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Effect of potato starch on LDPE and its suitability as food packaging film

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Abstract
This research work was done by incorporating potato starch to develop a biodegradable film using LDPE, glycerol, urea and talc powder. Potato starch incorporated LDPE film was made by blown film extrusion method with different proportions of potato starch T1 (5%), T2 (7.5%), and T3 (10%). Film was then tested for the mechanical and other properties for its suitability in food packaging. The thickness of the film was found in the range of 0.66mm to 1.25mm. The tensile strength was found better for T2 (13.02 MPa). Similarly dart impact resistance of the film was found to be in the range of 0.8 N to 1.2 N. Water absorption of the bio-based film increases from 0.030% to 0.066%. This result was promising so that this biodegradable film can be used for food packaging and it will not deteriorate the environment. The need for bio-plastics is now more than ever as the rate of plastic production and air pollution has increased at a rapid rate.

Keywords: Potato starch, thermoplastic starch, polymers, biodegradability, hydrophilicity

1. Introduction

As well known, synthetic polymer materials have been widely used in every field of human activity during the last decades. These artificial macromolecular substances are usually originating from petroleum and most of the conventional ones are regarded as non-biodegradable. However, the petroleum sources are limited and the blooming use of non-biodegradable polymers have caused serious environmental problems. In addition, the non-biodegradable polymers are not suitable for temporary use such as sutures. Thus, the polymer materials which are biodegradable have been paid more and more attention. Now a day's most of the food items are packed. In everyday life packaging is an important area where biodegradable polymers can be used. (Pawar 2013) [8]. This research aspect has been developed to study a "material" as substitute for petrochemical materials, i.e. plastic products, and to decrease the environmental pollution resulted from the petrochemical materials. Biotechnological processes are being developed as an alternative to existing route or to get a biodegradable biopolymers. This material is called as a biodegradable "Green Plastic", which is derived from plants and microorganisms. Biodegradable plastics arc those that can be degraded in landfills, composters or sewage treatment plants by the action of naturally occurring micro-organisms. Truely biodegradable plastics leave no toxic, visible or distinguishable residues following degradation (Mooney *et al.*, 2009) [6]. The term “biodegradable” materials is used to describe those materials which can be degraded by the enzymatic action of living organisms, such as bacteria, yeasts, fungi and the ultimate end products of the degradation process, these being CO_2, H_2O and biomass under aerobic conditions and hydrocarbons, methane and biomass under anaerobic conditions (Kuorwel *et al.*, 2011) [4]. Tharanathan (2003) [9] studied that the biodegradability is not only a functional requirement but also an important environmental attributes. Increased use of synthetic packaging films has led to serious ecological problems due to their total non-biodegradability. Continuous awareness by one and all towards environmental pollution by the latter and as a result the need for a safe, eco-friendly atmosphere has led to a paradigm shift on the use of biodegradable materials, especially from renewable agriculture feedstock and marine food processing industry wastes. Such an approach amounts to natural resource conservation and recyclability as well as generation of new, innovative design and use. Their total biodegradation to environmentally friendly benign products such as CO_2, water and quality compost is the turning point which needs to be capitalized and en-cashed. Polymer cross-linking and graft copolymerization of natural polymers with synthetic monomers are other alternatives of value in biodegradable packaging films. Although their complete replacement for synthetic plastics is just impossible to achieve and perhaps may be even unnecessary, at least for a few specific applications our attention and needful are required in the days to come. No doubt, eventually bio-packaging will be our future.

Biodegradable plastics are made from starch, cellulose, chitosan, and protein extracted from renewable biomass. The development of most bioplastics is assumed to reduce fossil fuel usage, and plastic waste, as well as carbon dioxide emissions. The biodegradability characteristics of these plastics create a positive impact in society, and awareness of biodegradable packaging also attracts researchers. Plastics are typically composed of artificial synthetic polymers. Their structure is not naturally occurring, so plastics are not biodegradable. Bio-plastics can be defined as plastics made of biomass such as wheat, wheat, sugarcane etc. These substances have been increasingly highlighted as means for saving fossil fuels, reducing CO_2 emission and plastic wastes. Biodegradability of bio-plastics has been widely publicized in society and the demand for packaging is rapidly increasing among retailers and the food. Biodegradable plastics or biodegradable polymers are plastic materials that undergo bond scission in the backbone of a polymer through chemical, biological and/or physical forces in the environment at a rate which leads to fragmentation or disintegration of these plastics (ASTM sub-committee D20. 96). Thus, our objective was to prepare a biodegradable plastic from renewable sources such as starch that would be environment-friendly, to optimize the preparation condition that would help us to study the feasibility and potential of this starch with other additives to obtain a biodegradable as well as high tensile strength plastic.

