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Synthesis of bioplastic from wheat chaff

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Abstract

Petroleum based plastics are facing a major problem in disposal and degradation and these are promoting destruction to the environment. The new field of bio-based plastics i.e. Starch based bioplastic is providing an alternative way to eradicate this problem. In recent years, many starch based bioplastic have been evolved but, till now no study related to wheat chaff has been recorded. This study entails the utilisation of easily available waste material i.e. Wheat chaff, for the production of biodegradable eco-friendly starch based bioplastic. For the fabrication of bioplastic, the initial step involves the extraction of starch that is done by treating wheat chaff with 25% ammonium hydroxide and this step follows the production of bioplastic by heating the starch in measured quantities of water, glacial acetic acid and plasticizers (Glycerol and Sorbitol) at 90^0 C for 45 minutes. On the basis of comparative analysis Glacial (4): Sorbitol (1) ratio was found best as plasticizer. 0.17g of starch and 1.45g of bioplastic per 1g of wheat chaff were generated. From this study, wheat chaff being easily accessible source of waste, can be used as a possible starch source for the fabrication of bioplastic.

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Introduction

The people in history utilized stuff which they found in nature to make the things that we would have preferred. In any case, the creation of plastic approximately a hundred years past, completely modified our reality. It transformed us. However, this miracle of innovation got out of hand. Plastic has immersed the earth, it has attacked the creatures we eat and now it's discovering its way into our bodies. It is horribly hard to see how essential plastics became to our regular daily existences. Plastic is produced using polymers and we can shape new engineered polymers [1].

Manufactured polymers have remarkable attributes. They are light weight, solid and can be formed into practically any shape. Plastic can be effectively mass-delivered without requiring a tedious manual work and its crude material is accessible in immense amount and economic, thus the brilliant time of plastic started. Today nearly everything is least halfway produced using plastic, our telephones, PC, furniture, apparatuses, houses and autos. Plastic has since a long time ago grind to a halt to be a progressive material as opposed to that it became refuse. Since synthetic polymers are so durable, plastic takes between 500 and 1000 years to break down [2]. Plastic pollution is a complicated problem. Biodegradable bioplastic is only suitable solution of this problem. Biodegradable and biocompatible polymers are nowadays gaining importance worldwide in both basic and applied research fields such as pharmacological, biomedical and environmental applications [3-6]. Nowadays it is indispensable to have a potential bioplastic material in alternate over the conventional plastics. The bioplastic obtained will be environmentally friendly, trendy, user friendly and degradation tractable properties.

Materials and methods

Comparison of different bio-waste for bioplastic formation

Bioplastic from Potato peel

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First collect the potato peel and cut into small pieces. Grind the potato with the help of water (100ml). Now pour the liquid through a sieve. Allow the liquid to rest for about 10 – 15minutes. Now decant off supernatant from the beaker and collect the precipitates. Dry the extracted precipitate in the oven. To it, add 25 ml of distilled water and 3ml of HCl (0.1M). Add 2-2.5 ml of glycerol. Heat the mixture for about 15-20 minutes. After that, add NaOH (0.1M). Now the content is poured in the moulds. Allow it to dry at room temperature.

Bioplastic from Wheat Chaff

Collect the wheat chaff of about 5g. Treat wheat chaff with HCl (0.1 M) for about 20-30 minutes. Allow the liquid to rest for about 10 – 15minutes. Now decant off supernatant from the beaker and collect the precipitates. The starch is treated with HCl (0.1 M) + glycerol (2-3 ml). Heat the mixture about 20-30 minutes. Later add NaOH (0.1 M) to it. Now pour the content in the moulds. Allow it to dry at room temperature.

Bioplastic from Mango seed

Collect the mango seed. Mash up the mango seed properly with the help of motor and pestle.Treat the mango seed with HCl (0.1 M) for about 20-30 minutes. Allow the liquid to rest for some time about 10 – 15minutes. Now decant off supernatant from the beaker and collect the precipitates. The starch is treated with HCl (0.1 M) + glycerol (2-3 ml). Heat the mixture about 20-30 minutes. Later add NaOH (0.1 M) to it. It occurs formation of thick jelly material. Remove it from heat. Now pour the content in the moulds. Allow it to dry for about 2-3 days at room temperature.

Estimation of starch content obtained from different bio-wastes

Estimation of the starch content of corn and wheat chaff has been performed on the basis of Dubois method.

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Effect of HCl (0.1N) and Ammonium hydroxide (25%) on extraction of starch from wheat chaff.

