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Preparation and Study of Mechanical and Biodegradable Properties of PVA Based Bioplastic Blends Derived from Broken Rice Flour

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ABSTRACT

A promising answer to lessen the utilization of the traditional plastics of petrochemical origin and, consequently, plastic waste disposal, is their replacement with biodegradable materials (generally called "bioplastics"). In modern times, bioplastics have attracted significant attention because of their environmental advantages. This research work focuses on synthesis and study of mechanical and biodegradable properties of rice flour starch-based plastics. Rice flour is made up of micronized rice grains, which retain their vital carbohydrates and proteins; unlike pure rice starch, rice flour comprises roughly 78% starch and 7% protein. Rice flour is a starchy substance with low-cost, because it can be produced from rice that is broken during processing. Films from rice starch and rice flour were prepared by casting, with PVA (cross linker) and glycerol as plasticizer. PVA was varied in mass ratios of 05, 10, 15 and 20% in the starch /PVA blend. Mechanical properties (such as tensile strength, percentage elongation, and thickness) of the blends were studied. The results showed that 20% PVA plastic had the highest tensile strength, elongation and thickness of 10.02 MPa, 484.69%, and 0.44 mm respectively. Biodegradability test was done via soil-burial method and the PVA/rice flour blend was noted to be biodegradable.

Key words: Bioplastics, Rice flour, Tensile strength, Percentage elongation, Biodegradability test

Plastics are one of the most important petrochemical-based products and they are used in all aspects of life. Plastic's leading market is packaging, an application whose growth was enhanced by a global shift from reusable to single-use containers. Worldwide, more than 8.3 billion tonnes of plastic have been produced since 1950, and about 60 per cent of that has ended up in landfills or in the natural environment. As an outcome, the share of plastics in municipal solid waste (by mass) amplified from less than 1% in 1960 to more than 10% by 2005 in middle- and high-income countries [6]. The vast mainstream of monomers used to make plastics, such as ethylene and propylene, are derived from fossil hydrocarbons. None of the generally used plastics are biodegradable. As a result, they accumulate, rather than decompose, in landfills or the natural environment [2]. A promising answer to lessen the utilization of the traditional plastics of petrochemical origin and, consequently, plastic waste disposal, is their replacement with biodegradable materials (generally called "bioplastics"). In modern times, bioplastics have attracted significant attention because of their environmental advantages. Biopolymers may be naturally occurring materials in which most of the materials formed in nature during the life cycles of green plants, bacteria, animals and fungi are polymers or polymer matrix composites. Plants generally produce massive amounts of biomass by carbon dioxide fixation through photosynthesis. Plant biomass synthesis is estimated to be about 140 billion tonnes annually [4]. Biomass includes materials such as lignin, cellulose and starch which are produced continuously and are almost inexhaustible, unlike fossil fuels. It is not surprising that plastics are also being made from plant polymers since the first known man-made plastic material (in 1862) was cellulose nitrate [7] and another one of the earliest plastics used in the mid-nineteenth century, collodion, was made with cotton cellulose [3]. In recent times, starch has emerged as one of the primary raw materials for eco-friendly plastics. Thermoplastic starch (TPS) is relatively new material for application as biodegradable plastic. In spite of its biodegradability, starch-based bioplastics still possesses some disadvantages as compared to its petrochemical based counterpart. Mostly starch based bioplastics are water solubility and have poor mechanical properties. The water resistance of TPS may be enhanced by integrating it with biodegradable polymers. In this research article, biodegradable composites of broken rice flour using glycerol as a plasticizer and polyvinyl alcohol as cross linker were

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synthesized and Mechanical properties (tensile strength, percentage elongation, young modulus and Thickness) and the blends were studied [1]. In addition, the biodegradability of the bioplastic samples was studied using soil burial method.

