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Development of Innovative Biodegradable Film from Low Cost Wild Plants – An Effective Alternative to Plastic

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Abstract

Plastic has increased the rate of environmental pollution, as it takes decades to decay into environment. This has diverted the mind of researcher for developing sustainable and cost-effective alternatives of plastics. To avoid use of plastic, a biodegradable film has been developed in the current study with natural ingredients i.e. Terminalia catappa and Oryza Sativa extract. Different blends were analyzed for functional properties, and blend containing 25mL/25mL of both of the extracts was selected for final testing. Each film was observed to have different chemical, mechanical physical and biological properties. Sample 1 is found to possess the highest value of tensile strength (5.21MPa) and the value of elongation at break of sample 3 (7.13%) was the highest among all three newly developed biodegradable films, whereas the sample 2 showed the least value for both of the tests carried out. Biodegradable films have shown lower transparency than control. It may be due to the thickness and fillers used in the making of biodegradable films. The results of biodegradation by burial in soil clearly indicate quick biodegradation ability of newly developed films as compared to the control; each film was degraded completely in sterile soil in 7 to 9 days. The control sample (polyethylene film) did not show any structural degradation and change in shape. Reaction of the three newly developed biodegradable films with acid, base, salt and alcohol was also studied. Strong acid caused definite effects on all three films, whereas reaction with alkali made shape change in the newly developed biodegradable films. Based on the results sample 3 prepared with 25mL/25mL Terminalia catappa and Oryza Sativa extract with 2gm guar gum was found to possess the best chemical, mechanical physical and biological properties; as well a sustainable and cost-effective hand alternative of plastics.

Keywords: Biodegradable films, *Terminalia catappa* and *Oryza Sativa*

Introduction

Plastic packaging has been utilized worldwide but it generates significant externalities. Irrespective of the financial losses, the query of plastic's effect at the surroundings and human health is a prime thing of the controversies surrounding plastic today. Scientists have proven that the toxicity of plastic pollution, inclusive of nano plastics, has a poor effect on marine animals (Arnaud 2019). Synthetic polymers are essential in lots of branches of industry, in particular within side the packaging industry. However, it has an unwanted affect at the surroundings and reasons issues with deposition of waste and consumption. Therefore, there's an inclination to update the polymer with biodegradable polymer that undergoes a process (Faris, Noriman *et al.* 2014). Starch, cellulose and latex have captured the focus of researcher in developing plant based material such as biodegradable plastic (Moire, Rezzonico *et al.* 2003). Biodegradable plastics isolated from transgenic plants, which might have packaging and coating applications for example, might be environmentally friendly alternatives to synthetic petro chemical polymers and a further field of an imagined plant-based material economy. Different agricultural expression

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systems that can be used for large-scale production of recombinant proteins have been developed in recent years. These systems include promoters, intracellular targeting and organ-specific expression (Ma, Drake *et al.* 2003).

Terminalia catappa, which is also known as Indian almond, java almond, and tropical almond tree; are generally found in coastal plains, and near river mouths. Various parts of the plant are used for medicinally that may include; diabetes, skin diseases, sores, diarrohea, fever, numbness, colic, pain jaundice, dysentery leprosy, coughs, headaches, indigestion. Roots, fruits, bark, leaves and roots of *Terminalia catappa* are all important sources of tannin and the gum is obtained from the trunk of *Terminalia catappa* (Zan 2011).

Rice (*Oryza Sativa*) is one of the leading food crops of the world and is a staple food of over approximately one-half of the world population (Singh, Kaur *et al.* 2005). Rice production in China has a spectacular increase in the recent years and is approximately 30 per cent of the total rice production of the world (Zhang 2007). Rice that is low in amylose and high in amylopectin is sticky in the wake of cooking. It is ideal for risottos and rice puddings; sticky rice (glutinous rice) is likewise favored in Asian cooking since it is anything but difficult to eat with chopsticks. High edibility is one of the drawbacks of the carbs in sticky rice. For high-carb sustenance, great absorbability isn't generally positive since it might cause an unfortunate spike in glucose, particularly among diabetics (Li, Prakash *et al.* 2016).

The present study aims to synthesize eco-friendly biodegradable films from plant sources i.e. *Terminalia catappa* and *Oryza Sativa;* and to develop an alternative for conventional petrochemical plastic in a cost-effective way. The physical, mechanical and biodegradable properties of the newly synthesized eco-friendly biodegradable film are also evaluated in the current study. It is recommended to carry out a study of the usage of newly developed biodegradable film in packaging of food commodities.

Methodology

Chemicals and Glassware

Analytical grade chemicals were used for analysis. All glassware was pre-rinsed with 10% HCl followed by deionized water.

