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Biodegradable sheet: A blend of corn starch & chitosan an alternative to conventional plastics

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Abstract
A study on biodegradable sheet: A blend of Corn Starch and Chitosan- An alternative to conventional plastics, was carried out by compression moulding method, incorporating thermoplastic chitosan in thermoplastic Corn Starch matrix, using glycerol, citric acid, and water. Functional properties like Tensile strength, Elongation at break % and biodegradability properties were studied. The sheets were made in two different proportions, T1 and T2 with varying composition of Corn Starch and chitosan. T1 with 60% Corn Starch and 40% Chitosan whereas T2 with 70% Corn Starch and 30% Chitosan. Biodegradable sheets were prepared with average thickness of 1.341 mm. Treatment T1 with higher chitosan percentage showed a better tensile strength of 6.40 MPa as compared to treatment T2 having lesser chitosan percentage of 4.37 MPa. However treatment T2 with higher starch composition resulted in better elongation at break % of 138.06% as compared to Treatment T1 having 119.8 % elongation at break. From the result it can be concluded that the addition of chitosan increase tensile strength while on other side starch provides better elasticity, so cornstarch can be a good biopolymer with another biopolymer chitosan and can be used a biodegradable packaging material. This result was promising and the biodegradable sheet can be used with varied applications for food packaging, holders as trays or partitions and will not harm the environment up to the extent as synthetic packaging material does.

Keywords: Corn starch, chitosan, biodegradability, compression moulding, mechanical properties

Introduction

Food packaging is concerned with the preservation and protection of all types of foods and their raw materials, particularly from oxidative and microbial spoilage and also to extend their shelf-life characteristics.

Increased use of synthetic packaging films has led to serious ecological problems due to their total non-biodegradability. Today's plastics are designed with little consideration for their ultimate disposability or recyclability. This has resulted in mounting worldwide concerns over the environmental consequences of such materials when they enter the waste stream after their intended uses, of particular concern are polymers used in single use, disposable plastic applications. They are not readily broken down by the natural elements in the environment or in waste management infrastructures such as composting to become a part of the biological carbon cycle of our ecosystem. Since the plastic is unable to be degraded by nature, the people tend to incinerate the plastic. In fact, poisonous gases such as dioxins, furans, and mercury will be produced and released to the air. These toxic substances are very harmful to the ecosystem and surrounding environment, this result in an irreversible build-up of these materials in the environment causing scaring of landscapes, fouling of beaches, and posing a serious hazard to marine life. Plastics are resistant to biological degradation because microorganisms don't have enzymes capable of degrading and utilizing most manmade polymers.

Polysaccharides such as starches offer several advantages for the replacement of synthetic polymers in plastics industries due to their low cost, non-toxicity, biodegradability and availability (Fajardo *et al.*, 2010) [3], Starch is a well- known polymer naturally produced by plants in the form of granules which can be obtained mainly from maize, potatoes, corn, and rice**.** Corn being widely available and low cost made is more favorable for biodegradable sheet formation. Chemically, starch is polysaccharide composed of the elements carbon, hydrogen and oxygen in the ratio of 6:10:5, leading to the molecular formula of $(C6H10O5)n$.

Chitosan, which is obtained by partial or total deacetylation of chitin, is one of the most abundant polysaccharides in nature, and a promising material for the production of packaging material is due to the attractive combination of price, abundance and thermoplastic behavior, apart from its more hydrophobic nature as compared to starch.

Moreover, chitosan is non-toxic, biodegradable, and has antimicrobial activity (Matet *et al.*, 2014) [5]. In case of polymers, biopolymer sheet evolved as the development of renewable resource by utilizing agricultural, eggshells and exo-skeleton seafood (chitosan) wastes instead of petroleum sources. Biopolymers from agricultural feed stocks and other resources have the ability upon blending or processing to result in such packaging materials. Their functionality can be better expressed by using in combination with other ingredients such as plasticizers and additives. 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. The potential uses for such biodegradable packaging materials include, use and throw disposable packaging materials, tray holdings, dividers, lamination coating, shrink packaging bags for agricultural mulching (nursery) etc.

