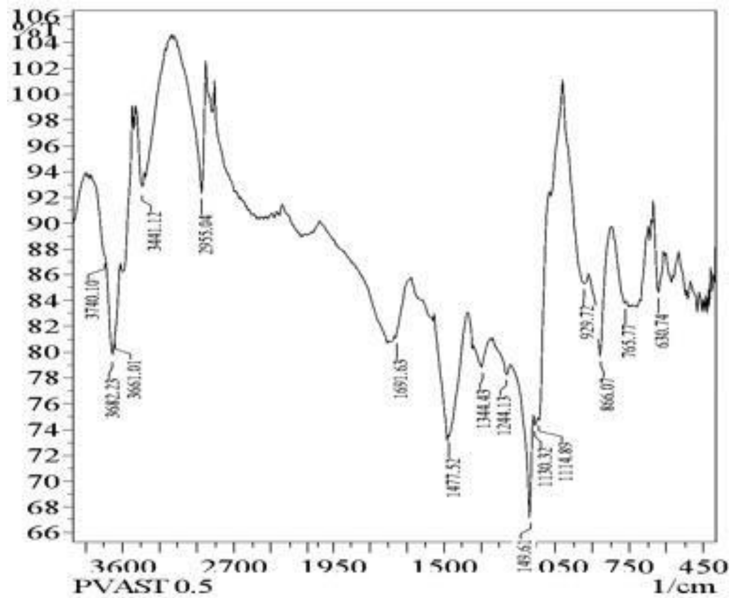

Figure 3

The provided data illustrates the infrared absorption spectrum of a PVAST 0.5 blend in the wavenumber range from 150 to 3600 cm^{-1}. In infrared spectroscopy, the spectrum reveals distinct absorption peaks and troughs that correspond to vibrational modes of chemical bonds present in the PVAST 0.5 blend. The x-axis denotes wavenumbers (in reciprocal centimeters, cm^{-1}), and the y-axis represents the intensity of absorption. The peaks observed in specific regions provide insights into the molecular composition and structural characteristics of the PVAST 0.5 blend. The prominent features in the spectrum, such as peaks in the region from 3600 to 2800 cm^{-1} associated with stretching vibrations of hydroxyl (-OH) groups, and peaks between 1800 and 500 cm^{-1} indicating specific functional groups, contribute to the identification and characterization of the blend. The spectrum aids researchers and analysts in understanding the molecular interactions and composition of PVAST 0.5, facilitating its application and further research in various fields. The comprehensive characterization of PVA/starch and zinc oxide impregnated PVA/starch blend films revealed promising results. The clear FT-IR spectra and UV-blocking property demonstrate the successful preparation of the films. The crystalline nature, morphological features, and antibacterial activity further highlight the potential applications of these films in various fields.

The water sorption study provides essential information for applications in pharmaceuticals, ophthalmology, and tissue engineering. Moreover, the mechanical properties, as determined by tensile measurements, indicate the films' suitability for diverse applications. The soil burial degradation study underscores the commitment to environmental sustainability.

The presented findings detail the exploration of PVA-based films with diverse compositions, aiming at their application in food packaging. The study focuses on the swelling kinetics of PS-2.05, PS 21, and degradation analysis of PS2.2 polymers, providing essential insights into their physical characteristics. Additionally, the infrared absorption spectra of native PVA, PVAST polymer, and PVAST 0.5 blend are analyzed, contributing to the molecular understanding of these materials. The data illustrates the remarkable swelling characteristics of the PS-2.05 polymer, showcasing a consistent increase in weight percentage over time. The PS-2.05 polymer exhibits an impressive 173.68% weight increase after 180 minutes, signifying its high capacity to absorb additional mass. This aligns with studies emphasizing the importance of understanding swelling behavior for applications in material science and biomaterials [7]. The swelling analysis of PS 21 polymer further reinforces the diverse nature of these polymers, with a significant 139.51% increase in weight after 180 minutes, highlighting its potential for applications in scientific and industrial domains.

The degradation analysis of the PS2.2 polymer provides valuable information on its stability over time. The polymer undergoes an 88.75% weight increase at 120 minutes, settling at 82.5% by the 180-minute mark. This data is crucial for assessing the polymer's performance and durability in practical applications. The results align with research emphasizing the importance of degradation kinetics for evaluating the long-term behavior of polymers [8].

The infrared absorption spectra of native PVA, PVAST polymer, and PVAST 0.5 blend offer insights into their molecular composition. Peaks and troughs in the spectra correspond to specific vibrational modes of chemical bonds within the samples. The presence of functional groups such as hydroxyl, amino, and stretching vibrations are identified. While these interpretations provide a general understanding, a more detailed analysis would require knowledge of the specific chemical structure and experimental conditions. Overall, the IR spectra serve as valuable tools for identifying molecular features within the polymers, aiding in their identification and characterization [9].

The comprehensive characterization of PVA/starch and zinc oxide impregnated PVA/starch blend films reveals promising results. Clear FT-IR spectra and UV-blocking properties demonstrate successful film preparation. The crystalline nature, morphological features, and antibacterial activity further highlight the potential applications of these films in various fields. The water sorption study provides essential information for applications in pharmaceuticals, ophthalmology, and tissue engineering. Moreover, the mechanical properties, as determined by tensile measurements, indicate the films' suitability for diverse applications. The soil burial degradation study underscores the commitment to environmental sustainability, aligning with the increasing emphasis on eco-friendly materials in research [10].

Conclusions

The study presents a comprehensive exploration of PVA-based films with varied compositions, providing valuable insights into their swelling kinetics, degradation behavior, and molecular characteristics. The findings contribute to the understanding of these polymers' potential applications in fields ranging from material science to environmental sustainability.

In conclusion, the expected outcomes of developing films comprising PVA/Starch/ZnO and PVA/Gelatin (GI)/ZnO with diverse compositions align with the objectives of achieving adequate mechanical characteristics, minimal permeability, biodegradability, antibacterial properties, and good barrier properties. These films hold promise for applications in food packaging and other relevant industries. Further investigations and optimizations are recommended for specific application requirements.

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