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Waste to wealth: Developing biofilm by utilizing pea industry waste

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Abstract
With the development of agro-based industry in India, the production of wastes increased rapidly by quantity as well as by variety. These industries produce large volume of waste, resulting from the production, preparation and consumption of food. Pea processing industry involves preserving green peas by freezing and marketing them for seasonal limitation and producing a very high amount of waste as a by-product. Inappropriate disposition of this waste not only result in environmental degradation and pollution, but also loss of valuable biomass resources. The present study was aimed to utilize pea peel waste in an efficient way for developing biodegradable film through value addition. The result revealed that the developed biodegradable film has good tensile strength (5.96 MPa), surface thickness (70 µm) and water solubility (2.46%). Therefore, biodegradable film can be the deputy of synthetic plastic with the advantage of employment generation, energy recovery and livelihood security which ultimately leads to sustainable environment and development.

Keywords: Pea peel, pea processing industry, by products, biodegradable film, livelihood security, agroindustry, agro waste management

Introduction

Pea (*Pisum sativum*) is a cool-season crop and one of the most important legumes, grows either alone or in combination with small grains, in the temperate climatic regions and it has been widely consumed as a legume or vegetable throughout the world for satisfying the purpose of human consumption as well as animal feeding. With the invention of canning, freezing, and cold storage, various pea processing industries make efforts to preserve and marketing them so that seasonal crops became available year-round. India is the second-largest producer of green peas next to China (Adeyeye, 2002) [1]. Established upon assumption, 30% of the total pea weight is owing to pea pods (fresh weight basis). Thus based on India's yearly production of peas, more than 1 million tons of pea peel waste is generated annually alone in India, of which sizeable extent is discarded as waste.

Agriculture based industries are the large or small scale industries, generally derived their raw material from agriculture products like vegetables, fruits, rice, sugar cane, etc. and related to production, processing, and packaging of these products using modern technologies and methods. The food processing industry is one of the incredible sectors with huge potential for development, growth and export. This industry observed as a boosting segment for the agricultural economy.

Agro-industries, mainly the food industry, besides benefits, produce huge amounts of solid or liquid organic wastes, which appear not only from processing but also from the production and consumption process. The quantity and composition of these wastes depend especially on the source of raw material and the type of processing steps, operations, and products.

To manage agro-industrial wastes, now days is very difficult. Organic waste contains numerous reusable material of high nutritive value such as protein, soluble sugar and fibers (Tamer and Copur, 2014) [7]. Direct discarding of these wastes in the soil causes severe environmental degradation problems. Beside their pollution and hazard aspects, in many cases, this was significant for the reason that the pea peels wastes are available in bulk at zero cost, can be used without much quality degradation and convert into useful products of higher value as compared to conventional green fodder, after biological treatment. Therefore, in this study, the recycling and utilization of pea peel waste are considered as an important step in environmental protection, energy structure, and economic development through converting pea peel waste produced from the pea processing industry into the biodegradable or biofilm.

Material and Methods

Sample collection

Fresh pea peels were collected from the pea processing industry, where pea seeds were separated from peels. These peels or empty pea pods were sorted and dried in a hot air oven for 48 hours at 70 ^{0}C. Dried peels were then grounded in powder form for further experiments.

Grafting of methyl-methacrylate onto pea peels

In the present study to develop a biopolymer, grafting of methyl-methacrylate (MMA) was done onto pea peel. The inhibitor content of MMA was removed by mixing 10 percent NaOH solution and repeated washing with distilled water (Joshi, *et al.* 2003) [6] and the obtained solution was used in the graft copolymerization process.

Procedure

Aqueous nitric acid 0.18M 100ml, 50 mg thiourea, a known amount of pea peel powder sample and 50mg potassium persulphate (KPS), were taken in a conical flask and flask placed on magnetic stirrer having dropping funnel and oxygen circulating tap (10 air-bubble/min). The content was then stirred at 45±1°C for four hours and excess of methanol was then added to quench the reaction (Joshi, *et al.* 2003) [6]. After that above thin solution was removed from the centrifuged content and the obtained solution was placed on a petri dish for hot bath sonication for 1 hour to get grafted content. The percentage of grafting yield and total conversion (monomer to polymer) of MMA onto samples were calculated according to the following formula-

$$\text{Grafting yield (\%)} = \frac{W_2 - W_1}{W_1} \times 100$$

$$\text{Total Conversion (monomer to polymer) (\%)} = \frac{W_3 - W_1}{W_4} \times 100$$