MATERIALS AND METHODS

The Broken rice that was utilized for this work was obtained from local rice mill from Vasai, India. The broken rice was further milled in a grinder to get a fine powder which was dried in an oven at 50°C for 24 hours before use. The powder was sieved through 250 µm size sieve. The different blends of broken rice flour were prepared using distilled water as a diluent i.e., 15% and 20%. The blends were further mixed appropriately and placed on an orbital shaker for 30 minutes. After that the blends were filtered using a muslin cloth placed on a 250 µm sieve so as to ensure that only liquid solution is collected in a collecting tray. The starchy solution thus obtained was used as a substrate for bioplastic production. An amount of starch extract, and glycerol were measured into a 500 mL beaker. The mixture was mixed thoroughly and thereafter, PVA was poured into the starch extract-glycerol mixture. Twelve samples were made with various amount of PVA as shown in (Table 1). The PVA based rice extract blend were made in a glass petri dish and then dried in an oven for 10 hours at a temperature range of 60-80°C.

Table 1 Composition of the bioplastic samples

Sample	Broken rice flour (%)	PVA (%)	Glycerol (ml)	Urea (g)	Precipitated silica (g)
A	15	5.0	2.5	0.5	0.5
B		10	2.5	0.5	0.5
C		15	2.5	0.5	0.5
D		20	2.5	0.5	0.5
E	20	5.0	2.5	0.5	0.5
F		10	2.5	0.5	0.5
G		15	2.5	0.5	0.5
H		20	2.5	0.5	0.5

Mechanical properties

Tensile strength and elongation

The tensile strength and elongation test was performed using a Shimadzu AG-IS 50 kn (Japan) testing machine according to ASTM D 882. The samples had a dimension of 130 mm × 25 mm with a gauge length of 25 mm at a cross head speed of 10 mm/min. Clamp the specimen at grip length. Set the speed of testing, load range and chart speed. Start the machine and record the load extension at the yield point and the load and extension at the moment of rupture. The tensile strength was expressed in MPa and elongation in percentage. Five specimens were used to obtain the average values for tensile strength and elongation at break.

Thickness

The thickness of the bioplastics was measured using a deadweight dial micrometer according to IS 2508. Five specimens, at least 5 × 5 cm in area of each sample were taken uniformly across the width of the test piece. The thickness of the bioplastics was measured by using the thickness gauge. The thickness was measured by holding the work piece between stylus and anvil, reading the value directly. Calculate the mean to obtain the average thickness of the sample.

Biodegradability studies

The bioplastic films were buried in composted soil that was purchased from a flower nursery; the test was conducted according to the method described by Thakore *et al*. [9] with a slight modification. Two different pots were filled to their approximate capacity of 10 L with soil and compost. The samples were cut into 70 × 50 mm pieces and buried in the soil at a depth of 10 cm. The soil was placed in the laboratory, and the moisture of the soil was maintained by sprinkling water at regular time intervals. The excess water was drained through a hole at the bottom of the pot [9]. The degradation of the samples was monitored at regular time intervals (7 days) by cautiously removing the sample from the soil and washing it gently with distilled water to remove soil from the film. The sample was dried under vacuum until a constant weight was obtained. Weight loss of the sample over time was used to indicate the degradation rate of the soil burial test.

The soil burial test was performed by evaluating the weight loss of the film over time. The weight loss was determined every seven days from the starting day, and was calculated as follows:

$$\text{Weight loss (\%)} = \frac{W_i - W_d}{W_i} \times 100$$

Where;

W_d is the dry weight of the film after being washed with distilled water,

W_i is the initial dry weight of the specimen

Table 2 Mechanical properties of bioplastic samples

Sample	Tensile strength (MPa)	Percentage elongation (%)	Thickness (mm)
	Mean	Mean	Mean
A	5.73	459.94	0.15
B	6.08	484.69	0.18
C	6.71	400.25	0.24
D	10.02	358.16	0.24
E	1.91	403.74	0.24
F	4.44	361.67	0.24
G	4.4	361.27	0.44
H	6.21	300.71	0.44

RESULTS AND DISCUSSION

Mechanical properties

The (Table 2) shows the values for tensile strength and percentage elongation for different blends obtained by mixing varying concentration of broken rice flour and PVA. It was observed that the Tensile strength of the samples increases with increase in the concentration of PVA. The tensile strength of the blends derived from 15% rice flour starch (A, B, C & D) was found to be 5.73, 6.08, 6.71 and 10.02 MPa respectively. However, the tensile strength of the blends derived from 20% rice flour starch (E, F, G and H) was found to be 1.91,4.44,4.40,6.21 MPa respectively.

