Utilization of pea industry waste for developing biodegradable product

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ABSTRACT: With the development of agro-based industry in India, the production of wastes from these industries 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 disposal of this waste not only results in environmental degradation and pollution, but also loss of valuable biomass resources. The present study was aimed to estimate the nutritional value of waste pea peels and to utilize them for developing bio-degradable product through value addition in an efficient way. The result revealed that waste pea peels have high nutritive value of crude protein (19.79%), and have a good amount of ash (7.87%), fat (2.27%) and fiber (1.84%). The biofilm developed under this study has good tensile strength (5.96 MPa), thickness (70 µm) and water solubility (2.46%). Therefore bio-film can be a substitute of synthetic plastic with the advantage of employment generation, energy recovery and livelihood security which would ultimately lead to sustainable development.

Key words: Agro waste management, agroindustry, biofilm, byproducts, livelihood security, pea peel, pea processing industry, proximate analysis

Agro-industries, mainly the food industry, besides providing many benefits, produce huge amounts of solid or liquid organic wastes, which appear not only from processing but also from production and consumption process. The quantity and composition of these wastes depend especially on the source of raw material and the type of the processing steps, operations and products. Agriculture based industries are the large or small scale industries, generally derive their raw material from agriculture products like, vegetables, fruits, rice, sugar cane, etc. and are related with 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 acts as a boosting segment for the agricultural economy.

India is the second largest producer of green peas next to China (Adeyeye, 2002). It is estimated that 30% of the total pea pod weight is owing to pea peels on fresh weight basis. Thus based on India's yearly production of pea, more than 1 million ton of pea peel waste is generated annually alone in India, of which sizeable extent is discarded as waste.

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 is 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 attempt to preserve and market them, so that the seasonal crop becomes available year-round.

Nowadays, management of agro-industrial wastes is a serious problem. Organic waste contains numerous reusable material of high nutritive value such as protein, soluble sugar and fibers (Tamer and Copur, 2014). Discarding these wastes directly in the open causes severe environmental problems. Pea peel wastes are available in bulk at zero cost, can be used without much quality degradation and converted 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 was considered as an important step in environmental protection, energy availability and economic development through converting pea peel waste produced by pea processing industry into biodegradable product or bio-film.

MATERIALS AND METHODS

Sample collection – Fresh pea peels were collected from pea industry and were sorted for further experiment.

Preparation of proximate analysis

For proximate analysis, pea peels were dried in hot air oven for 48 hours at 70°C and then grounded to powder form. Weende's system of analysis (Hanneburg and Stohmann, 1860) was used for proximate analysis of pea peels. In this process crude protein, ether extract, total ash, crude fiber, acid detergent fiber, lignin and cellulose were analyzed.

Grafting of methyl-methacrylate onto pea peels

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

Procedure

Aqueous nitric acid 0.18M 100ml, 50 mg thiourea, 1g pea peel powder sample and 50mg potassium per -sulphate (KPS), was put in a conical flask and placed on magnetic stirrer having dropping funnel and oxygen circulating tap (10 air-bubble/min). Then 4 ml MMA was added to the reaction mixture. The content was then stirred at 45±1°C for four hours and excess methanol was added to quench the reaction (Joshi *et al.,* 2003). For the separation of liquid, the content was centrifuged at 5000 rpm for 30 min. After this, the above thin solution was removed from the centrifuged content and placed on 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 bio- degradable film

For the preparation of bio-film, a known amount of grafted sample and 5 mg of talc powder were measured and transferred into 100 ml capacity beaker. Then a known amount of 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 hot bath sonicator for 20 min. After 10 min of sonication process, a known amount of polyvinyl butyral was added to the content.

The obtained mixture was then centrifuged at 5000 rpm for 5 min. and the supernatant mixture was carefully separated with the help of test tubes from the concentrated thick mixture. The obtained concentrated mixture was then poured onto a petri dish and covered by aluminium foil and then dried out at room temperature for 24 hour 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 developed product

Tensile strength

Tensile testing is a method, which determines the property of a material i.e. how the material will react when it is pulled apart by applying force. 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 1 mm to analyze tensile strength. The samples were cut into 4 inch in length. According to the standard the range of speed was set up to 0.05 to 20 inch per minute and time for test was set up to 30 seconds to 5 minutes. As per the ASTM D638 standards, sample should rupture in the end.

Surface thickness

The method was used for measuring distance between top and bottom of the surface. In present study, thickness meter was used to measure surface thickness of developed film with precision of 0.001mm. The thickness of the centre and other three randomly selected regions of the bio-film were taken. The mean value of measured thickness of the sample was calculated.

