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Developing Biodegradable and Cattle Edible Composite film for replacing non-biodegradable food packages (single use plastics)

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ABSTRACT

Nowadays, food packaging is manufactured keeping environmental safety in mind. That's why researchers have started making edible and biodegradable plastics and composites. Though human edible plastics are found in some advanced countries, in Bangladesh, edible food packages would be harmful to human digestion because of the polluted surroundings. Keeping that in mind, cattle edible food packages would be more suitable for Bangladesh, especially with a large cattle population. Moreover, in Bangladesh, a significant portion of single use plastic comes from food packages. Considering all these situations, in this experimental paper, cattle edible food package was developed which was biodegradable, antimicrobial, and oxidation resistant. The objectives of making this composite film were to reduce the use of single use plastics and non-biodegradable food packages and test the characteristics of the composite films. It is a composite film made with Gelatin (bio-polymer), food-grade glycerin, and grass extract. The resulting composite film could replace non-biodegradable polythene, multi-layer films (MLF), and especially single use food packaging. Firstly Gelatin, glycerin, grass, and water were mixed at a specific ratio. Then the mixture was heated, and later it was slowly cooled for three days. The biodegradability, melting point, moisture content, and cattle edibility tests were completed for the composite film. The composite film was found to be cattle edible with a biodegradability of 4.12% per day with a moisture content of 18.71%. It had a melting point of 102°C. Compared with typical food packages, it had relatively more moisture content and less melting point. Due to some economic and laboratory limitations, some errors and limitations were found, such as the composite film being weak and short, along with a slow developing process.

Keywords: MLF, Active Food Packaging, Cattle Edible Plastic, Oxidation, Antimicrobial

1. Introduction

Plastic was one of the most significant inventions of the 20th century, keeping pace with the industrial revolution. However, during the 21st century, plastic has become one of the most threatening problems modern society faces regarding sustaining the Environment.

Each year about 300 million tons of plastic are produced worldwide, almost half of which is disposable, and more alarming is that only 10-13% of plastic items are recycled. In fact, single-use plastic amounts to nearly 40% of all plastics consumed [1].

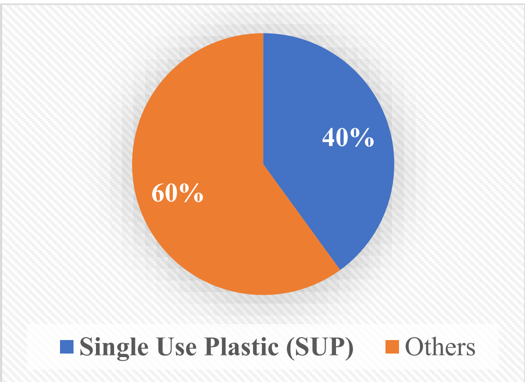

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Fig.1 Consumption of Plastic around the globe.

These items primarily include plastic bags, straws for soft drinks, soda and water bottles, and almost all types of food packages. Certain single-use goods are necessary and have improved both convenience and safety. An excellent example is plastic water bottles which are purchased one million times per minute worldwide [2]. Of course, bottled water can save lives in areas where the water supply is unsafe or unreliable. However, for many individuals, drinking bottled water is more about convenience, taste (or perception of taste), and receptivity to the claims made by the businesses selling the water, such as that it comes from pure mountain springs or has unexplained health advantages. Moreover, plastic bottles are used once and then thrown away. Most of the food is served and packed in a single-use manner, which has become the norm.

This problem is more acute in developing countries, especially in the 11th most densely populated country in the world, Bangladesh [3]. A two-year study carried out in the capital city, Dhaka, and other major cities like Rajshahi, Chattogram, and Sylhet showed that 87,000 tonnes of SUP (single-use plastics) were discarded each year, and almost 96% of SUP waste was produced by plastic containers of food (food packages) and personal care products. Besides, nearly 36% of the SUPs are neither biodegradable nor recyclable [4].

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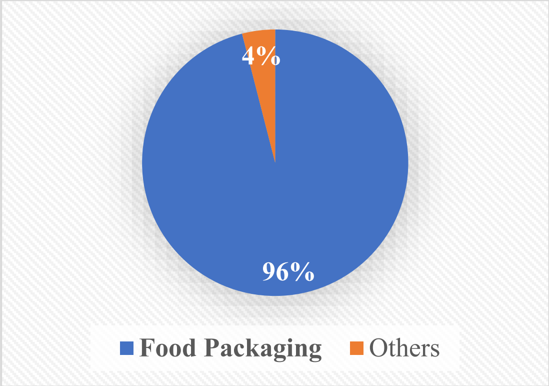

Fig.2 SUP consumption pattern in Bangladesh.

