International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(RESEARCH ARTICLE)

Bio-plastic from renewable biomass sources

Ashwinikumar B. Kshirsagar * and Ashok A. Shinde

Department of Plant Biotechnology, Institute of Biosciences & Technology, MGM University, Aurangabad (M.S.), India-431003.

International Journal of Science and Research Archive, 2023, 08(01), 225–235

Publication history: Received on 27 November 2022; revised on 09 January 2023; accepted on 12 January 2023

Article DOI: https://doi.org/10.30574/ijsra.2023.8.1.0012

Abstract

Bio-plastics are environment – friendly and biodegradable hence provide an effective way to replace the conventional plastics. In this experiment five different crops were taken and then extracted the starch from each crop. Starch is used as a source for producing bio-plastics. Bio-plastic were generated from different starches. Sorghum showed the maximum production of starch (369gm). 15% glycerol is used as a plasticiser and bio-plastics was produced from the extracted starch. Glycerol increases its flexibility. Sodium meta-bisulphate was used as a antimicrobial activity. Maize showed the maximum production of plastic i.e. 28.26 gm.

Once the bio-plastics made, the quality parameters were studied. Like tensile strength, elongation test and degradation test. While calculating tensile strength the stretchiness and toughness of that particular bio-plastic sample is important and the tensile strength of maize is 5.80 Mpa found to be maximum among all. An elongation test was carried out, and maximum elongation was takes place in plastic made from potato starch i.e it was elongated about 1.89 cm. In the degradation test the bio-plastic from rice takes more time for degradation. It degrades at the rate of 5.67 gm plastic in 10 days and plastic from sorghum degrades rapidly than other crops. In this study, the experiment conducted in order to produce biodegradable plastic from starch isolated from the different crops. The plastic sample produced may not characteristics of a petrochemical based plastic but it is good in biodegradability. Its tensile strength found that the plastic can be stretched as a conventional plastic. Bio-plastic s doesn't contain any harmful chemicals. It will help us to protect the environment.

Keywords: Bio-plastic; Crop; Antimicrobial; Biodegradable; Renewable

1. Introduction

Bio-plastics are plastics derived from renewable biomass sources such as vegetables fats oils, corn starch or micro biota (Chua, *et al.*, 2009). Bio-plastics are environment-friendly and biodegradable hence provide an effective way to replace the conventional plastics. Starchy material has been used as a source for producing bio-plastics. Generated bio-plastic films from different starches of potato, sweet potato, Rice, sorghum and maize (Saraswat, *et al*., 2010).

Beijernick first observed PHAs (Polyhydroxyalkanotes) as refractive bodies inside bacterial cells in 1888. However, PHA (Polyhydroxyalkanotes) composition was established by Lemoigne only in 1926. Though the promises of these biopolymers were recognized in the 1960s, its possible exploitation was seriously considered only in the late 1970s. In 1976, ICI (Imperial Chemical Industries) of England explored if PHB (Polyhydroxybutyrate) could be satisfactorily produced by microbial fermentation. In 1993, Zeneca Bio-products took over ICI's (Imperial Chemical Industries) activities and in 1996 Monsanto bought the bio-plastics production business from Zeneca. Monsanto closed down its activities in 1998 but many new players became active in this field. Since then some prominent ones are metabolix,

* Corresponding author: Ashwiniumar B. Kshirsagar, Email: aashwinn9@gmail.com
Department of Plant Biotechnology, Institute of Biosciences and Technology, MGM University, Aurangabad

proctor and gamble, DuPont, General motors, and Toyato etc. BIOPOL is marketed bio-plastics product (Anonymous, 2015).

About 4% of the world's total petroleum reserves are used for plastic preparation, which are getting exhausted precipitously. A total of 36.5 million tones/year (36.5 Kg / Individual) of municipal solid waste is generated in India. The volatile oil prices in past few years, due to the political tensions in the middle east and Africa, they are derived from biological resources like starch from corn, tapioca, cassava, wheat, rice, etc. which are easily available in bulk quantities.

