DEVELOPMENT AND CHARACTERIZATION OF SUSTAINABLE FOOD PACKAGING FILM BASED ON POLYVINYL ALCHOHOL / K-CARRAGEENAN / KODO MILLET (PASPALUM SCORBICULATUM) HUSK

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Keywords

Sustainable food packaging, Ecofriendly, Agro-waste, Value addition

Introduction

One of the major environmental problems of 21st century is non-biodegradable polymers usage for single use and throw applications, which are manufactured in huge amounts all over the world because of their low cost, easy processability and their use make our lives easier and comfortable. In recent days, the primary aim of polymer researcher is to produce polymers that meet the requirements of this age that are biodegradable and compatible with environment. In this regard biodegradable polymers are gaining huge potential for food packaging applications. The FDA approved biodegradable polymers like Polyvinyl Alcohol (PVA) and *k*-Carrageenan along with a value added production-Kodo millet husk are selected for the present study. To enhance the functionality of the food packaging materials many active ingredients are added into the packaging films. These active ingredients will enhance the shelf life of food without degrading the basic functioning of packaging like containment, protection and marketing.

The fundamental idea behind using active packaging rests on either the intrinsic qualities of the polymer employed as the packaging material or the introduction/inclusion/ entrapment of explicit active chemicals inside the polymer.

In active packaging systems, active compounds such antimicrobial agents, oxygen absorbers, water vapor absorbers, preservatives, ethylene scavengers and other such substances are incorporated into a package to improve its protection function. In the present study the essential oils with inherent antimicrobial activity will be incorporated to facilitate the extended functionality of PVA/k-Carrageenan/KMH composite film.

PVA is a biodegradable polymer which is non-toxic, biocompatible, water soluble. It has good thermal stability up to 200℃, great mechanical endurance, excellent film forming capability. It is transparent and cost low when compared to other biopolymers. It is sensitive to moisture and this property can be altered by using fillers in varying concentrations. k-Carrageenan is a polysaccharide extracted from red algae/sea weed by hydrolysis, ultrasonic-assisted or microwave-assisted extraction methods. It forms homogeneous film-forming solutions and can be fabricated by direct coating, solvent casting or electrospinning. It is a low cost polymer with biodegradability, compatibility, and inhibits microbial growth (Barrier properties). Kodo millet husk is a lignocellulosic husk which is dehusked before using grains. These husk are usually burnt post-harvest and it results in emission of large amounts of greenhouse gases. These crop residues have great accessibility, biodegradability, easy renewal, and ecological compatibility. An effective food packaging material considered should embrace many integrated features such as: nontoxicity, barrier to flavor/aroma/moisture/oxygen, visibility of product, stable performance over elevated temperature range, good mechanical strength, easy processability, benign to environment, recyclable and sustainable. Polymer food packaging material can exhibit most of the aforementioned characteristics if designed and handled suitably.

The present research work involves preparation of composite film, their optimization and incorporation of the Essential oil to the optimized composite film followed by its characterization that will help us analyze its mechanical properties, barrier properties, shelf-life, antimicrobial activity and soil biodegradability.

Objectives

The objectives of the study are as follows

- To prepare and optimize PVA/k-Carrageenan/KMH composite film
- To characterize the prepared film for its mechanical properties, barrier properties, heat sealability, migration or leaching etc.
- To prepare active packaging film by incorporating essential oils to the best or optimized film and conduct mechanical tests, antimicrobial and soil biodegradability studies followed by one case study.

Methodology

Experimental Work

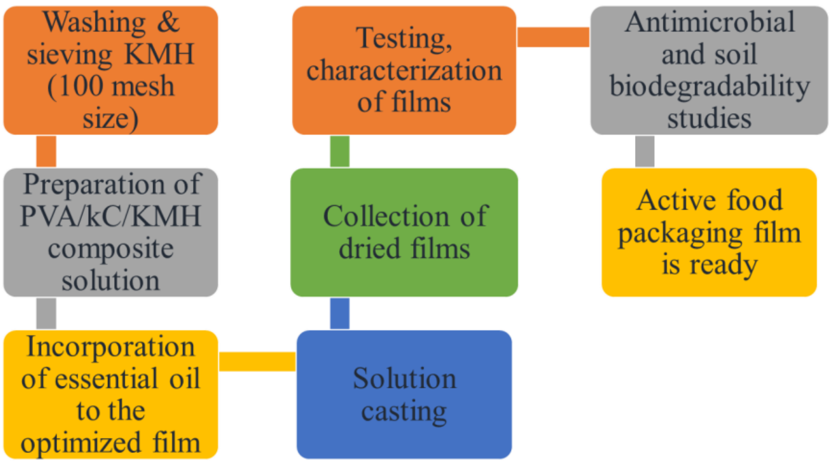


Figure 1: Flowchart of experimental work plan

Results and Conclusions

Composite film optimization

The PVA was selected as major film component. But the main drawback of PVA is its moisture sensitivity. To overcome this property of the PVA, k-Carrageenan is selected which is also a FDA approved biodegradable polymer. The PVA and k-Carrageenan was blended in 80/20 weight proportion to ascertain the best composition in terms of transparency, mechanical strength and physical appearance of the film. To prepare a value added product, Kodo millet husk was used in varying concentrations to prepare composite films of PVA/Kc/KMH. Following compositions of films were prepared.