The elongation at break reduces 459.94% to 358.16 % for samples A-D and 404.74 % to 300.71% for samples E-H respectively. This decrease in the elongation at break in the samples may be attributed to the addition of the precipitated silica as a filler. With the increase in the filler content in the polymer matrix mechanical properties improve up to a certain limit, beyond that they start deteriorating. Poor adhesion between matrix and filler is also a one of the factor responsible for this decrease [8].

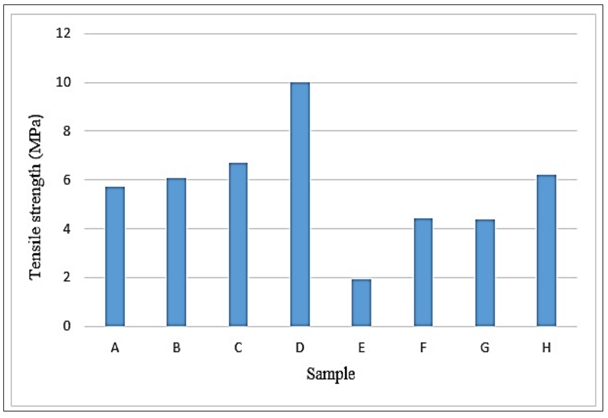

Fig 1 Tensile strength of the bioplastic samples

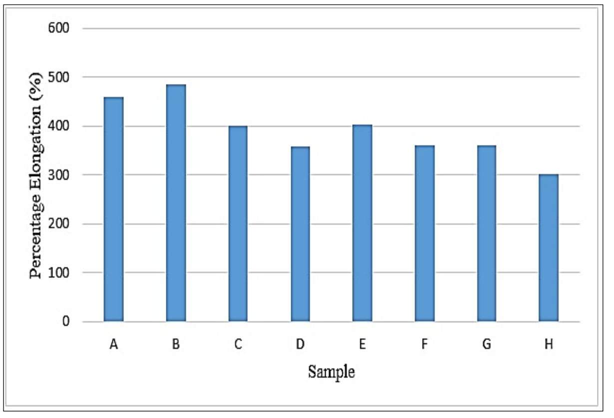

Fig 2 Percentage elongation of the bioplastic samples

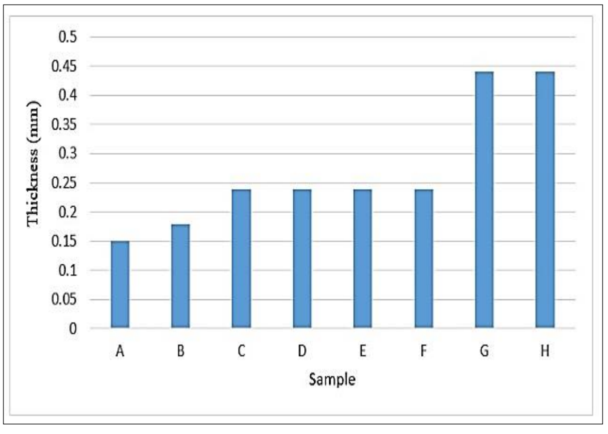

Fig 3 Thickness of the bioplastic sample

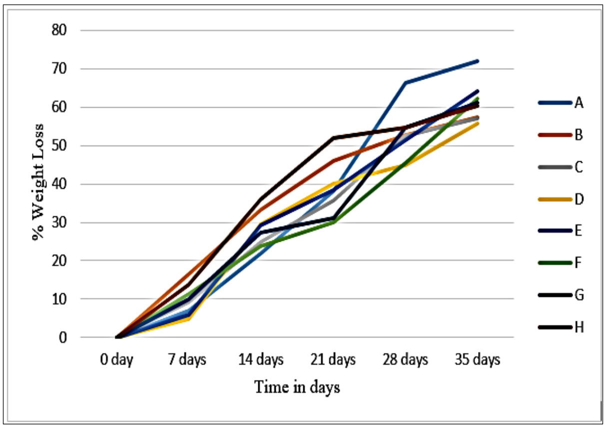

Fig 4 Percentage Weight loss of bioplastics

The thickness of the sheets obtained from broken rice flour starch/PVA ranged between 0.15-0.44 mm.

Biodegradability studies

Data depicted in (Fig 4) shows the degradation of different blends of broken rice flour-based bioplastics in soil. With respect to the observations, it can be seen that the % biodegradability of the blends decreases with the increase in the composition of PVA [5]. However, all the blends showed substantial amount of reduction in weight over a period of 35 days and hence they are biodegradable. It was observed that the highest percentage of biodegradation was shown by sample A i.e., 71.82%. The % degradation of samples A, B, C and D were reported as 71.82%, 57.21%, 57.18% and 55.62% respectively. Whereas the % degradation of samples E, F, G and H were reported as 64.05%, 62.12%, 61.16% and 60.42% respectively.

CONCLUSION

Bioplastics with good biodegradable properties could be successfully developed by using 15% and 20% of broken rice flour. The plastic samples produced were characterized in order to determine their mechanical properties and biodegradability. The samples showed a highest tensile strength of 10.02 MPa which is fairly good enough. The tensile strength can be