Scanning Electron Microscopy (SEM) analysis

This type of electron microscopy produces images of a sample by scanning with focused beam of electrons. By using SEM, surface morphology was examined in the present study. The sample was oven dried at 50°C for overnight and coated with gold film to get clear microscopic image.

Fourier Transform Infrared (FTIR) spectroscopy

The technique was used to obtain an infrared spectrum of absorption or emission of a solid, liquid or gas. An FTIR spectrometer simultaneously collects high-spectral-resolution data over a wide spectral range. Fourier transform infrared spectroscopy was carried out using Bruker Alpha model with spotlight 600 frontier spectrometer with Spectrum Image laser class 1 software.

Sample was oven dried at 50°C for overnight and was measured for transmittance over a range from 400 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°C and initial weight was taken of the film. The film samples were immersed in beaker containing 50 ml of distilled water and placed in an incubator at 30 °C for 24 hours. Thereafter that the film samples were dehydrated in hot air oven at 90°C for 24 hours. The dehydrated film sample was weighed for determining weight of the water soluble solid. Finally, the water dissolved portion of the dried film sample was calculated by using following formula:

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

RESULTS AND DISCUSSION

Proximate analysis

To estimate the proximate values, pea peel sample was dried at 70°C for 24 hours. The proximate analysis included the composition of ash, crude fiber, crude protein, ether extract, acid detergent fiber, lignin and cellulose. The proximate composition mean values and S.D. on dry weight basis are shown in Table 1. In pea peel, the contents of crude protein, ether extract, total ash and crude fiber were recorded as 19.80 percent, 2.27 percent, 5.65 percent and 1.84 percent respectively.

The procedure of acid detergent fiber is used for quick assessment of lignocelluloses in foodstuff. In the present investigation, lignin content was obtained through treating ADF by 72 percent H_2SO_4 solution.

Table 1: Proximate composition values of the pea peel

S. No.	Parameters	Variables
		Mean± S.D
1.	Crude Protein (%)	19.80±1.65
2.	Ether Extract (%)	2.27±0.61
3.	Total Ash (%)	5.65±0.33
4.	Crude Fibre (%)	1.84±0.011
5.	Acid Detergent Fiber (%)	54±1.00
6.	Lignin (%)	25±1.41
7.	Cellulose (%)	30±1.58

It was revealed from the experiment that the value of acid detergent fiber obtained in pea peels was 54 percent, whereas, contents of lignin and cellulose in pea peel were calculated as 25 per cent and 30 per cent respectively.

Product formulation through value addition

Using pea peel waste to formulate bio-plastic can provide sustainable substitute to non-biodegradable plastic. As bioplastics are developed from natural biopolymers, which consist of cellulose, hemicelluloses and lignin (Chen, 2014), these are non-hazardous materials and environmental friendly composites. According to Verma *et al.* (2011) pea peels have good composition of cellulose (61.35%) and lignin (22.12%). As per results of the present study it was obvious that pea peels have good amount of cellulose and lignin, hence, pea peels can be used as biopolymer to produce bio-products.

Graft Co-Polymerization

To develop biopolymer, grafting of methyl-methacrylate (MMA) was done onto pea peel. It was observed from the graft co-polymerization experiment that the obtained grafted samples were viscous, when experiment was started and after drying, it was converted into powder form.

Table 2: Values of grafted yield and total conversion of samples

Grafted sample	Graft yield (%)	Total conversion (%)
Pea peel	7.13	31.4

The results presented in 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 bio-film

Figure 1 illustrates bio- film developed from pea peel. The developed bio- films were somewhat yellow in colour, smooth, thick and showed even surface with fine edges, but due to transparency, the colour was negligible.

The observed values of characteristics i.e. tensile strength, surface thickness and water solubility test of developed bio-film are depicted in Table 3. Scanning electron microscopy (SEM), and Fourier-transform infrared (FTIR) spectroscopy are illustrated in figure 2 and figure 3.

Tensile Strength: From the experiment, tensile strength of bio-film was observed to be 5.96 MPa. This was observed higher than the tensile strength (2.85 MPa) of bio-film developed by Azeredo *et al*. (2009) from mango puree.

Surface Thickness: Thickness of the developed bio-film was found to be 70 µm, whereas, a corn starch based film prepared by Bertuzzi *et al.* (2012) reported film thickness ranging from 30µm to 100µm.