Ingredients

Leaves of *Terminalia catappa* and *Oryza Sativa* were collected directly with extra care from locally grown tree/ plant at Orangi Town, Karachi. Identification of the *Terminalia catappa* and *Oryza Sativa* leaves was confirmed by the Botany Department, University of Karachi.

Preparation and Formulation of Biodegradable Films

The dirt and other possible impurities were removed by washing the sample with distilled de-ionized water. *Terminalia catappa* and *Oryza Sativa* leaves were kept for fifteen days at room temperature for drying. The dried leaves of *Terminalia catappa* and *Oryza Sativa* were grinded into powder and 10gm of powdered leaves were extracted using water:ethanol (5:95v/v) as a solvent by soxhlet extraction method. In Table-1 the formulation of newly established biodegradable films has been summarized, in synthetic polyethylene films ws used as control.

Table 1: Formulation of Biodegradable Films

S.No	Ingredients	Control	Sample1	Sample2	Sample3
1.	*Terminalia catappa* Extract	Nil	25ml	25ml	25ml
2.	*Oryza Sativa* Extract	Nil	25ml	25ml	25ml
3.	Gelatin	Nil	16g	Nil	Nil
4.	Xanthan Gum	Nil	Nil	2g	Nil
5.	Guar Gum	Nil	Nil	Nil	2g
6.	Water	Nil	20ml	20ml	20ml
7.	Glycerol	Nil	2-5drops	2-5drops	2-5drops

After mixing the ingredients the mixture was heated with constant stirring on a hot plate until the thick gelatinized consistency occurred. The paste was then poured onto aluminum foil and placed in hot air oven at 45°C for 2 days. The films were peeled off and processed for further analysis as shown in Figure-1.

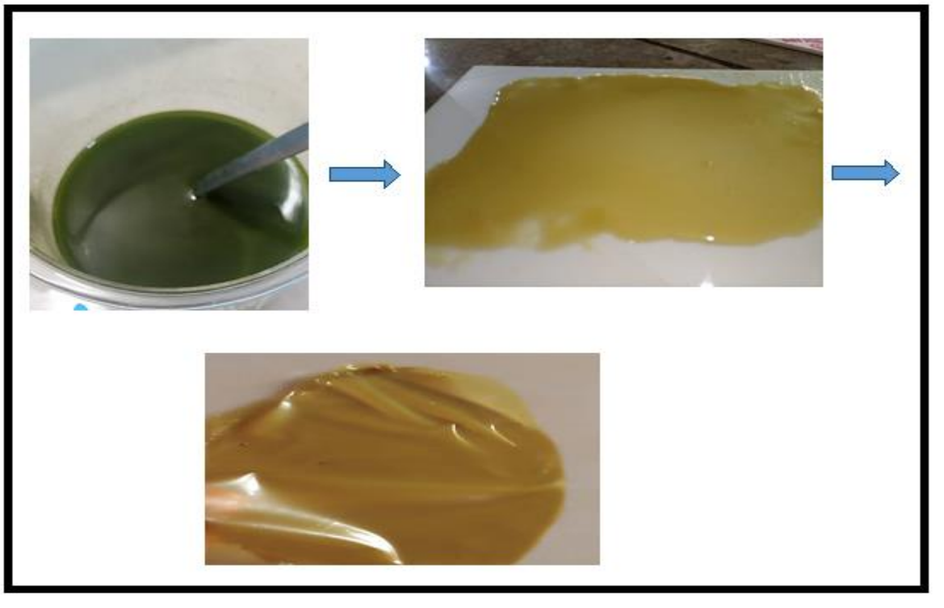

Figure 1: Preparation of Biodegradable Films

Characterization of Biodegradable Films

A screw gauge was used for measuring the thickness of the newly prepared films. The films produced were cut into 2cm × 2cm dimension for testing. At random positions, the thickness of each film samples measured and values were noted. The mean values of thickness were used in the further tests. Other physical tests were carried out by the methods prescribed earlier; such as the swelling percentage by ASTM D570 (Standard 1998), water absorption percentage (Krishnamurthy and Amritkumar 2019), film transparency (Riaz, Lei *et al.* 2018), water solubility of the film samples (Saberi, Chockchaisawasdee *et al.* 2017), tensile strength by ASTM D882-02 (International 2012), chemical resistance (Jack, Ngah *et al.* 2017), flame test (Levitan 2016), transparency test (Mulyono, Suhartono *et al.* 2015) and heat seal strength by ASTM F88 (ASTM 2015). Thermo-gravimetric analysis of the biodegradable films was carried out by using thermal analyzer—Universal V4.4A, TA Instruments, USA.