Consequently, it is high time more environmentally friendly and biodegradable alternatives replaced regular food packaging. That's where cattle edible food packages come in. Easily accessible and economical chemicals and cattle food extracts (Cynodon dactylon, known as Bermuda grass or Durva grass) are used in making these types of packages. The important thing is that these packages retain the primary characteristics of food packaging, like being light in weight and chemically stable. Additionally, edible food packaging includes active food packaging material that prolongs the shelf life of goods. On top of that, as the number of cattle in Bangladesh is about 23.4 million [5], these packages can be an affordable alternative nutrient source for cattle.
This study performs a sequential assessment of developing cattle edible composite film by following a cost-effective method to substitute typical food packages and becoming a feasible option for cattle food in Bangladesh.

2. Literature Review

Tarique J, Sapuan S, and Khalina A investigated the production of arrowroot starch (AS) films utilizing solution casting and glycerol (G) in various plasticizer ratios. The physical, mechanical, and structural properties, along with other properties of the manufactured films, were assessed. Glycerol was added to the AS film-making solution to lessen the films' fragility and brittleness. Film thickness, moisture content, and water solubility all increased in response to an increase in glycerol concentration, whereas density and water absorption decreased. G-plasticized AS films had significantly lower tensile strength [6].
Said N and Sarbon N explored the possible use of gelatin-based film made from several gelatin sources as a biodegradable food packaging material. The features of single gelatin-based films have been compared to those of active gelatin-based composite films. The total solid (TS) amount in each film significantly impacted the physical characteristics of gelatin-based films, such as colour, thickness, and biodegradability. While compared to mammalian and marine gelatin films, poultry-based gelatin films offered more excellent mechanical and light barrier qualities. This research provided information on gelatin-based film characteristics, mechanical properties, and physical characteristics [7].

3. Methodology

3.1 Selecting and Sourcing of Chemical Compounds

Firstly, Gelatin was selected. Collagen, which makes up most of the protein in the skin, bones, and white connective tissues of animals, is converted into this protein through partial hydrolysis. Gelatin was utilized because it produces coatings that are consistent, strong, clear, reasonably flexible, and easily absorbed by water. Thus, these coatings are perfect for making photographic films [8]. Gelatin was bought from chaldal.com, which is a website for online shopping. But using Gelatin alone is not viable because of its poor mechanical properties, especially in a wet state. That's why food-grade glycerin (which is a carbohydrate) was used. It greatly enhanced the mechanical properties of the film. Besides, Food-grade glycerin was selected to keep the film edible. This food-grade glycerin was bought from SR Laboratory Care BD.
Lastly, some cattle food gradient (Cynodon dactylon) was utilized to make the film cattle edible.

3.2 Apparatus Required

i. Wight scale
ii. Electric Heater
iii. Blender
iv. Filter cloth
v. Beaker (500ml)
vi. Non-stick pan
vii. Spoon

3.3 Sequential Procedure for preparation of the film

i. Firstly, 2.5g of grass and 400g of water were measured with a weight scale. Then a blended mixture of grass and water was prepared. This blended mixture was filtered through a cloth into a beaker. After that, 15g gelatin and 2.5g glycerin were measured and mixed with the grass-water mixture resulting in the stock solution.
ii. The stock solution was heated at 600°C for 25 minutes on an electric stove. During this heating process, the solution was stirred continuously with a spoon. If it were not stirred, there would have been residue on the bottom of the pan. Moreover, It was not allowed to be boiled vigorously.
iii. After the solution became considerably concentrated, it was poured into a non-stick surface as a skinny layer. Subsequently, it was kept in the dark for 72 hours at room temperature without any disturbance.
iv. After 72 hours, a thin film layer formed on the non-stick surface. Finally, it was separated from the non-stick surface very carefully.

3.4 Film Analysis

Biodegradability, thickness, melting point, moisture content, and cattle edibility of the composite film were tested.

3.4.1 Biodegradability Test

Firstly, a part of the film was cut off. After measuring the weight, its weight was 2.7g. Later this film was kept in a pot of soil at a 3-inch depth. The weight of the product was measured at 5 days intervals. By using this data, the biodegradability of the film was found.

3.4.2 Measurement of Thickness

A screw gauge was used to measure the thickness of the composite film.