There are various types of bio-plastic in those soy-based bio-plastics, starch-based bio-plastics, polylactide (mostly from plants), Poly 3-hydroxy butyrate (PHB), poly 3-hydroxyalkanotes (PHA), Misc. Bio-plastics Aliphatic polyesters, Polylactic acid (PLA) are includes (Anonymous, 2015). All plastics are considered polymers. Polymers are large molecules consisting of many repeating units, called monomers. The starch granules consist of amylase and branching points of amylopectin molecules. In this experiment five types of starch i.e. potato, maize, sweet potato, sorghum and rice provided the repeating units of glucose molecules, which make up the polymer chains. The different compositions of these starches were affecting the mechanical properties of the resulting plastics prepared. The additive like glycerol was also investigated to explore their contributions to the properties such as flexibility, brittleness, and clarity. Once the plastic film is made, a tensile test was used to compare the strength of samples by finding the force needed to break the plastic. Polymer scientists routinely employ the tensile test method to quantify the toughness and stretchiness of many different materials. Tensile strength (or stress) is calculated by dividing the applied force needed to break a sample, by the cross-sectional area. This accounts for the size of the sample as well as the force applied (Wissinger, *et al.,* 2015). Because of the fragmentation in the market and ambiguous definitions it is difficult to describe the total market size for bio-plastics, but estimates put global production capacity at 327,000 tones (NNFCC Bio-plastics 2014). The data compiled in cooperation with the research institutes IfBB – Institute for Bio-plastics and Bio composites (University of Applied Sciences and Arts Hannover, Germany) and nova-Institute (Hurth, Germany) shows that the global bio-plastics production capacity is set to increase from around 1.7 Million tones in 2014 to approximately 7.8 Million tons in 2019 (European bio-plastics).

In India there is lack of awareness and especially the market dealing with eco-friendly product but there is potential for companies wishing to enter this market. On a brighter note Jammu and Kashmir is the first state in India to have to have dedicated bio-plastic s product manufacturing facility with an installed facility of about 960 Metric tones / Year. The Jammu and Kashmir agro industries Ltd. has started his joint venture with "Earth soul" India to launch the countries first integrated biopolymer facility that can manufacture 100% bio degradable and compostable product. Ravi Industries in Maharashtra, Harita NTI Ltd. and Biotech bags in Tamilnadu are also pioneers in bio-plastics in India (Anonymous, 2015).

One of these unit located in North India is producing 30-40 tones/ Year of biodegradable plastics in the granular form. Their products have been quality tested in India's premiere research institutions. Their focus has been mainly on the packaging sector (carry bags, shopping bags, woven sack, and disposable containers etc.) The selling price of the biodegradable plastic is Rs. 80-100/Kg and the price of a normal plastic product is Rs. 60-70/ Kg. Further there is an excise duty of 16% on all products. Unfortunately cost constraints have limited their markets, and thereby production. The company claims its products are biodegradable when buried or under continued exposure in atmosphere in 4 to 24 weeks thereby avoiding environmental pollution. The market size of biodegradable plastics is estimated at present to be 46,000 tones in India and is likely to go up to 96,000 tones in 2006-07 based on a 15% penetration level of potential segments (Anonymous, 2015).

There is number of uses of bio-plastics in that Packaging, Electronics, Automotive, Food service, Cosmetics and Textile, Horticulture and agriculture, Medicine and personal care, Construction and housing. Bio-plastics are used for disposable items, such as packaging, crockery, cutlery, pots, bowls, and straws (Chen, *et al*., 2012). They are also often used for bags, trays, fruit and vegetable containers and blister foils, egg cartons, meat packaging, vegetables, bottling for soft drinks,dairy products etc. These plastics are also used in non-disposable applications including mobile phone casings, carpet fibers, insulation car interiors, fuel lines, and plastic piping. There are number of challenges to adopt the bio-plastics. All bio-plastics are relatively more expensive than oil based plastics. There are high research and development costs associated with them. The scale of production is low, and hence the price bias exists. There are technical uncertainties with the right choice of material for selected applications. Within waste management, local authorities have not treated bio-plastics as compostable material. An international standard for degradable materials is now being developed, which is vital for the bio-plastics stream to operate successfully (Anonymous-2015). Bio-plastics shows various properties that are similar to the petro plastics in that Some are stiff and brittle, Some are rubbery and moldable, Degrades at 185 °C, moisture resistant, water insoluble, optically pure, impermeable to oxygen, must maintain stability during manufacture and use but degrade rapidly when disposed of or recycle (Suszkiw, *et al.,* 2005).

The demand of the plastic is very high across the world but there is various adverse effects of petrochemical based plastics on the environment and health hence to full fill this demand and to avoid these adverse effects, bio-plastic is the best alternative for the conventional plastic. Presently bio-plastic is made from the PHA, PHB and Starch. Majority of plastic industries used PHA and PHB.