Where,

W_1 = Sample weight (g),
W_2 = Grafted polymer (g),
W_3 = Weight of monomer (g),
W_4 = Weight of product co-polymer (g)

Preparation of biodegradable film

A known amount of grafted and chloroform was added to the content and the beaker was covered with aluminum foil to avoid the evaporation of chloroform. The beaker was then placed into a hot bath sonicator for 20 min. and a known amount of polyvinyl butyral was added in content.
The obtained mixture was then centrifuged at 5000rpm for 5 min. and the supernatant mixture was carefully separated from the concentrated thick mixture. The obtained concentrated mixture was then poured onto a petri dish and covered by aluminum foil and then dry out at room temperature for 24 hours to develop the film. The dried film was then peeled off from the petri dish and was collected in an airtight polythene bag.

Characterization of the developed product

Tensile Strength

Universal tester was used in the present study to measure the tensile strength of developed biofilm. The tensile strength of biofilm was analyzed by ASTM D638. According to ASTM D638 standards, the thickness of the sample should be less than 1mm to analyze tensile strength.

Surface Thickness

In the present study, the thickness meter was used to measure the surface thickness of the developed film with a precision of 0.001mm. The mean value of the measured thickness of the sample was calculated.

Scanning Electron Microscopy Analysis (SEM)

By using SEM, surface morphology was examined in the present study. The sample was oven-dried at 50 °C for overnight and coated with a gold film to get a clear microscopic image.

Fourier Transform Infrared Spectroscopy (FTIR)

Fourier transform infrared spectroscopy was carried out using the Bruker Alpha-model with spotlight 600 frontier spectrometer with Spectrum Image laser class 1 software. The sample was oven-dried at 50°C for overnight and was measured for transmittance over a range from 4000 to 600 cm^{-1}

Water Solubility (WS) Test

The water solubility test for the present study was determined by using the method described by Han, *et al.* (2015). The sample was dried for 2 hours in a hot air oven at 70^{O}C and initial weight was taken off the film. The film sample was immersed in a beaker containing 50 ml of distilled water and placed in an incubator at 30 ^{O}C for 24 hours. After that, the film sample was dehydrated in a hot air oven at 90^{O}C for 24 hours. The dehydrated film sample was weighed for determining the weight of the water-soluble solid. Finally, the water dissolved portion of the dried film sample was calculated by using the following formula -

$$\text{WS (\%)} = \frac{\text{Wt. of the initial dried sample - Wt. of the insoluble dried sample}}{\text{Wt. of the initial dried sample}} \text{X100}$$

Result and Discussion

Product formulation through value addition

Utilizing pea processing industry byproduct or empty pea peels to formulate biodegradable film or bioplastic can provide a sustainable substitute to non-biodegradable plastic. As bioplastics are developed from natural biopolymers, which are consist of cellulose, hemicellulose, and lignin (Chen, 2014) [4] and these are non - hazardous materials and environmental friendly composites. According to Verma *et al.* (2011) [9], pea peels have a good composition of cellulose (61.35%) and lignin (22.12%). Similarly, Upasana and Vinay (2018) [8] studied that pea peels have a high nutritive value of crude protein (19.79%) and a good amount of ash (7.87%), fat (2.27%) and fiber (1.87%). Hence, pea peels can be used as a biopolymer to produce the biodegradable film.

Graft co-polymerization

To develop a biopolymer, grafting of methyl-methacrylate (MMA) was done onto pea peel. It was observed from the experiment of Graft Co-Polymerization, the obtained grafted sample was viscous when the experiment was started and after drying, it was converted in powder form.

Table 1: Values of grafted yield and total conversion of samples

Grafted Sample	Graft Yield (%)	Total conversion (%)
Pea Peel	7.13	31.4

Table 2 showed that the graft yield of methyl-methacrylate (MMA) onto pea peel was 7.13 percent and the total conversion was 31.4 percent.

Characterization of developed biofilm

Figure 1 illustrated biofilm developed from pea peel. The developed biofilms were somewhat yellow in color, smooth, thick and show even surface with fine edges, but due to transparency, the color was negligible.

