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Development of Biodegradable Tableware from Ricestraw by Using Different Plasticizers

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present research work focused on developing Biodegradable tableware composed of rice straw and plasticizers like sorbitol, polyvinyl alcohol (PVA). In the manufacture of the concentration of sorbitol used was 20%, 30%, 35%, and 40% and PVA used was 2%, 5%, and 10% by weight dry ingredients. Mechanical properties such as tensile strength, compressive strength, water absorption, were studied in fabricated BD plate. Maximum compressive strength of 55.79 kgf and tensile strength of 40.79 mpa is obtained at the optimal concentration of sorbitol and PVA is 30% and 5% respectively. The developed biodegradable tableware serves as the alternative solution for plastic tableware such that the developed plate withstands for one month free from fungus

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1. INTRODUCTION

Plastic chosen as the packaging material due to its safe, robust characteristics and also low cost. Synthetic plastics which are derived from non-renewable resources can cause environmental damage. Hence the plastic is not considered environmentally friendly because it will not be easily decomposed into the soil. To overcome this problem biodegradable materials can be made using natural resources [1-4].

“India ranks second in terms of rice production all over the world, with an annual output of 117.47 MT” [5] +Rice production plays a major role in the economy of the country, but the rice straw management became a huge problem resulting in pollution to the environment and soil infertility open-burning of the rice straw in the field produces a generous amount of emissions such as SO_2, NOx, including toxic gases such as carbon monoxide (CO), furans, volatile organic compounds (VOC), carcinogenic polycyclic aromatic hydrocarbons (PAH), resulting in persistent respiratory conditions and air pollution” [6,5].

“Rice straw is a vegetable waste with abundant cellulose (32-47%), hemicellulose (19-27%) and lignin (5-24%)” [7]. “It is known as a potential feedstock for fuel ethanol production”. The rice straw can be used to produce biodegradable plastic packs, which can provide a sustainable solution for straw management and reducing the usage of synthetic plastic without polluting the nature. Rice straw fiber has lignocellulosic characteristics and also contains abundant amount of cellulose which can be used to produce biodegradable plastics or bio-plastic packaging materials [8].

The longevity and strength of the tableware can be improved by adding additives such as starch and plasticizers i.e., sorbitol and polyvinyl alcohol [9,10]. For this concern, biodegradable edible plate is evolved in recent years to reduce the usage of plastic [11-13]. The aim of this paper is to develop biodegradable cups with ricestraw sorbitol and poly vinyl alcohol as plasticizers and starch as filler which can be overcome environmental problems due to use of synthetic plastics to manufacture biodegradable plates. Further, the physical mechanical and biodegradable properties of biodegradable material are also investigated.

2. MATERIALS AND METHODS

2.1 Raw Material Preparation

The dry clean rice straw was milled using grinder to pass through a 60-mesh screen. Then the cut rice straw was transferred into a beaker and treated with 12% w/v NaOH solution [14]. The mixture was heated in autoclave for 1 h at a temperature range of 121◦C for delignification (Amal. E et al). After heating, the mixture was filtered and washed several times to separate the insoluble pulp and remove the excess NaOH. or until the pH of the washing becomes neutral. The delignified straw was air dried and weighed.

2.2 Preparation of Material for Tableware

Corn starch (2%), sorbitol (20%, 30%, 40%), polyvinyl alcohol (2%, 5%, 10%) were added to the degraded ricestraw then grounded into a fine slurry. Then the material is subjected to compression moulding into tableware using 180◦C and 1800kg/cm^2 pressure for 48 sec.

2.3 Thickness

The equipment micrometer (Mitutoyo, Japan) was used to measure the thickness of the developed tableware with an accuracy of ± 0.001 mm. Ten different points (Approx.) of measurements were carried out on individual material.

2.4 Moisture Content

The moisture content of the developed material was calculated by using the standard procedure AOAC,2005. A piece of sample with 1.5 cm x 1.5 cm was taken into Petri dishes and weighed (W1). After weighing, the Petri dishes with the sample were placed in the hot air oven at a temperature of 105 °C and dried to constant weight, which took about 8-10 h. After completion of drying, the Petri dishes were transferred to a desiccator and then weighed (W2). The moisture content was measured in a wet basis percentage. The moisture content of the tableware sample was determined by the following equation:

$$\text{Moisture content(\% w.b)} = \frac{W1-W2}{W1} \times 100$$

Where, W1 = Initial weight of the sample,g W2 = Final weight of the sample, g

2.5 Water Absorption Capacity

The sample of 2.5 cm × 2.5 cm was cut into pieces and weighed (W1). The sample was then dipped in deionized water (25^{o}C) for 24h. The wet sample was sponged with filter paper to remove additional surface water and swelled sample was weighed (W2). It was expressed in percentage. The experiments were carried out in triplicates and mean values were noted. The amount of water absorbed from the sample was calculated by using the standard equation:

$$\text{WAC (\%)} = \frac{\mathbf{W1-W2}}{\mathbf{W1}} \times 100$$

2.6 Tensile Strength

The tensile strength was determined using a tensile testing machine (Model: GP-10-DX; Test Techno consultants, Vadodara, India) per the ASTM-D882 standard method. Tensile tests were performed at room temperature with a crosshead speed of 10 mm/min. At least three specimens were tested for each film and the average values are reported.