2. Materials and Methods

Table 1: Composition of developed bio-based plastics

Sr. No.	Treatment	Potato Starch (%)	LDPE (%)
1	T_0	0	100
2	T1	5	95
3	T2	7.5	92.5
4	T3	10	90

2.1 Materials used

The materials that were used for the preparation of bio-based plastics film were Potato starch, Low density polyethylene (LDPE) granules, Talc powder, Urea, Glycerol.

Processing equipment Beaker, Glass Rod, Measuring Cylinders, Hot air oven, Electronics Weighing Balance, Twin Screw Extruder, Blown Film Extruder, Micrometer, Dart Impact Tester, Universal Testing Machine. Evaluation of Properties of Biodegradable Film Film Thickness, Tensile Strength, Dart Impact Test, Test for Biodegradability, Water Absorption Test,

2.2 Methodology

Film Preparation: Potato starch-based LDPE film was prepared as shown in Fig 1.

Mixture of Potato Starch, LDPE, Urea, Talc Powder

⇓

Mixture added to Glycerol

⇓

Compounding by Twin Screw Extruder

⇓

Pelletizing in pelletizer

⇓

Blowing of pellets by Blown Film Extruder

⇓

Potato Starch based LDPE Film

Fig 1: Flowchart for film preparation

2.3 Statistical analysis: Statistical analysis was conducted as per the data obtained from four treatments of and was analyzed statistically by Analysis of Variance technique-ANOVA one way classification. This technique was developed by Dr. R.A. Fisher in 1923.

3. Results and Discussion

The results obtained for various test on the "effect of potato starch on LDPE and its suitability as food packaging film" are summarized below

3.1 Development of potato starch incorporated LDPE packaging film

The biodegradable film sample was prepared using LDPE different composition of potato starch and additives such as glycerol, urea and talc powder. The sample of LDPE was labelled as T0, sample with 5% potato starch labelled as T1, sample with 7.5% potato starch labelled as T2, sample with 10% potato starch labelled as T3. Table 2 shows the different composition of LDPE, potato starch and additives. The film developed were shown in Fig 2 Fig 3.

Table 2: Different Composition of Biodegradable Film

Treatment	LDPE (%)	Potato Starch (%)	Glycerol (ml)	Urea (mg)	Talc Powder (mg)
T_0	100	…..	…..	…..	…...
T_1	95	5	100	40	40
T_2	92.5	7.5	100	40	40
T_3	90	10	100	40	40

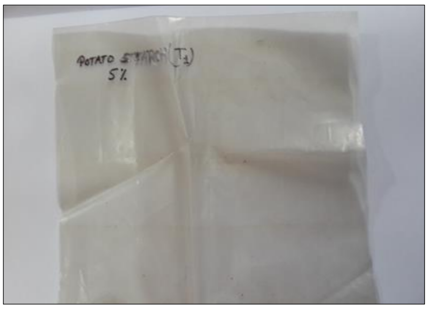

Fig 2: Biodegradable Film (T1)

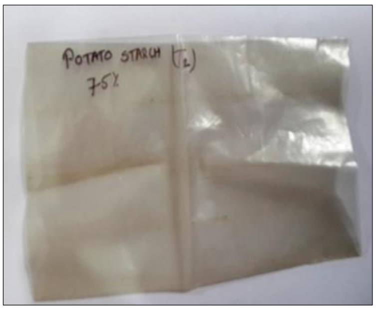

Fig 3: Biodegradable Film (T2)

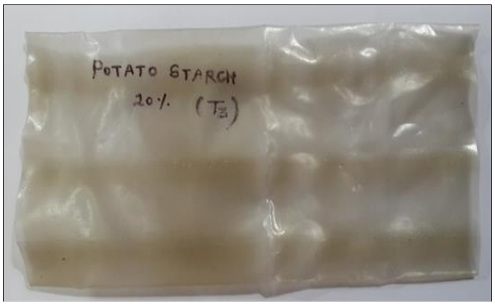

Fig 4: Biodegradable Film (T3)

3.2 Evaluation of properties of produced biodegradable film thickness

Thickness is the physical property which is usually defined as the distance between the top and bottom. Thickness of packaging material should be same throughout as it affects the other properties of packaging materials. The film thickness was kept approximately constant and the thickness was measured at four different points of each sample. The mean thickness was then calculated using screw gauge and it was observed that the mean thickness was in the range of 0.65 mm to 1.2 mm. All the readings are shown in the Table 3 and are graphically plotted in Fig. 4. Similar results were obtained in the studies conducted by Oromiehie *et al.*, (2012) [7] whose work was on physical and thermal mechanical properties of corn starch/LDPE composites.