This study were intended to standardize the bio-plastic production and to achieve bio-plastic production through different field crops or different sources of starch like potato tubers, sweet potato tubers, maize, rice and sorghum seeds. The water and alkali extraction method were used for extraction of starch. Then glycerol used as a plasticizer for the making of bio-plastics. Once the plastic film is made, a tensile, degradation, elongation test were used to compare the strength of the sample. Research focused on production of bio-plastics from starchy material. The present research work was carried out to enhance the good recovery of starchy material from field crops for production of bio-plastic.

2. Material and methods

2.1. Experimental site and details

All the experimental studies were conducted in the department of plant biotechnology, MGM University, Aurangabad (M.S.). The details of various material and methods were adopted during the course.

2.2. Treatment Details

Statistical Design: Completely Randomized Design

Number of Treatments: 05

Number of Replication: 04

Table 1 Treatment Details

Treatments (T)	Starch Sources
T1	Potato (tubers)
T2	Sweet potato (tubers)
T3	Rice (seeds)
T4	Maize (seeds)
T5	Sorghum (seeds)

2.3. Starch extraction from potato / Sweet potato tubers

Grate about 1 Kg potato tube. The potato does not need to be peeled, but it should be clean. Put the potato into the mortar and add about 1000 ml distilled water Grind the potato. Pour the liquid off through the tea strainer into the beaker, leaving the potato behind in the mortar. Add 100 ml water, grind and strain twice more. Leave the mixture to settle in the beaker for 5 minute. Decant the water from the beaker, leaving behind the white starch which should have settled in the bottom. Add about 100 ml distilled water to the starch and stir gently. Leave to settle again and then decant the water, leaving the starch behind (Tsakama, et al, 2010).

2.4. Starch extraction from sorghum

Steep the 100 gm. of grain with 50 gm KOH and 467 ml of 5.25% NaCl solution in a 1L beaker and heat during 7 minutes with a magnetic stirrer at 60 °C. Cool down the mixture to room temperature. Screen and wash the grains until completely discolored. Blend the grain with distil water in a wearing blender for 2 min, screen the homogenate through an 80 mesh sieve and repeat step 3-4 times. Screen the precipitate through 200 and 270 mesh sieves. Centrifuge at 460 rpm during 20 minutes and scrap away the mucilaginous layer. Suspend the precipitate starch in water, repeat steps 5 and 6 necessary until the starch slurry pH is near to neutrality. Dry in an oven at 45 °C overnight to 12% moisture content (Perezsira,, *et. al.,* 2004).

2.5. Starch extraction from Maize

Aqueous sodium hydroxide (NaOH) (0.1 or 0.4% *w/v*) was prepared by dissolving NaOH pellets in 600 ml distilled water with the solution constant temperature water bath (25 or 55 °C). Maize seeds (100gm) were accurately weighted and added to 600 ml of the alkali solution with continuous agitation to obtain uniform dispersion. The corn flour to steep water ratio of 1:6 will found to effectively disperse protein with a minimum loss of starch. After 30 or 90 min. steeping, the flour was ground for 5 min. in a wearing blender at high speed and screened (200 mesh) to remove fibrous material. Then slurry tabled at 180/min. on a 10 feet long, 4 inch wide galvanized through having 1 in slope. The precipitate starch washed twice with 500 ml distilled water to remove residual protein and non starch components. The solid content of the starch were determined by drying a 20 gm sample of the dried starch for additional 2hr at 103 °C (Perez, *et. al.,* 2017).

2.6. Starch extraction from Rice

100gm Rice flour (Disperse in 1500ml D.W. Adjust to pH 10 with 1 N NaOH; stand for 1hr with moderate stirring.).Centrifuge at 5000 rpm for 30 min. Residue (Extracted with 1 L DW for 24hrs at 4 °C).Centrifuge at 10000 rpm for 30 min. Residue (Extracted with 1L 2% Nacl, for 24hrs, at 4 °C). Centrifuge at 10000 rpm for 30 min and Discard Supernatant. Residue (Extracted with 300ml of 0.1 N NaOH twice for 48hrs at 4 °C). Centrifuge at 10000 rpm for 30 min. Discard the supernatant, collect white starch layer. Re-suspend in 80% ethanol (Blended for 1 min using stirrer). Heating on water bath at 80°C for 1hr. Settle for 4hr at 4°c and discard supernatant. Residue freeze dehydrate. Starch Powder (Perez, *et. al.,* 2017).