So the new innovative technique in the production of biodegradable packaging can promote a sustainable solution to reduce plastic waste together with food waste in long term. Biodegradable packaging shows a great sign to overcome the pollution since it is biodegradable. Prolong to that, it is potentially suitable to replace the plastic materials from petroleum based. Therefore, biodegradable packaging is the better alternative to minimize the cost of solid waste management in India.

Materials and Methods

The Materials like Chitosan, Corn Starch, Citric acid and Glycerol were used, following Compression moulding method for biodegradable sheet preparation.

This chapter includes the design and preparation methods.

Experimental Plan

Various experimental variables is shown in the Table 1

Table 1: Experimental Plan

Variables	Level	Description
Product	1	Biodegradable Sheet
Method	1	Compression Molding Method
Constituents	4	Chitosan, Corn Starch, Citric Acid & Glycerol
Treatment	2	T1 , T2
Mechanical Properties	2	Thickness , Tensile Strength
Degradability Test	1	Soil Degradability Test
Replications	3	3 replications

Treatments used for study

The composition of Corn starch and Chitosan are shown as in Table 2.

Table 2: Different Composition of Treatments used

S. No.	Treatments	Corn Starch (%)	Chitosan (%)
1	T1	60	40
2	T2	70	30

Preparation of biodegradable sheet

The biodegradable sheet was prepared as following the study of Lopez *et al.*, 2014 [4], with few modifications as per the resources available at and research requirements. The entire process of preparation of biodegradable sheet is explained with the help of flow diagram in Figure 1.

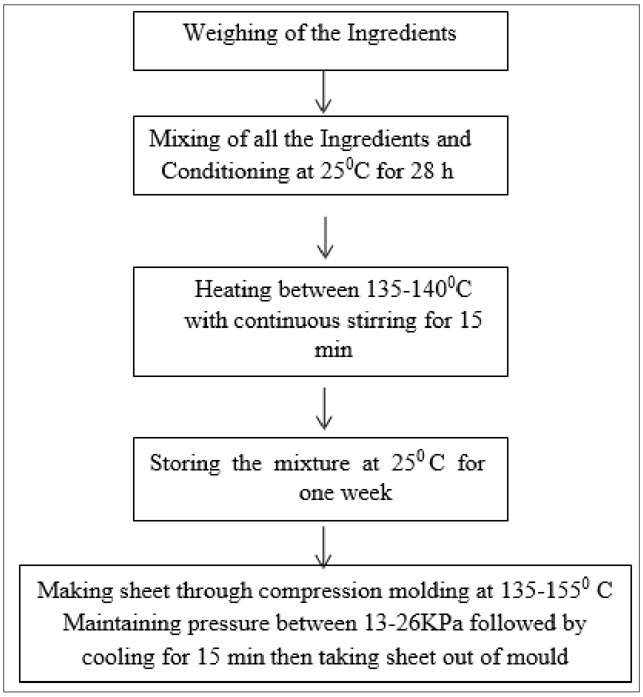

Fig 1: Flow diagram of biodegradable sheet preparation

The biodegradable sheets of two proportions were made by compression molding method.

Physical Evaluation of Biodegradable sheet

Thickness

Thickness gauge was used to measure the thickness of prepared chitosan and corn starch biodegradable sheet. Both of the sheets were tested from three sides to get the mean thickness. The thickness of the sheet was an important parameter because the strength and other parameters are strongly associated with thickness. Thickness is one parameter which is directly related to economy and completely depends on use of sheet or film as packaging material. Less than 1 mm is considered as film.

Tensile strength

Tensile strength is an ability of plastic material to withstand maximum amount of tensile stress while being pulled or stretched without failure**.** Elongation at break also known as fracture strain or tensile, elongation at break is the ratio between increased length and initial length after breakage of the tested sample at a specified temperature. It is related to the ability of a plastic sheet to resist changes of shape without cracking.