Biological parameters

Soil Burial Biodegradation

The newly developed biodegradable films and control samples were cut into small strips. The films were buried in garden soil for specified amount of time to check biodegradation of samples. Climate and temperature conditions were also recorded. Biodegradation of biodegradable films and synthetic polyethylene plastic was compared (Leja and Lewandowicz 2010).

Results and Discussion

Physical Properties of biodegradable films has been compared in Table 2. Sample-3 is found to be the more ductile, with soft and flexible texture. Whereas sample-2 was found to be brittle with rough and less flexible texture.

Table 2: Physical Properties of Biodegradable Films

S.No	Properties	Sample-1	Sample-2	Sample-3
1.	Ductility	Moderate	Low	High
2.	Brittleness	Moderate	High	Moderate
3.	Texture	Smooth shiny surface and flexible	Rough and less flexible	soft and flexible
4.	Recasting ability	Yes	Yes	Yes

Table 3 presents the thickness and transparency of the three films. Biodegradable films have shown lower transparency than control. It may be due to the fillers used in the making of biodegradable films. Sample-3 showed better transparency as compared to other two samples. The results of transparency of the films are found to be better than the topiaco film reported earlier (Mulyono, Suhartono *et al.* 2015).

Table 3: Thickness and Transparency of Biodegradable Films

S.No	Properties	Control	Sample-1	Sample-2	Sample-3
1.	Thickness (mm)	0.12	0.29	0.31	0.27
2.	Absorbance	0.398	0.494	0.532	0.421
3.	Transmittance%	39.99	32.03	29.44	37.92
4.	Transparency	13.34	5.19	4.74	5.85

Table 4 shows percentage of water absorption with respect to mass gained, by the three films, and the trend was similar to swelling percentage. Sample-2 has swollen the most among all other samples of biodegradable films. It may be due to the starch and hydroxyl group not involved in cross linking of filler reacting with water leading to swelling of biodegradable film (Saberi, Chockchaisawasdee *et al.* 2017).

Table 4: Water Absorption Property of Biodegradable Films

S.No	Properties	Sample-1	Sample-2	Sample-3
1.	Mass before immersion (g)	0.30±1	0.28±1	0.28±1
2.	Mass after immersion (g)	0.40±1	0.78±1	0.43±1
3.	Percentage	33.3	178.6	53.6

The results of reaction of the three newly developed biodegradable films with acid, base, salt and alcohol are summarized in Table 5 (Sample-1), Table 6 (Sample-2) and Table7 (Sample -3). Strong acid caused definite effects on all three films, whereas reaction with alkali made shape change in the developed biodegradable films. The results of chemical reaction of the films with solvents are found to be comparable with the results reported earlier (Jack, Ngah *et al.* 2017).

Table 5: Chemical Reactions of Bio Degradable Films Sample-1

S.No	Properties	HCl (0.1M)	NaOH(0.1M)	NaCl (Sat)	Ethanol (50%)
1.	Change in dimension	✓	X	X	X
2.	Dissolved in the liquid	✓	X	X	X
3.	Absorbed the liquid	✓	✓	✓	✓
4.	Wrinkle	X	X	X	X
5.	Softend	✓	✓	✓	✓
6.	Brittle	X	X	X	X

Table 6: Chemical Reactions of Bio Degradable Films Sample-2

S.No	Properties	HCl (0.1M)	NaOH(0.1M)	NaCl (Sat)	Ethanol (50%)
1.	Change in dimension	✓	X	X	✓
2.	Dissolved in the liquid	✓	X	X	X
3.	Absorbed the liquid	✓	✓	✓	✓
4.	Wrinkle	X	X	X	✓
5.	Softened	X	✓	X	✓
6.	Brittle	X	X	X	✓

Table 7: Chemical Reactions of Bio Degradable Films Sample-3

S.No	Properties	HCl (0.1M)	NaOH(0.1M)	NaCl (Sat)	Ethanol (50%)
1.	Change in dimension	✓	X	X	X
2.	Dissolved in the liquid	✓	X	X	X
3.	Absorbed the liquid	✓	✓	✓	✓
4.	Wrinkle	X	X	X	X
5.	Softened	✓	✓	✓	✓
6.	Brittle	X	X	X	X