The observation values of characteristics i.e. tensile strength, surface thickness, and water solubility test of developed biofilm are depicted in table 2. Scanning electron microscopy (SEM), and Fourier-transform infrared spectroscopy (FTIR) are evaluated in figure 2 and figure 3.

Tensile Strength: From the experiments, the tensile strength of biofilm was observed to be 5.96 MPa. This was observed higher than the tensile strength (2.85 MPa) of biofilm developed by Azeredo *et al*. (2009) [2] from mango puree.

Surface Thickness- Thickness of the developed biofilm was found to be 70 µm, whereas, a cornstarch-based film prepared by Bertuzzi *et al.* (2012) [3] and they observed film thickness ranged from 30µm to 100µm.

Water Solubility: Water solubility may be described as the maximum possible concentration of a material dissolved in water. It was revealed from the water solubility test that biofilms prepared from pea peel appeared to be easily dissolved in water and solubility was 2.46 percent. Han *et al.* (2015) [5] developed bioplastic film from soy protein and observed 7.37 percent water solubility which was slightly higher than recorded in the present study.

Table 2: Characteristics of the developed biofilm

Characteristics	Pea peel Biofilm
Tensile Strength(MPa)	5.96
Surface Thickness (µm)	70
Water Solubility (%)	2.46

Scanning Electron Microscopy Analysis (SEM): SEM picture evaluated the surface morphology of developed biofilm at 50 µm and it was observed from the image that slightly porous smooth exhibited no breakage at the surface and specifically film appearance was transparent.

Fig 1: Developed Bio Film from Pea Peel Waste

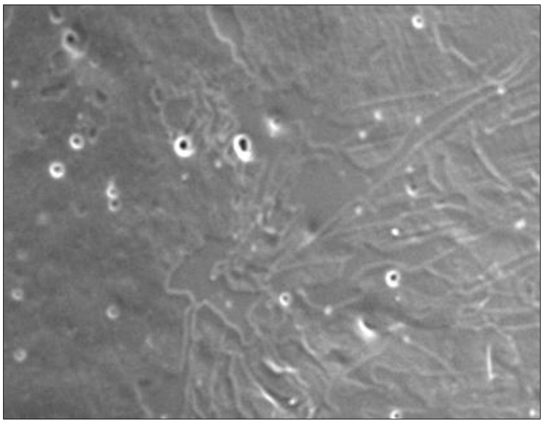

Fig 2: SEM image of developed Bio Film

Fourier Transform Infrared Spectroscopy (FT-IR): FT-IR analysis results in absorption spectra which provide information about the chemical bonds and molecular structure of a material. Polyvinyl Butyral (PVB) represents the characteristics (FTIR) assignments (cm^{-1}) related to its structure. From the graph, it was observed that the peak at 3735, 3621, 3378 cm^{-1} indicated the presence of aromatic group and 2934 cm^{-1} showed C–H asymmetrical stretching band of most aliphatics and aromatics groups. The peak located in 2360 and 2333 cm^{-1} region represents the symmetrical characteristics of amine group. The stretching of peak at 1659 cm^{-1} may be due to amide group. The broad peak at 674 cm^{-1} represented the vibrational bending of the alkyl group.

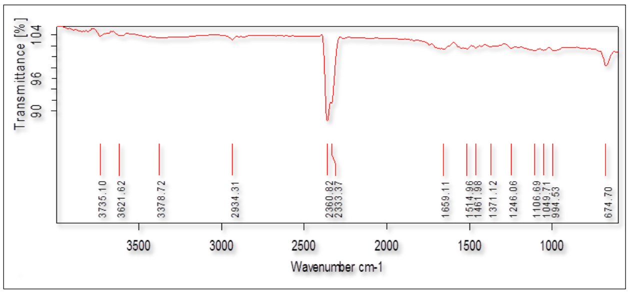

Fig 3: FT-IR spectrum of developed Bio Film

Conclusion

It can be concluded that pea processing industry waste, which otherwise is discarded in bins or used in animal feed, rich in proximate composition and can be used for preparing value-added products. Biodegradable film prepared from pea peel have good tensile strength, surface thickness, water solubility and transparency and can be utilized as a substitute of synthetic plastic or used as a mulching sheet in agricultural activities and this efficient management of pea processing waste leads to secure livelihood, pollution-free environment and sustainable development.

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