2.7. Preparation of bio-plastic sample

15 gm of dried starch were taken and diluted with 150 ml distilled water in a 500 ml beaker. Then add the 18 ml HCl was pipette out in the mixture and the same amount of NaOH added into it for neutralization of pH. Then 12 ml of glycerol is added. Stir the mixture continuously while heating slowly on a hot plate. Bring the mixture to a gentle boil. The mixture became white in colour and change to transparent or translucent. It was also thicken. Once the initial white colour of the starch is completely gone and the mixture has thickened remove from the heat. If overheated lumps may begin to form. Total heat time is approximately 10 -15 minutes. One drop of food colouring can be added at this stage if desired. Pour the sample slowly into a labeled weighing dish. Try to remove any lumps that remain as well as any air bubbles by using a glass stir rod. Allow all samples to dry undisturbed on the lab bench over the weekend or several days until completely dried (Wissinger, *et al.,* 2015).

2.8. Quality Study

Amount of different sources of starchy material and bio-plastics: The different field crops was taken for extraction and production of starch i.e. 1 kg of potato tuber, sweet potato tubers, rice, sorghum, maize seeds respectively for each replication and also measured the amount of plastic that produced from 15 gm/ kg starch.

2.9. Tensile strength of samples

Carefully peel the plastic film away from the drying dish. Record any qualitative observations such as color, size, texture, flexibility, and ease of removal from the dish. Created a dog bone shaped template as instructed. Examined the plastic film and find the area of interest of defects such as small tears, ridges, air bubbles, curves, etc. Cut out a portion of the sample using the template. Using the digital Vernier caliper, we measured the thickness and width (in millimeters) of the sample in the centre of the dog bone shape. Make sure the caliper has been properly zeroed before each use. Use binder clips to secure the sample at both ends of the dog bone. Attach the hook of the trigger or spring to one clip while a partner holds the other clip stationary. Using the scale, pull the other clip very slowly until the sample breaks. Check that the sample broke somewhere in the thinner part of the dog bone and did not just slip out of the clip. After the sample breaks, record the force from the scale. Make sure if using the trigger scale to reset it to zero each time and convert force to Newton (1 lb. = 0.45 kg = 4.448 Newton). And recorded the force of the sample and calculated the cross-sectional area. Convert tensile strength from Pa to MPa.(Pa = 1 x 10-6 MPa). If there are enough samples, repeat. 2 or 3x and average your values for tensile strength (Susilawati, *et. al.* 2019).

2.10. Elongation test

Biodegradable plastic firstly measure the initial length and stretched when it became length where it is the maximum strength of the biodegradable plastic that was been made. The strength of a strip of plastic is technically the force it can bear, under tension, per unit cross sectional area of the film, without breaking. The "cross sectional area" is measured as the width times the thickness. If want to do is increase the strength of your piece of plastic, the simplest thing to do is make it thicker: this would allow the piece of plastic to bear a greater load under tension without breaking. However, it would not increase the strength, which is a technical property of a plastic that doesn't change with the size and shape of the piece of plastic you are considering. Tensile testing determines the amount of stress each material can sustain prior to failure as well as the amount of elongation at the time of failure (Susilawati, *et. al.* 2019).

2.10.1. Biodegradability test (soil burial method)

The soil burial test provided a realistic environment where soil humidity, temperature, types and the amount of micro-organisms were less in control and changed with seasons. All the tested films were same shape and size in order to avoid the effects of film's shape on it biodegradability. The loss of weight of the films monitored by means of sample collected from the soil at regular time interval. The films were buried in the soil and the sample was removed for evaluation at 2 days interval. Through the result obtained, observed that all the biodegradable bio-composite film expected for degradation process completed within 90 days whereas the film degraded in 15 days.

2.10.2. Analysis of data

The experiment was conducted under completely randomized design (CRD).The data obtained on various observations were analyzed by "Analysis of variance" method (Panse and Sukhatme, 1967).

3. Results and discussion

The result obtained in the present investigation on "Production of bio-plastic from starchy material of field crops" is presented under the following heading. The data of extraction of starch from different crops is shown in following table and depleted in graph.