Table 3: Thickness of biodegradable film

Thickness of film (mm)				
Treatment	**R_1**	**R_2**	**R_3**	**Mean**
T_0	0.95	0.95	0.95	0.95
T_1	0.65	0.68	0.65	0.66
T_2	0.95	0.98	0.95	0.96
T_3	1.25	1.25	1.1	1.2

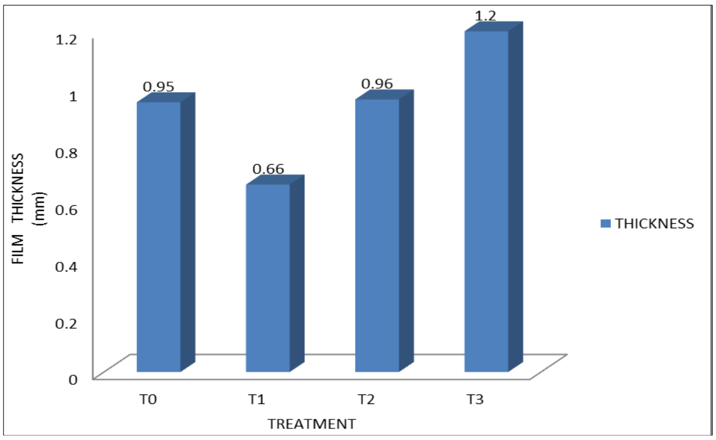

Fig 5: Effect of different treatment on Thickness of Film

3.3 Tensile strength

Tensile strength is the ability of a material to withstand a pulling (tensile) force. It is customarily measured in units of force per cross-sectional area. This is an important concept in food packaging. A higher tensile strength is generally preferred for food packets used for shipping and it helps to ensure better seal. To be plasticized with some plasticizers i.e. Glycerol was used in this study. The plasticized films were prepared and tested for tensile strength using texture profile analyzer in which the exact tensile strength can be measured according to ASTM D882.

The tensile strength of films T1, T2 and T3 are depicted in Fig 5. The results showed that the sample T2 was found to have the maximum strength i.e. 13.02 Mpa force and the minimum strength was showed by the sample T3 i.e. 7.21 Mpa force. These differences on the mechanical behavior of the formulated films could be explained by the plasticizers (present in biodegradable potato starch film) interacting with film constituents causing changes in the properties of the continuous phases. Similar results were obtained in the studies conducted by Lu *et al.* (2009) [5], whose work was on starch-based completely biodegradable polymer materials and Ezeoha *et al.* (2013) [3] whose work was based on cassava starch and PVA.

3.4 Elongation at break

The elongation at break of LDPE/potato starch composite films is inversely proportional with starch content due to its embrittlement properties. The elongation at break decreases from 333.49% down to 176.34% with increase in starch content from 5 to 10%. This is due to (i) physical incorporation of starch in the matrix of LDPE that weakens the London forces between LDPE layers and (ii) the fact that starch, a low molecular weight polymer, has lower elongation compared to LDPE. Incorporation of starch causes discontinuity in the film matrix, leading to lower elongation due to lack of chemical interaction between starch and LDPE. Approximate results were obtained in the studies conducted by Oromiehie *et al.*, (2012) [7] whose work was on physical and thermal mechanical properties of potato starch/LDPE composites an indication of the elongation at break results achieved is depicted in Fig 6.

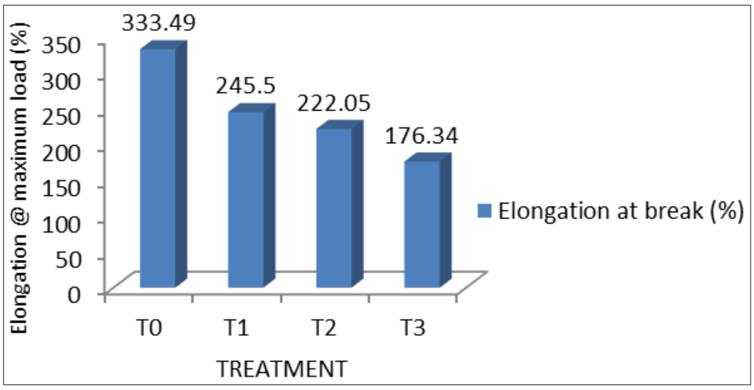

Fig 6: Elongation at Break

3.5 Dart impact test

The impact failure load obtained from a drop height of 66 cm for sample T0, T1, T2 and T3 was depicted in table 4. The dart impact resistance of T2 was found to be 1.02 N which is the best among the all treatment. The dart impact of biodegradable film depends upon the thickness of the film. Fig 7 showed the dart impact resistance of different treatment of bio plastics.