Treatment of Hydrochloric acid (0.1N) and Ammonium Hydroxide (25%) for starch extraction

Weigh 20g of wheat chaff. Add the weighed wheat chaff in 100ml of HCl (0.1N). Similarly, in 100 ml of Ammonium Hydroxide (25%), add 20 g of wheat chaff. After that, following steps were followed with HCl and Ammonium Hydroxide treated wheat chaff in order to extract starch, respectively. Heat the mixture at 90^{o}C on hot plate for 45 minutes. Filter the mixture with the help of sieve. Allow the solution to cool down and let the precipitates settle down in the beaker. Decant the solution. Add 25ml dH_2O to the settled starch and mix well. Centrifuge it for 2 min at 5000rpm. Decant the supernatant as starch has settled at the bottom. Add 25ml dH_2O to the starch and mix well again. Centrifuge it for 1 min at 5000rpm. Again, decant the supernatant and add 25ml of 70% ethanol for washing. Centrifuge the mixture of starch and ethanol for 1 min at 5000rpm. Decant the supernatant and repeat this step if needed. Now, all the ethanol to evaporate and transfer the starch to petri dish and allow it to dry.

Evaluation of different plasticizers i.e. Glycerol and Sorbitol for bioplastic formation

Glycerol , Sorbitol and combination of both in different ratio has been evaluated as Plasticizer for bioplastic formation from biowaste wheat shaft. For bioplastic formation, weigh 15gms of ammonium hydroxide extracted starch and add 100ml of dH_2O in it in 250ml beaker. Then prepare following different combinations of Plasticizers:

1. Add 20ml glycerol and 10ml of glacial acetic acid to it.
2. Add 20ml sorbitol and 10ml of glacial acetic acid to it.
3. Add 10ml glycerol, 10ml Sorbitol and 10ml of glacial acetic acid to it.
4. Add 16ml Glycerol, 4ml Sorbitol and 10ml of glacial acetic acid to it.
5. Add 12ml Glycerol, 8ml Sorbitol and 10ml of glacial acetic acid to it.

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6. Add 8ml Glycerol, 12ml Sorbitol and 10ml of glacial acetic acid to it.
7. Add 4ml Glycerol, 16ml Sorbitol and 10ml of glacial acetic acid to it.

After preparing above mention mixtures following steps were performed: Heat the mixture at 90^{o}C until the solution becomes quite thick (approx. 45min). Pour the mixture into moulds. Allow it to solidify for 2-3 days.

Evaluation of stress and strain tolerance of bioplastic

Spring Constant equipment is used to measure stress and strain tolerance. The bioplastic is cut in square shape (4X4 cm^2) and weighed. The bioplastic is held with help of some metallic support to the equipment. Applied some force on opposite end of bioplastic to measure the elasticity. The pointer is attached to the equipment where the bioplastic tears it shows the elasticity. By the reference of elasticity, we could measure the stress and strain of bioplastic. To the same position of the equipment now we add on weights and observe the pointer. Once pointer reaches the elasticity measurement, we stop adding weights and calculate the weights that we have added. We could measure the elasticity and stress and strain by this procedure.

Results

Comparison of different bio-waste for bioplastic formation

In present study, it was revealed that 0.98g, 0.21g and 0.17g extracted crude starch powder has been obtained from 1g of potato, mango and wheat chaff, respectively. After quantitative analysis of extracted crude starch powder, potato showed maximum concentration of starch i.e. 0.66 mg/ml followed by wheat chaff (0.45 mg/ml), However, minimum concentration of starch was observed in mango seed i.e. 0.27 mg/ml. After extraction of starch, bioplastic preparation has been performed with different biowastes. Weight of bioplastic produced per gram of

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respective substrate was estimated (Table 1). Maximum weight of bioplastic i.e. 2.5 g was obtained in case of potato and minimum in case of mango (1.32g). However, 1.45g bioplastic has been prepared with 1 g of wheat chaff.

Starch Extracted by 0.1N HCl and 25% Ammonium Hydroxide

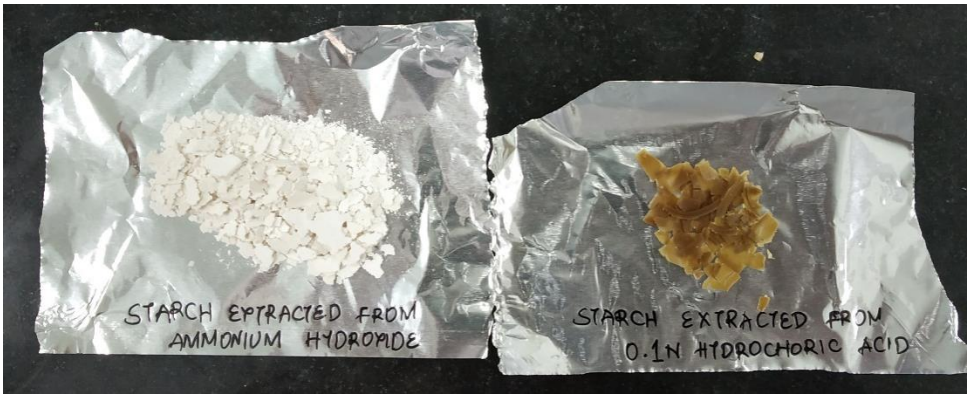

Fig.1 Starch extracted from 0.1N HCl and 25% Ammonium Hydroxide

Table 1: Amount of starch extracted from Ammonium hydroxide and Hydrochloric Acid