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

Table 3: Characteristics of the developed bio- film

Characteristics	Pea peel bio-film
Tensile strength(MPa)	5.96
Surface thickness (µm)	70.00
Water solubility (%)	2.46

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

Fourier Transform Infrared (FTIR)spectroscopy

FTIR analysis results in absorption spectra which provide information about the chemical bonds and molecular structure of a material. Polyvinyle Butyral (PVB) represents the characteristics of 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 mostly aliphatic and

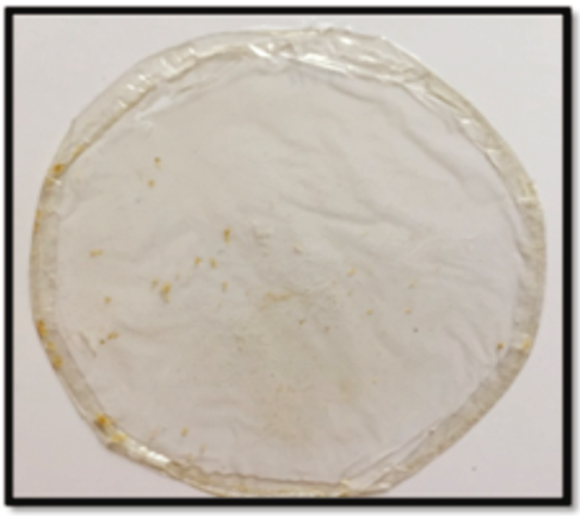

Figure1: Developed Bio Film from Pea Peel Waste

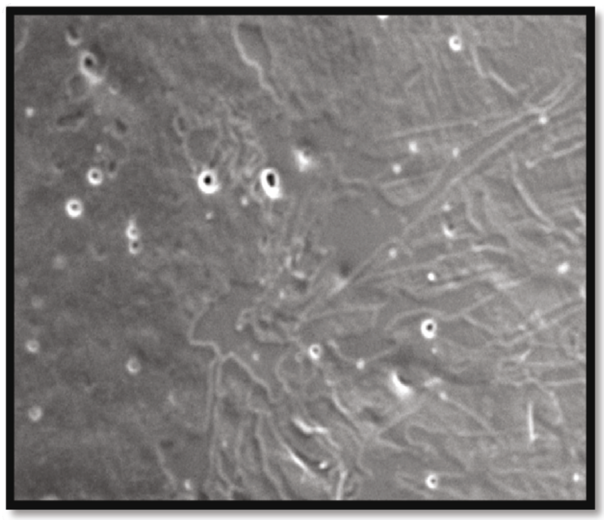

Figure2: SEM image of developed Bio Film

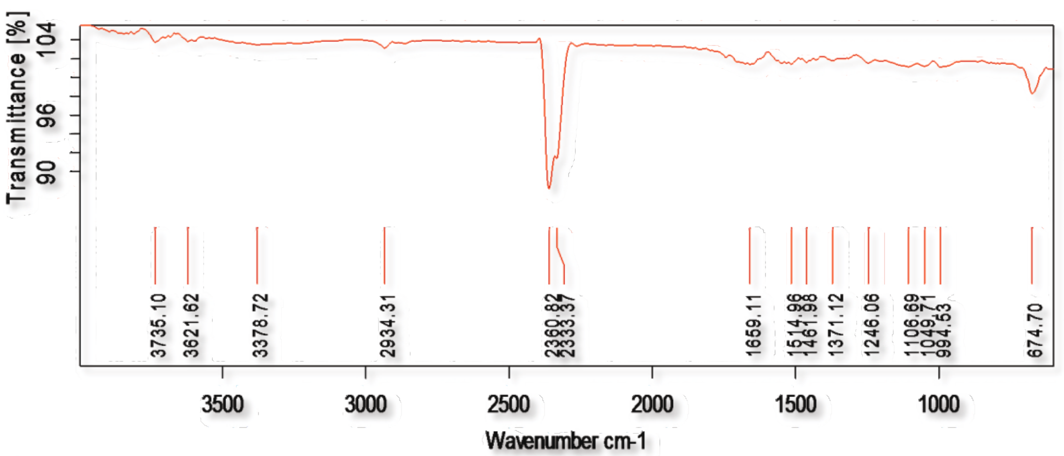

Figure3. FT-IR spectrum of developed Bio Film

aromatic groups. The peak located at 2360 and 2333 cm^{-1} regions represented 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 banding of the alkyl group.

CONCLUSION

In agro industries, organic wastes, which so far were mainly disposed of are now considered a natural wealth, which has tremendous potential not only for generating livelihoods for the poor but can also enrich the soil through composting and recycling rather than creating pollution. Pea processing industry wastes, which otherwise are discarded or used as animal feed, are rich in proximate composition and can be used for preparing value added products. Bio-films prepared from pea peel in the present study have good strength, thickness, water solubility and transparency and can be utilized as a substitute of synthetic plastic and such efficient management of pea processing waste will lead to secured livelihood, pollution free environment and sustainable development.

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