Table 2 Production of bio-plastic from starchy material of field crops

Treatment (T)	**A.**	**B.**
	Amount of starch produced from different field crops /1 Kg.	**Production of bio-plastic from starchy material / 15 gm**
T1	165	21.99
T2	148	27.42
T3	227	25.49
T4	317	28.26
T5	369	26.11
Mean	245.2	25.85
S.E.±	2.65	0.20
CD	8.00	1.06

2.A Amount of starch produced from field crops

The data presented in the above table revealed that the starch production was significantly influenced from the different crops i.e. potato, sweet potato, rice, sorghum and maize. From the above mentioned results the starch produced from the sorghum i.e. treatment T_5 is significantly superior (369 gm) over rest of the treatments. Hence the T4 (Maize) is significantly superior over the T_1, (potato) T_2, (sweet potato) and T_3 (rice). Whereas, least produced starch was observed in T_2 (148 gm)(Table2).

2.B Production of bio-plastic from starchy material

From the above mentioned results the biodegradable plastic produced in treatment T_4 (Maize) 28.26gm, T_5 (sorghum) 26.11, T_3 (rice) 25.49gm, T_2 (sweet potato) 27.42gm, were at par and found significantly superior over T_1 (potato) 21.99gm (Table2).

3.1. Quality Study

3.1.1. Tensile strength

The tensile strength of the biodegradable plastic was measured and the results are given below in the table 3 and depleted in the (Figure 3).

3.1.2. Biodegradability test

The biodegradability test was done by the soil burial method. The results were discuss in the below table 4 and depleted in the (Figure 4).

3.1.3. Elongation test

The elongation test and results were shown in the below table 4 and depleted in the (Figure 4).

Table3 Quality Study of Different Field Crops

Treatments (T)	**A**	**B**	**C**
	Tensile strength (Mpa)	**Amount of degraded plastic (gm)**	**elongation size of plastic (cm)**
T_1	4.12	5.35	1.89
T_2	4.07	4.89	1.65
T_3	5.08	1.05	0.85
T_4	5.80	5.13	1.45
T_5	4.55	5.67	1.25
Mean	4.72	4.41	1.41
S.E.±	0.15	0.01	0.02
CD	0.81	0.07	0.11

3A. The data mentioned in the table 2(A) the mean tensile strength of biodegradable plastic was 4.72 Mpa,. The maximum tensile strength observed in T_4 treatment i.e. maize (5.80Mpa) and significantly superior results over rest of all the treatments T_1 (potato), T_3 (rice), T_5 (sorghum). Whereas, T_2 (sweet potato) treatment observed as least tensile strength (4.07Mpa) (Table 3). (Figure 10).
3B. The data mentioned in the table 2(B) the mean degraded plastic was 4.41. The degradation rate found at par in T_1 (5.23), T_2 (4.89), T_3 (1.05), T4 (5.13) and found significantly superior over T_5 (5.67) (Figure 11).
3C. The data mentioned in the above table 2 (C) revealed showed that the treatment T_1 (potato) significantly superior over the T_3 (Rice), T_5 (maize), T_4 (sorghum), T_2 (sweet potato), those showed 1.65 cm, 1.25 cm, 1.45 cm and 1.65 cm elongation respectively. Whereas, T_3 shows that least elongation than among all the treatment i.e. 0.85 cm (Figure 9 &10) (Table 3).

3.2. Outcome of the Research work

- From 1 kg sorghum there was maximum extraction of starch i.e. 369 gm and from Sweet potato least amount of starch is extracted i.e. 148 gm.
- After extraction procedure, plastic is made from 15gm starch and glycerol is used as a plasticizer. From maize there was maximum production of bio-plastics up to 28.26 gm because it has maximum amount of starch and from potato least amount of plastic is produced up to 21.99 gm.
- Tensile strength is calculated to quantify the strength and toughness of the bio-plastic. The tensile strength of starch extracted from maize found to be highest i.e 5.80 Mpa.
- The degradation test was taken and plastic made from maize starch took maximum time for the degradation at the rate of 1.05 gm plastic in 10 days and plastic made from sorghum starch took least time for degradation because it degrades rapidly at the rate of 5.67gm plastic in 10 days.
- Elongation test was carried out and the bio-plastic s from potato is elongated about 1.89 cm. While the initial length of the plastic is 4cm and after elongation, length of the plastic increased up to 5.89 cm.