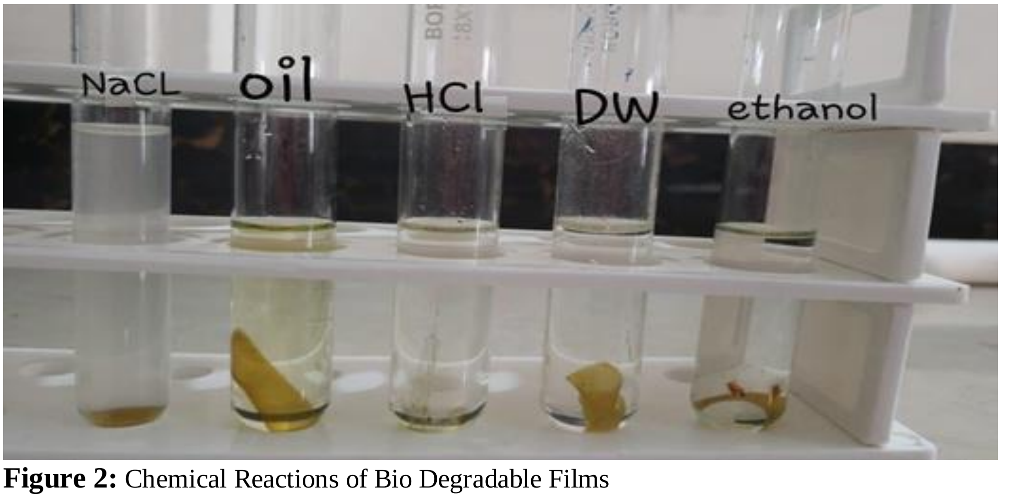

Figure 2: Chemical Reactions of Bio Degradable Films

Reaction of the three newly developed biodegradable films with acid, base, salt and alcohol was also studied, and the results are shown in figure 2. It can be clearly observed that strong acid caused definite effects on all three films, whereas reaction with alkali made shape change in the newly developed biodegradable films.

Results of tensile strength and elongation at break of the newly developed films are summarized in Table 8. Sample 1 is found to possess the highest value of tensile strength (5.21MPa) and the value of elongation at break of sample 3 (7.13%) was at higher side among all three newly developed biodegradable films, whereas the sample 2 shown the least value for both of the tests carried out. Tensile strength is the structural resistance of newly developed films against tension caused by load and elongation at break capability of natural fibers to resist in change of shape. The structural strength and toughness is the basic reason of high tensile strength value of the sample 1, and high elongation value of sample 3 is may be due to the long ductility of the film, that may be due to the glycerol which improve the mechanical properties and flexibility of the films. Type of plasticizer may also contribute the mechanical properties of the newly developed films (Kumar and Singh 2008).

Table 8: Mechanical Properties of Biodegradable Films

S.No	Properties	Sample-1	Sample-2	Sample-3
1.	Tensile Strength (MPa)	5.21	0.88	1.94
2.	Elongation at Break (%)	33.65	2.63	71.13

Biodegradation by burial in soil is displayed in Figure 3. The biodegradation of newly established films was tested daily. On day 5 the films have been degraded in the soil and small pieces are observed (Figure 3). The results clearly indicate quick biodegradation ability of newly developed films as compared to the control. The results were found to be satisfactory, as expected; each film was degraded completely in sterile soil in 7 to 9 days. The control sample (polyethylene film) did not show any structural and change in shape. This test was crucial or key test for packaging films. The degradation results are found to be better than the results (9-12 days) of biodegradable films developed from cassava reported earlier (Retnowati, Ratnawati *et al.* 2015).

Figure 3: Biodegradability of Bio Degradable Films

Conclusions

Biodegradable films have been developed in the current study with blend of *Terminalia catappa* and *Oryza Sativa* extract. Different blends were analyzed for functional properties, and blend containing 25mL/25mL of both of the extracts was selected for final testing. Each film was observed to have different chemical, mechanical physical and biological properties. Sample 1 is found to possess the highest value of tensile strength (5.21MPa) and the value of elongation at break of sample 3 (7.13%) was at higher side among all three newly developed biodegradable films, whereas the sample 2 shown the least value for both of the tests carried out. Biodegradable films have shown lower transparency than control. It may be due to the thickness and fillers used in the making of biodegradable films. The results of biodegradation by burial in soil clearly indicate quick biodegradation ability of newly developed films as compared to the control; each film was degraded completely in sterile soil in 7 to 9 days. The control sample (polyethylene film) did not show any structural and change in shape. Reaction of the three newly developed biodegradable films with acid, base, salt and alcohol was also studied. Strong acid caused definite effects on all three films, whereas reaction with alkali made shape change in the developed biodegradable films. Based on the results sample 3 prepared with 25mL/25mL *Terminalia catappa* and *Oryza Sativa* extract with 2gm guar gum was found to possess the best chemical, mechanical physical and biological properties; as well a sustainable and cost-effective hand alternative of plastics.

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