Table 1: Composition of films prepared

S. No	Composite Designation	PVA (wt%)	KC (wt%)	KMH (wt%)
1.	80/20/0.15	80	20	0.15
2.	80/20/0.25	80	20	0.25
3.	80/20/0.35	80	20	0.35
4.	80/20/0.45	80	20	0.45
5.	Neat PVA	100	0	0
6.	80/20/0	80	20	0

Tensile Testing

For food packaging applications material has to possess some mechanical strength otherwise it may cause accidental failure of material during handling and processing condition. The tensile testing of films was carried out using UTM at crosshead speed of 5 mm/min using 50 kg load cell according to ASTM D 638. The result of the test is shown in the graph given below. The tensile strength, peak load, percent elongation and ultimate modulus were directly given by the software.

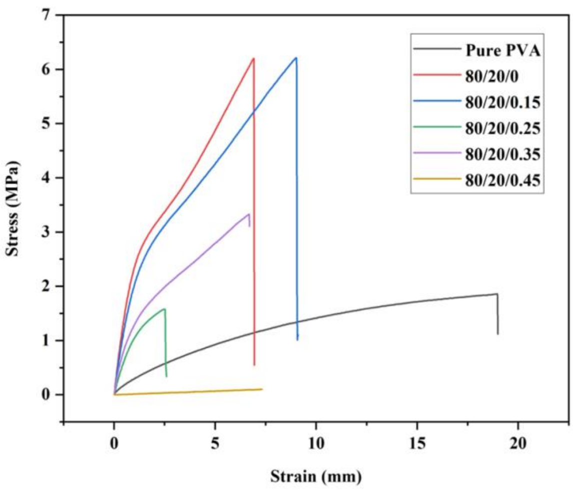


Figure 8: Tensile properties of composite films

From the above figure we can say that as the filler concentration increased the fracture got more brittle. The composite film 80/20/0.15 exhibited good tensile strength when compared to pure PVA film.

Tear Resistance Test

Tear strength of the film is another property which is very important for packaging material to retain the packaging integrity. In the present study tear propagation resistance of the films were tested and the results are shown in table below. From the above table we can infer that as the filler concentration increased, the tear strength significantly reduced. The composite film 80/20/0.15 showcased good tear resistance when compared to pure PVA.

Table 2: Tear strength of the films prepared

S. No.	Film Composition PVA/KC/MH (wt/wt%)	Peak load (Kg)	Tear Strength (N/mm)
1.	**80/20/0.15**	**1.52**	**0.018**
2.	80/20/0.25	1.27	0.020
3.	80/20/0.35	1.23	0.019
4.	80/20/0.45	1.26	0.019
5.	Neat PVA	1.27	0.020
6.	80/20/0	1.70	0.026

Water Vapor Transmission Rate

Many food items are sensitive to moisture so they demand higher barrier materials for their packaging. For example, chips, biscuits, bread or any fried items require complete barrier of oxygen and water vapor to preserve their native traits like taste, crispiness and aroma. PVA is sensitive to moisture and hence to overcome this property, k-Carrageenan was used. The affinity to water of the prepared composite films is tested and the values are discussed below.