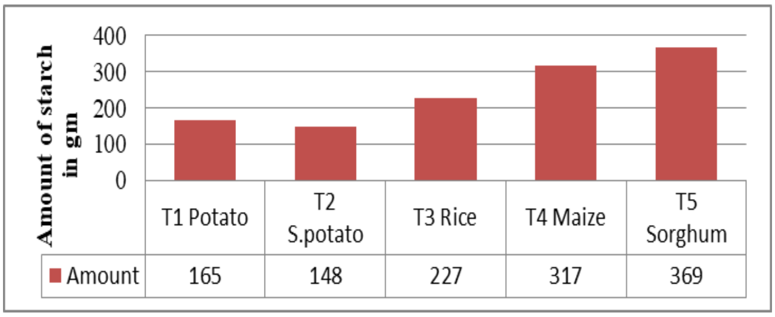

Figure 1 Extraction of starchy material from field crops

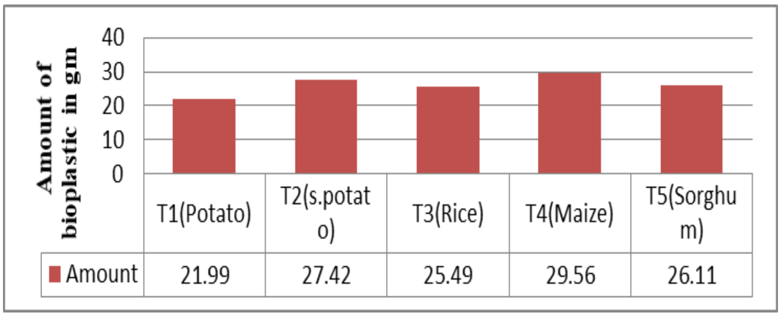

Figure 2 Production of bio-plastic from extracted starchy material

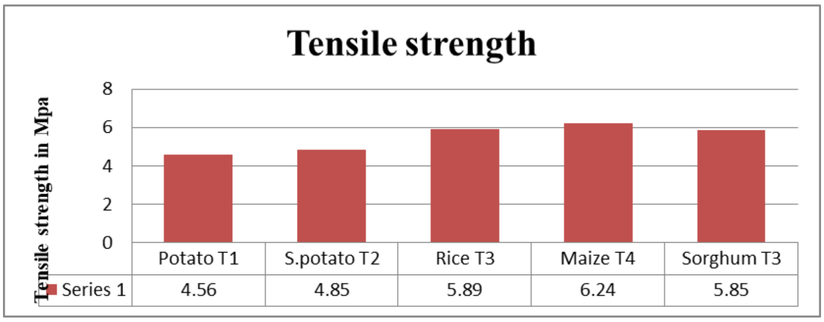

Figure 3 Measuring tensile strength of bio-plastic using vernier caliper