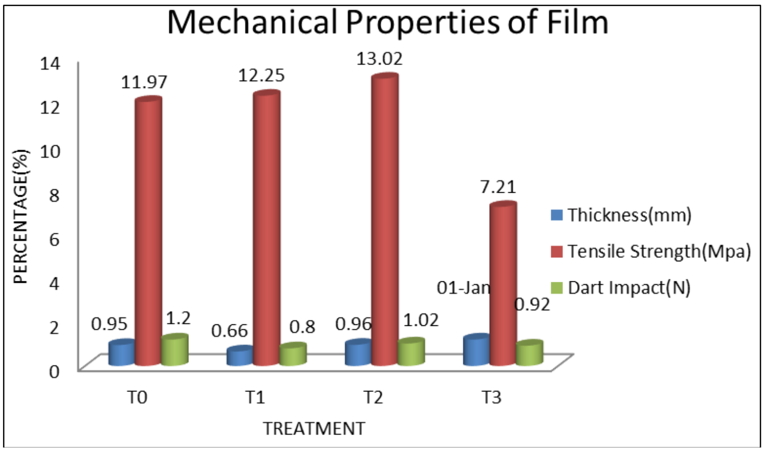

Fig 7: Effect of different treatment on tensile strength, thickness and dart impact test

3.6 Water absorption

The water absorption of composite films is directly proportional to starch amount incorporated into polymer matrix. In other words, the water absorption would increase by increasing the starch content in LDPE. The starch is responsible for water absorption due to hydrophilic nature of starch and ionic character of hydroxyl groups of starch. Composites with more water absorption have lower mechanical properties.

Regarding the starch content, the water absorption of pure PE, composites and pure starch is varied from 0.005 up to 0.070%. Table 4 showed reasonable water absorption in comparison with Oromiehie *et al.*, (2012) [7] work.

Table 4: Water Absorption of the Film

Water Absorption of film (%)				
Treatment	**R_1**	**R_2**	**R_3**	**Mean**
T_0	0.005	0.005	0.005	0.005
T_1	0.024	0.030	0.032	0.028
T_2	0.040	0.046	0.048	0.044
T_3	0.054	0.062	0.070	0.062

3.7 Soil burial biodegradation method

Soil burial experiments represent a more significant approach to natural environments. In addition, using a natural complex media, with broad mixed microbial communities it should be expected a higher mineralization of polymeric materials. So samples were submitted to soil burial tests, in order to assess the biodegradability of LDPE/Potato Starch based blends films in an approximately natural environment. River soil used in biodegradation experiment was taken from Yamuna river front Prayagraj has a total nitrogen content of 1.34g/kg and SO content of 2.95wt %. Before performing each characterization on LDPE/Potato Starch based blends films that had been incubated in soil, all samples were washed with distilled water until all visible residues were removed. Samples were then dried in a desiccators containing silica gel for at least 72 hours before analysis. Biodegradability is property of material which ensures that it is completely compostable and does not cause any harm to the environment. Different sets of samples were kept in compost for 30 days. It was observed that all the biodegradable film with and without additives degraded within 10 days. There was no loss in weight of plastics kept in compost. 2g of each sample was taken and the weight loss percentage was studied. All the relevant readings of the biodegradation are shown in the Table 5 Azahari *et al.*, (2011) [2] on biodegradation studies of polyvinyl alcohol/corn starch blend films in solid and solution media showed the similar results.

Table 5: Biodegradability of Film

Treatment	10 days (%)	20 days (%)	30 days (%)
T0	0	0	0
T1	0	0	0
T2	0	0	0.07
T3	0	0	0.10

3.8 A declaration by authors as per certificate given below

This to certify that the reported work in the paper entitled "The effect of potato starch on LDPE and its suitability as food packaging film" submitted for publication in the journal "Journal of Scientific and Industrial Research (JSIR)" is an original one and has not been submitted for publication elsewhere. I/we further certify that proper citations to the previously reported work have been given and no data/tables/figures have been quoted verbatim from other publications without giving due acknowledgement and without the permission of the author (s). The consent of all the authors of this paper has been obtained for submitting the paper to the journal "Journal of scientific and industrial research (JSIR)".

4. Conclusion

It could be concluded that

- Potato starch incorporated LDPE bio-plastics film can be prepared in three proportion T1, T2 and T3 using blown film extrusion method.
- Mechanical properties of T2 sample was found reasonably better as compared with other sample.
- Potato starch incorporated LDPE film can be used for food packaging application.

It could be concluded that the starch has direct effect on biodegradation because micro-organisms would attack to starch leading to biodegradability of the composite films from this result it can be concluded that potato starch can be a good polymer with LDPE and can be used as a packaging material. It can be regarded as a boon for our society in controlling pollution.

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