Ammonium Hydroxide	**Hydrochloric acid**
2.34g	0.40g

High amount of starch 2.34 g has been extracted from Ammonium Hydroxide (25%) treatment as compared to 0.1 N Hydrochloric acid (0.40g). There is difference in colour of extracted starch. Brown coloured in case of Hydrochloric acid and white coloured in case of Ammonium Hydroxide extracted starch (Fig 1, Table 1).

Evaluation of different amounts of plasticizer for bioplastic formation

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Different plasticizer i.e. glycerol, sorbitol and combination of both has been used for bioplastic formation.

The following observations were made after 5 days of drying of the bioplastic;

Table 2: Stress Tolerance Analysis of bioplastic

Sample Ratio **Glycerol to Sorbitol**	**Sample weight** **(grams)**	**Length Broken** **At (cm)**	**Weight (grams)** **Bioplastic hold before breakage**	**Weight bioplastic hold before breakage per 1 gram**
100% Glycerol	8.0	4.0	72	9.0
100% Sorbitol	-	-	-	-
4:1	6.0	9.5	142	23.6
3:2	8.0	6.0	96	12.0
1:1	-	-	-	-
2:3	6.5	7.8	120	18.3
1:4	-	-	-	-

The samples that contained 100% sorbitol, 1:1,1:4 ratios of glycerol to sorbitol were unable to show stress tolerance. The bioplastic that could retain the maximum weight was with 4:1 ratio of Glycerol to Sorbitol. Weight bioplastic of 4:1 ratio hold before breakage per 1 g was 23.6 g. The minimum stress tolerance was with 100% Glycerol . Weight bioplastic of 100% Glycerol hold before breakage per 1 g was 9.0g (Fig 2; Table 2).

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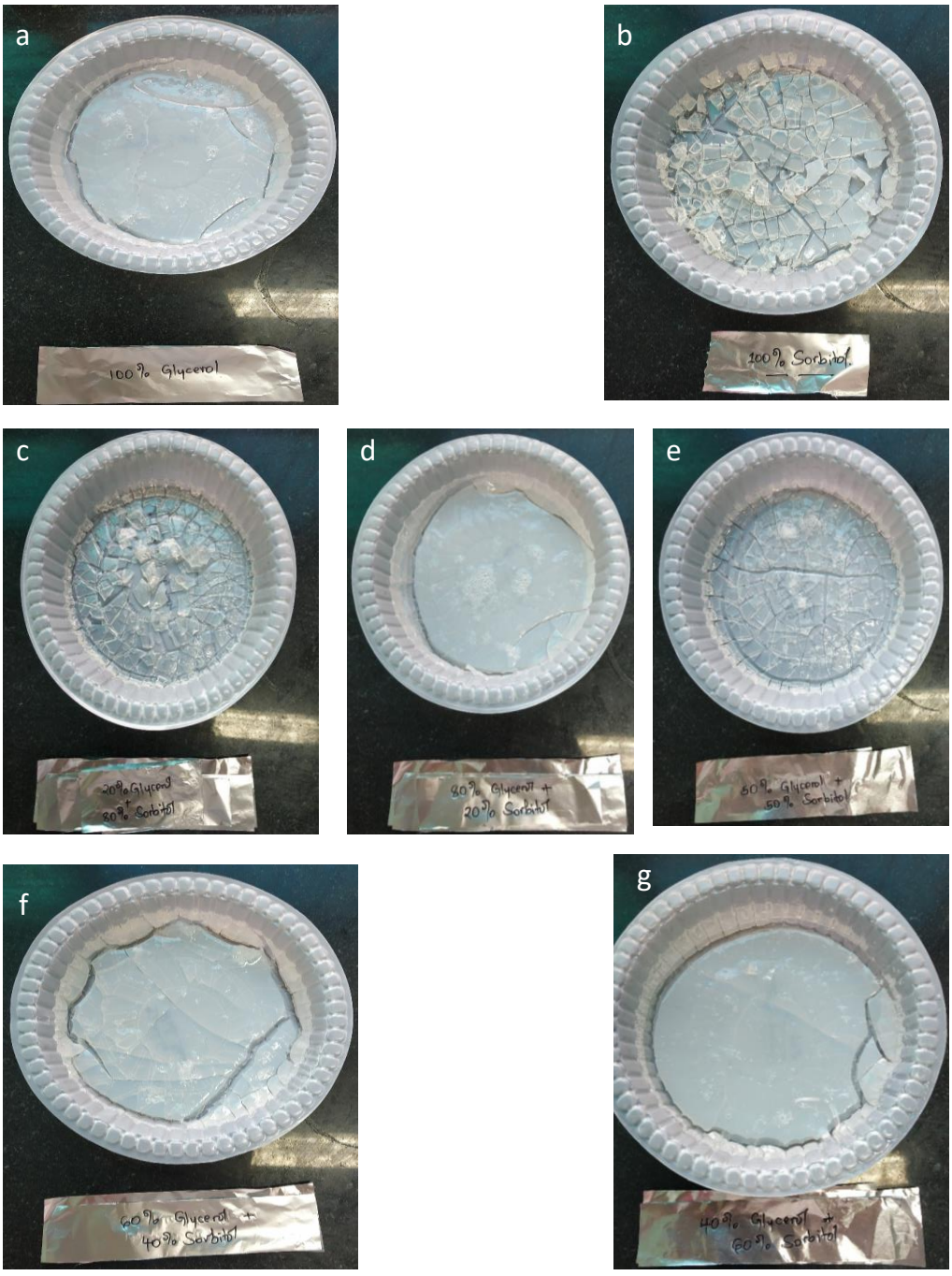