Biodegradability

Biodegradation is a process, which describes the organizational structures for the micro-organic mineralization. These micro-organisms make bio plastics in carbon dioxide, methane, water and biomass. The biodegradability test was done to know the impact on environmental pollution. The main goal was to achieve the degradability of the prepared sheet. For this purpose, the samples were buried in the local soil. The test was performed with some modifications as per the following cited paper (Azahari *et al*., 2011) [1].

Results and Discussion

The findings of the research including the study of physical and biodegradable properties are explained in the following headings.

Physical Properties Thickness

Thickness in mm of the both the sheets T1 and T2 are given in Table 3.

Table 3: Thickness of the Biodegradable Sheet

Treatment	R1	R2	R3	Mean (mm)
T1	1.217	1.214	1.219	1.216
T2	1.987	1.20	1.212	1.466

As from the results obtained, the thickness of both sheet were 1.21 and 1.46 mm respectively for T1 and T2. The treatment T2 with higher starch ratio showed slightly more thickness than treatment T1 having less starch ratio, which is in relation from the results found by Navarro *et al.* (2008) [7].

Tensile Strength

The tensile strength and elongation at break % of the sheet*s* T1 and T2 are given in Table 4.

Table 4: Properties of Biodegradable Sheet

Treatment	Replication	Dimension (mm)	Thickness (mm)	Tensile Strength (MPa)	Elongation at Break (%)
T1	1	30 x 80	1.217	5.84	119.4
	2	30 x 80	1.219	6.79	121.1
	3	30 x 80	1.214	6.58	119.1
Mean		30 x 80	1.216	6.40	119.8
T2	1	30 x 80	1.987	4.87	138.6
	2	30 x 80	1.20	4.53	138.9
	3	30 x 80	1.212	3.72	136.7
Mean		30 x 80	1.466	4.37	138.06

The results showed that the sample T1 was found to have the maximum strength, i.e.

6.40 MPa and T2 showed 4.37 MPa. Also, for elongation at break %, sample T2 was found to have maximum % break and sample T1 has the lower respectively 138.06% and 119.8%. These differences on the mechanical behavior of the prepared sheet are due to the changes of the proportions of the additives including plasticizers. Two graphs Fig, 2 and Fig 3 were plotted to represent the relationship of tensile strength and elongation at break % of Treatment 1 versus Treatment 2 respectively, making it clear that chitosan provide strength to the film, on the other side starch helps in providing desired elongation. The above results are in relation with the study of Lopez *et al*., (2014) [4] and Ming *et al*., (2011) [6].