The tensile strength was calculated by using the following formula.

$$\text{TS} = \frac{F}{L \times W \times T}$$

Where, TS = Tensile strength, MPa F = Tension at break, N, L = Length of plate, mm W= Width of plate, mm, T = Thickness mm

2.7 Compressive Force

The ASTM D 6241 method (*17*) was used with some modifications for the compressive force measurement. compression tests were performed with Stable Micro System TAXT plus Texture Analyzer [15].

2.8 Biodegradability Test

The biodegradability of the tableware was determined based on the tableware weight loss after burying the cup in soil. A 5×5 cm^2 square piece was taken and weighed (W1). The samples were placed in an open field. The sample was buried inside the soil for two months. After 20 days, the sample was removed from the soil, cleaned and weighed (W2). Weight loss of tableware was determined by using the following formula [16].

$$\text{Weight loss (\%)} = \frac{W_1 - W_2}{W_1} \times 100$$

3. RESULTS AND DISCUSSION

3.1 Thickness

The thickness of the material was increased by increasind the amount of material for molding. The maximum thickness of the material i.e., 1.982mm observed at 30% sorbitol and 10% poly vinyl alcohol concentration.

3.2 Tensile Strength and Water Absorption Capacity

The material made from rice straw by adding different concentrations of sorbitol and PVA as mentioned above were tested for tensile strength. It was found that all maximum tensile strength of 40.79 mpa was observed at 30% sorbitol and 5% PVA. And minimum tensile strength of 20.16mpa was observed at 40% sorbitol and 10% PVA. The destruction of original hydrogen bonding by sorbitol addition would improve the mobility of the macromolecular segments, resulting in the highly enhanced flexibility of the PVA films The weakening of intermolecular interactions between adjacent chains causes a decrease in tensile strength, increasing the free volume and lowering the mechanical strength. Regarding water absorption capacity, minimum was observed at 30% sorbitol and 5% PVA due to According to [17] macromolecules. With the increase of sorbitol, the water content at equilibrium increased. There were six –OH groups per sorbitol molecule, which could form hydrogen bonding interactions with both PVA and water, thus increased the quantity of bonded water and depressed the water release during drying". Water uptake of rice straw based tableware with sorbitol was ten times lower than that of non-plasticized films, according to [18].

3.3 Compressive Strength

The material made from ricestaw by adding different concentrations of sorbitol and PVA as mentioned above were tested for tensile strength. It was found that all maximum compression of 55.79 mpa was observed at 30% sorbitol and 5% PVA. And minimum compression of 27.6mpa was observed at 40% sorbitol and 10% PVA. As an increase in the concentration of sorbitol, there is a continuous decrease in compressive strength, but an increase in PVA concentration increased the compressive strength. This is owing to the mechanical strength of the BD material is influenced by an excess of additives. When lignin is combined with these hetero-polysaccharides, it provides flexibility and stiffness against dynamic loads which leads to increase in compressive strength. These findings are consistent with those published by Maheswari et al. [19].

3.4 Biodegradability

Soil burial degradation studies were carried out to evaluate the biodegradability of the material under natural environmental conditions. After the burial of the films in the soil for 180 days, the percentage weight loss was recorded The buried material exhibited reduced size. The degradation rate 20% sorbitol and 5% PVA was much faster. The presence of starch increases the microbial attack and the biodegradation rates by stimulating biofouling and the adhesion of microorganisms to the surface leading to roughness and forma-tion of crevices.The weight loss of the composite films during150 days soil burial study was above 70%

4. CONCLUSION

In this study, rice straw collected from thefarmerswere used for development of biodegradable tablewareBesides, plasticizers were used as a source of increasing the strength and flexibility.The best condition of tableware obtained at 5% PVA concentration and concentration of sorbitol 25% with tensile strength 40.79MPa.

5. SUGGESTIONS FOR FUTURE WORK

Effect of different plasticizers on physical, mechanical and biodegradable properties of tableware. Design and development of machine for the manufacturing of tableware.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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