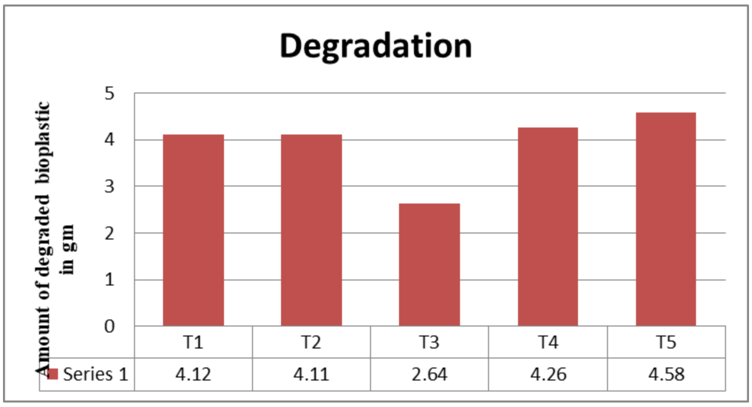

Figure 4 Degradation test by soil burial method

Figure 5 Elongation Test

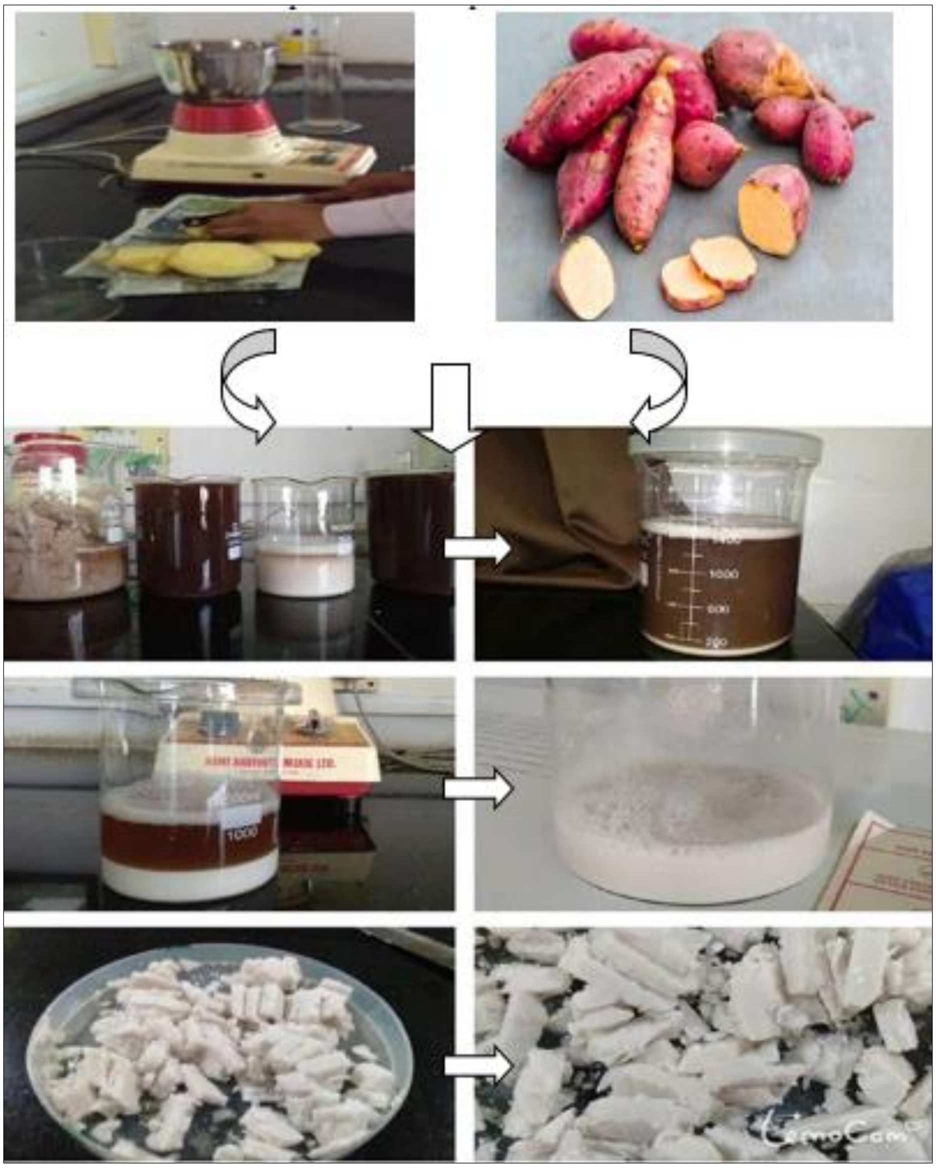

Figure 6 Starch extractions from potato and sweet potato tubers (1. Pulp 2. Residual starch 3. Starch 4. Purified Starch 5 & 6 Oven dried starch)