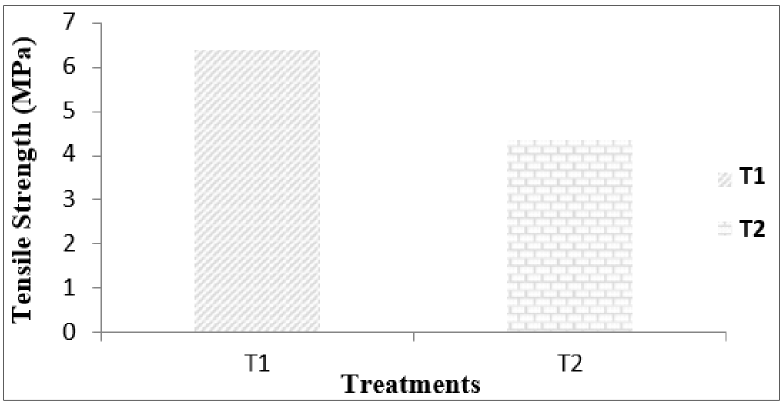

Fig 2: Tensile Strength of the Biodegradable Sheet

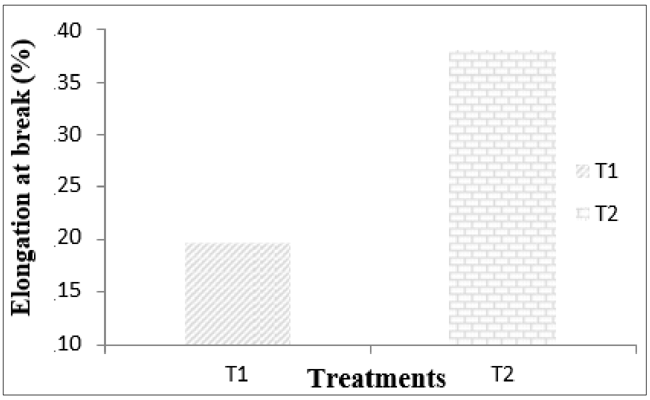

Fig 3: Elongation at break of biodegradable sheet

Biodegradability

To check the biodegradability, Weight was taken after 2nd and 4th week after preparation of the sheet and the weight loss calculated by the below mentioned formula,

$$\text{Weight loss} = \frac{(\text{Initial weight} - \text{Final weight})}{\text{Initial weight}} \times 100$$

All the readings of the degradation are shown in the Table 5. Result showed that sample T2 shows the higher percentage of weight loss, i.e. 22 % and T1 has the lower percentage of weight loss, i.e. 14 % after 4 weeks. It also showed that the degradability rate in 1st week is higher than compared to other weeks of every sample. The values are represented graphically in the .Fig 4 which show degradability after second and fourth week of observation.

Table 5: Degradation (%) of Biodegradable Sheet

Treatment	2nd Week (%)	4th Week (%)
T1	9	14
T2	18	22

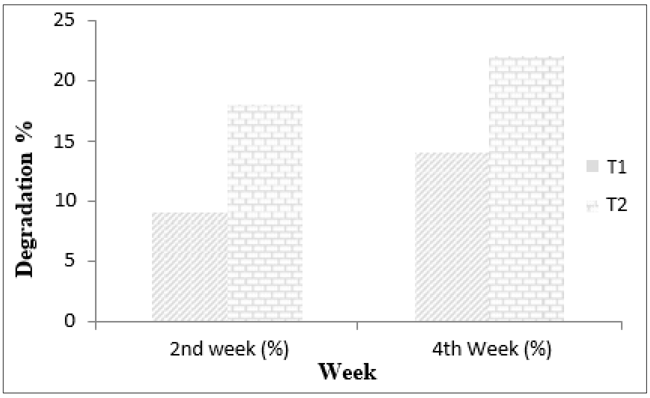

Fig 4: Degradability Test of biodegradable sheet

On observing above degradability results, and evidence from past research of Ezeoha and Ezenwanne (2013) [2], which states that biodegradable film produced was found to have a biodegradability of 41.27% compared to 10.33% and 85.99% for polythene and paper respectively it can concluded that biopolymers like starch and chitosan can replace synthetic polymers on biodegradation aspect as seen from biodegradability test, microorganisms would attack to natural polymers, destroying its state and leading to biodegradability, result in better and fast degradability of biodegradable sheet than synthetic ones.

Conclusion

It can be concluded that addition of chitosan increases tensile strength while on the other side starch provides better elasticity, making it clear that starch on one side increases elasticity and chitosan provides strength. The Tensile strength of sheet determines of which use the sheet should be taken in, like if material is to be used as holding material which requires strength; hence a higher tensile strength can be of use which can be a good replacer for plastics one.

It can also be concluded that biopolymers like starch and chitosan can replace synthetic polymers on biodegradation aspect as seen from biodegradability test, microorganisms would attack to natural polymers, destroying its state and leading to biodegradability, result in better and fast degradability of biodegradable sheet than synthetic ones. Corn starch on other side can be a good polymer with another biopolymer chitosan and can be used as a packaging material. It can bring a tremendous change in whole packaging sector and also will have a surprising role to minimize the increasing environmental pollution and disaster.

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