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Fig 2(a) Bioplastic formed from 100% Glycerol; (b) bioplastic formed from 100% Sorbitol ; (c) bioplastic formed from 20% Glycerol and 80% Sorbitol ; (d) bioplastic formed from 80%Glycerol and 20%Sorbitol; (e) bioplastic formed from 50% Glycerol and 50% Sorbitol;(f) bioplastic formed from 60% Glycerol and 40% Sorbitol; (g) bioplastic formed from 40% Glycerol and 60% Sorbitol

DISCUSSION

Bioplastics are degradable forms of plastics that are synthesized from various renewable biomass origin, for example vegetable fats and oils, starch or micro-organisms [7]. These bioplastics are easily degraded in the environment by the use of micro-organisms [8]. The bioplastics can be categorized broadly into four major groups; Starch based bioplastic, cellulose based bioplastic, Lignin based bioplastic and plant proteins [9]. Starch based bioplastics can be easily obtained from kitchen wastes and its production is relatively easier and less costly as compared to the other raw material sources [10-12].

In present study, a novel raw material for the production of bioplastic, wheat chaff was used. Its starch content was estimated and the starch concentration was obtained to be 0.45mg/ml as compared to potato with a concentration of 0.66mg/ml. The extracted starch content in 1gram of wheat chaff is approximately 17%. Carmona et al. [13] reported that average starch yield from plantain peel and cassava is 5.7g and 0.25g respectively. For the bioplastic production, 1gram of the wheat chaff was used and able to produce 1.45grams of the bioplastic. In a similar study to produce starch based polymer from potato starch, 15grams of sample produced 44.8grams polymer [14].

A comparative analysis was also done to find out maximum starch extraction from the wheat chaff by using two chemical methods i.e. 25% Ammonium hydroxide and 0.1N HCl. The results unveiled that higher starch was extracted by ammonium hydroxide treatment, 0.62g whereas the

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0.1N HCl treatment yielded 0.17g of starch. Madson [15] documented, starch extracted from corn by ammonium hydroxide treatment increased the yield by 20%.

During the bioplastic formation, different compositions of plasticizers (Glycerol and Sorbitol) were used for its formulation and its tensile strength was estimated. The following compositions were used i.e. 1:1, 4:1, 3:2, 2:3, 1:4, 100% Glycerol and 100% Sorbitol. The results unfolded that the bioplastic with 4:1 (Glycerol to Sorbitol) showed the maximum tensile strength and accommodated 23.6g weight before breakage. The samples with least tensile strenght were obtained from 100% glycerol and 100% Sorbitol. High tensile strength at low concentration of plasticizer is because of the supremacy of strong hydrogen bonds produced by starch–starch intermolecular interaction over starch–plasticizer attraction [16]. A related study of sugarpalm bioplastic documented that the tensile strength of bioplastic constituting 15% Sorbitol-plasticizer followed by Glycerol and Sorbitol- plasticizer and Glycerol-plasticizer is 28.35MPa, 15.82MPa and 9.59MPa respectively [17].

In present study, wheat chaff is used as raw material for extraction of starch. The usage of wheat chaff for bioplastic formation has not been reported yet. The wheat chaff used is also a readily available source of material and is a waste material from most households. In conclusion, concentration of starch in wheat chaff is 0.45mg/ml and 1g of wheat chaff produced an approximate amount of 1.45g of bioplastic. The starch extracted from Ammonium Hydroxide was more than that from 0.1N of HCl. According to tensile strength the strongest bioplastic is one that contains 4:1 ratio of Glycerol to sorbitol.

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