further improved by reducing the amount of glycerol content and addition of filler materials. Moreover, the samples showed a higher % elongation at break which can be limiting factor as such sample cannot be used for applications like making bottles or articles. Furthermore, the bioplastics obtained during this study were biodegradable and eco-friendly, broken rice flour being obtained on a large scale from rice processing plants can thus be looked as a potential substrate for production of bioplastics.

LITERATURE CITED

1. Avérous L, Fringant C, Moro L. 2001. Starch-based biodegradable materials suitable for thermoforming packaging. *Starch Stärke* 53: 368-371.
2. Barnes DK, Galgani F, Thompson RC, Barlaz M. 2009. Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society B: Biological Sciences* 364(1526): 1985-1998.

3. Beilen V, Poirier JB. 2007. Prospects for biopolymer production in plants. *Adv. Biochem. Engin/Biotechnology* 107: 133-151.
4. Bouws H, Wattenberg A, Zorn H. 2008. Fungal scretomes-nature's toolbox for white technology. *Applied Microbial Biotechnology* 80: 381-388.
5. Eterigho EJ, Farrow TS, Ejejigbe SE, Daniel GO. 2017. Study of the physical properties and biodegradability of potato-starch based plastics. *In*: Proceedings of the World Congress on Engineering and Computer Science, San Francisco, USA. 2: 1-5.
6. Jambeck JR, Geyer R, Wilcox C, Siegler TR, Perryman M, Andrady A, Law KL. 2015. Plastic waste inputs from land into the ocean. *Science* 347(6223): 768-771.
7. Nawrath C, Poirer Y, Somerville C. 1995. Plant polymers for biodegradable plastics: *Cellulose, Starch and Polyhydroxyalkanoates. Molecular Breeding* 1: 105-122.
8. Srivastava A, Maurya M. 2015. Preparation and mechanical characterization of epoxy-based composite developed by biowaste material. *International Journal of Research in Engineering and Technology* 4(4): 397-400.
9. Thakore IM, Desai S, Sarawade BD, Devi S. 2001. Studies on biodegradability, morphology and thermomechanical properties of LDPE/modified starch blends. *European Polymer Journal* 37: 151-160.