Figure 7 Starch extractions from maize and sorghum seeds

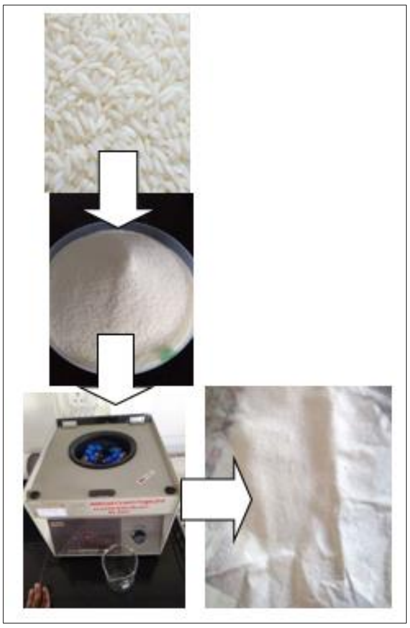

Figure 8 Starch extractions from Rice seeds

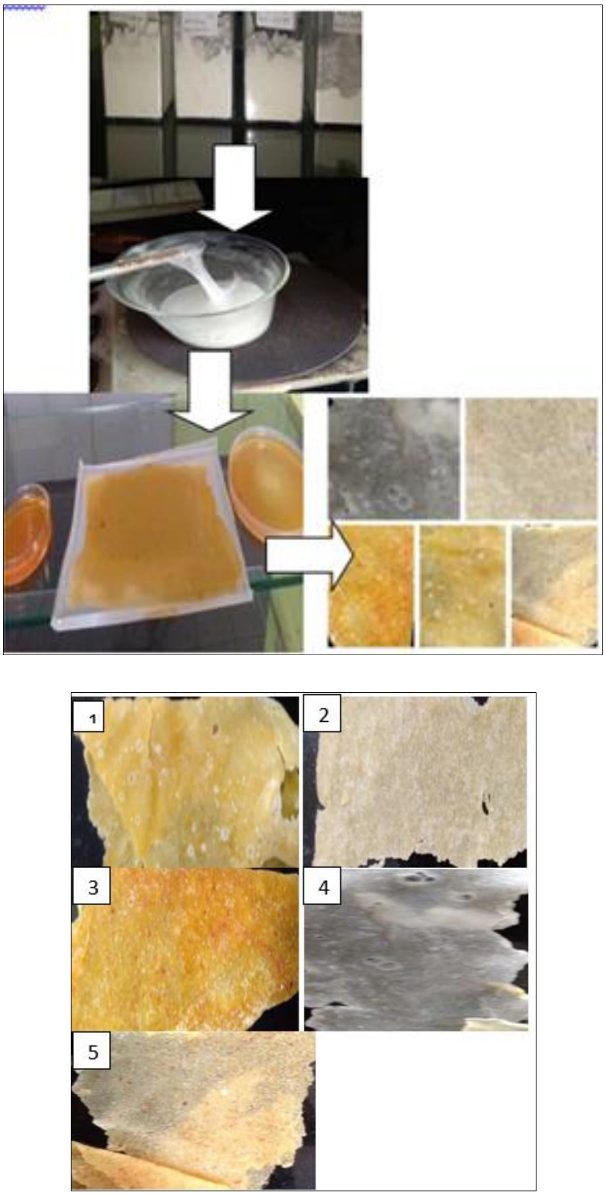

Figure 9 Bio-plastic productions from Starch (1.Potato: Bio-plastic 2. Rice: Bio-plastic 3. Maize: Bio-plastic 4. Sorghum: Bio-plastic 5. Sweet Potato: Bio-plastic)

Figure 10 Tensile strength and Elongation test

Figure 11 Bio-degradability test

4. Conclusion

In this study, the experiment conducted in order to produce biodegradable plastic from starch isolated from the different crops. Bio-plastics can help us to protect the environment and this is safe in all the aspects as well as bio-plastic is future that should not be ignored.

Compliance with ethical standards

Acknowledgments

We would like to show gratitude all the participants in the study. We also thank the MGMU, CABT and IBT who graciously provided all the plant biotechnology reagents used and their staff who helped us handle the samples.

Disclosure of conflict of interest

The authors declare no conflict of interest.

Statement of ethical approval

The current investigation is part of the research work.

References

[1] Anonymous, 2015. Bio-plastic Review :http://shodhganga.inflibnet.ac.in

[2] Chen, G. and Patel, M. 2012. Plastics derived from biological sources: Present and future: technical and environmental review. Chemical Reviews. 112(4):2082–99.

[3] Chua, H., peter, H. F. and Cheek. K. Ma. 1999. Accumulation of biopolymers in activated sludge biomass. Applied Biochem and Biotech. Humana Press. Inc.78: 389–99.

[4] Panse, V. G. and Sukhatme, P. V. 1969.Statistical Methods for Agricultural Workers. New Delhi, ICAR: 259.

[5] Perezsira, E. E. and Marylaresamaiz. 2004. Laboratory scale method for isolation of starch from sorghum. Jr. of Food Engi. 64: 515–19.

[6] Saraswat, Y., Patel, M., Sagar, T., and Shil, S., 2010. Bio-plastic from starch, International conference on multidisciplinary research and practice. 1(8): 2321-2705.

[7] Suszkiw J (2005) Electroactive bio-plastic s flex their industrial muscle. Agric Res. 53(12):10

[8] Susilawati S, Rostini I, Pratama RI, Rochima E. Characterization of bio-plastic packaging from tapioca flour modified with the addition of chitosan and fish bone gelatin. World Scientific News. 2019;135: 85-98.

[9] Tsakama, M., Mwangwela, A.M., Manani, T.A. and Mahangu, N.M. 2010.physiochemical and pasting properties of starch extraction from sweet potato. African Jr. of Food Sci. and Tech. 1(4): 090-098.

[10] Tsakama M., Mwangwela A., Manani T., Mahungu N. (2010) Physicochemical and pasting properties of starch extracted from eleven sweet potato varieties. African Journal of Food Science and Technology 1:090-98.

[11] Wissinger, J., Harris, R., Johnson, A., Ahrenstorff, C. and Laura Seifert., 2015.Bio-plastic .