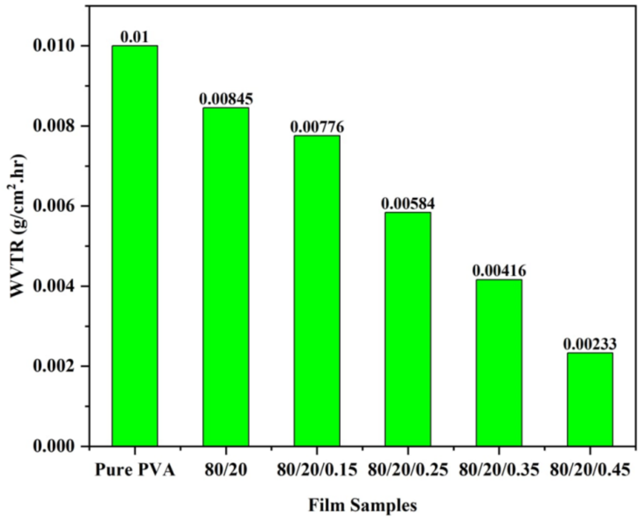
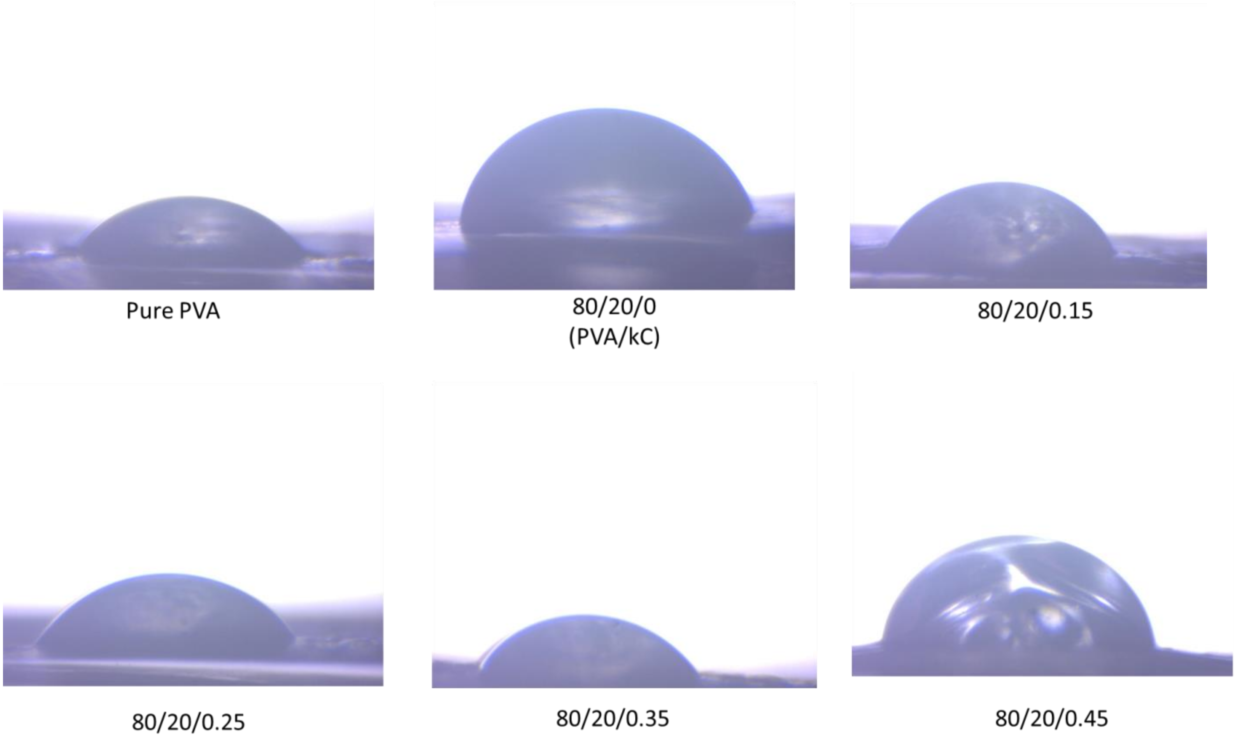


Figure 9: WVTR values of composite films

From the above figure we can infer that the composite film with highest concentration of KMH exhibited lowest WVTR value of 0.00233 g/100 in^2 /24hr proving its ability to resist the transmission of water vapor when compared to pure PVA and PVA/Kc blend.

Water Contact Angle Measurement

Water contact angle will immediately give an indication of the wettability of the material. If the measured contact angle is above 90 degrees, the material is said to have poor wetting and is termed hydrophobic. If the contact angle is below 90 degrees, a term hydrophilic or hygroscopic is used. The images given below give the idea of composite films' affinity towards water.



Figures 1,2,3,4,5 & 6: Water droplets making an angle with the film surface

Table 3: Water contact angles of films

Type of films	Contact angles
PVA	**46.04**
PK	**81.29**
80/20/0.15	52.91
80/20/0.25	48.78
80/20/0.35	55.27
80/20/0.45	**74.1**

From the above figures and table, we can infer that the Pure PVA is hygroscopic in nature whereas, PVA-kC blend (80/20/0) and 80/20/0.45 (PVA/kC/KMH) exhibited hydrophobicity.

Conclusions

- Good tensile strength is exhibited by 80/20/0.15 PVA/kC/KMH composite film when compared to pure PVA film.
- The 80/20/0.15 PVA/kC/KMH composite film exhibited better tear resistance than the pure PVA film.
- The composite film with highest concentration of KMH exhibited lowest WVTR value of 0.00233 g/100 in^2 /24hr proving its ability to resist the transmission of water vapor.
- Pure PVA is hygroscopic in nature whereas, PVA-kC blend (80/20/0) and 80/20/0.45 (PVA/kC/KMH) exhibited hydrophobicity.

Description of the innovation in the project

From an intensive review of literature, the use of combination of polymers; Poly Vinyl Alcohol, k-Carrageenan and Kodo millet husk to prepare composite films for sustainable food packaging has been found novel. Kodo millet husk is an agro-waste which is either dumbed or burnt after the harvesting of Kodo millets. The use of its husk will provide an alternate use of agro-waste to create a value added product and the use of essential oils such as Eucalyptus oil, Linseed oil and Clove oil impart antioxidant and antimicrobial properties to the films thereby increasing the shelf life of food products packed in them.

Scope of the study

- Conduct characterization of films for their heat seal-ability, migration(Leaching), thermal transitions (DSC) and FTIR analysis and choose the best/optimized film.
- Incorporation of different essential oils to the optimized film.
- Characterization of oil incorporated films for their mechanical, thermal and chemical properties.
- Soil biodegradability tests followed by one real time case study.