3.4.3 Melting Point measurement

For this, a part of the film was taken in a beaker. A thermometer was also kept in the beaker. Afterwards, the beaker was put on a heater, and the temperature was increased very slowly. After some time, when the film started melting, the temperature was noted. During this heating process, it was to be aware that the temperature should not be increased very quickly. If it had been done so, the film would have ignited instead of melting.

3.4.4 Moisture content measurement

A part of the film was cut off to determine moisture content and measured to be 3.10 g. After that, this portion of the film was taken in a beaker. Then The beaker was put on a heater at 100°C. During this process, the weight of the film was taken at 5 minutes intervals. Finally, by using this data, moisture content was determined.

3.4.5 Cattle Edibility

Initially, the film was cut into small pieces. Then it was mixed with husk and rice straw and put in front of a cow.

4. Results

4.1 Resultant Composite Film

Fig.3 A view of the developed composite film.

4.2 Biodegradability

Table 1 Data for biodegradability test.

Observation No.	T(d)	m	Δm
1	0	2.70	0
2	5	2.09	0.61
3	10	1.55	0.54
4	15	1.03	0.52

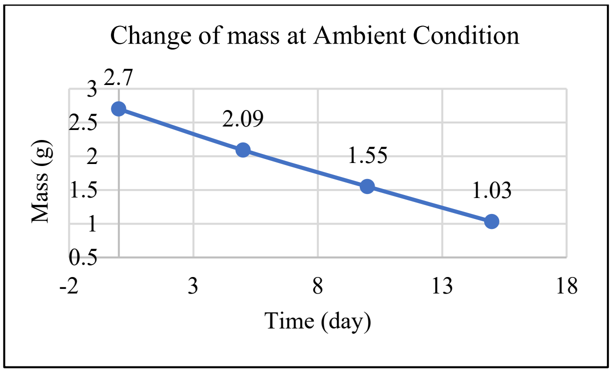

Fig.4 Depletion of mass of the composite film at ambient conditions.

The initial mass of the composite film was 2.70 g
The final mass after 15 days was 1.03 g
Mass loss after 15 days was (2.70-1.03) = 1.67 g
So, the biodegradability of the composite film was $= \frac{1.67}{2.70} \times 100\% = 4.12\%$ per day.

4.3 Measurement of Thickness

The thickness of the composite film was 0.07-0.09 mm.

4.4 Melting point Measurement

The melting point of the film was 112°C.

4.5 Moisture Content measurement

Table 2 Data for moisture content test.

Observation No.	T(m)	m	Δm
1	0	3.10	0
2	5	2.98	0.12
3	10	2.85	0.13
4	15	2.74	0.11
5	20	2.65	0.09
6	25	2.59	0.06
7	30	2.55	0.04
8	35	2.53	0.02
9	40	2.52	0.01
10	45	2.52	0.00

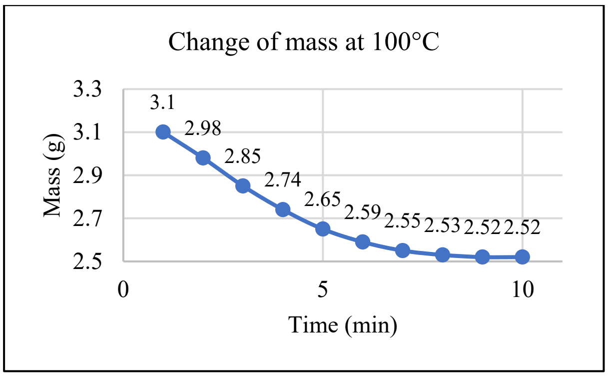

Fig.5 Depletion of mass of the composite film at 100°C.

The initial mass of the composite film was 3.10 g
The final mass after 45 minutes of heating at 100°C was 2.52g
Mass loss was = (3.10-2.52) = 0.58g
That means the film contained approximately 0.58g of water that was vaporized.
So, the moisture content of the composite film was = $\frac{0.58}{3.10} \times 100\% = 18.71\%$

4.6 Cattle Edibility

The cow ate the prepared mixer of husk and rice straw mixed with pieces of the composite film without any trouble. Later after observation, it was found that the cow had no health-related issues.

5. Discussions

The total area of the film was calculated by measuring the radius of the two circular films. The radius was about 7.5 cm. The total cost of the 0.035 m² film was 30 BDT which is 10-20 times higher than the typical plastic bags. Therefore, the production cost would reduce the scope for bulk manufacturing.

As mentioned earlier, the thickness of the film was measured with a screw gauge. The present plastic bags in the market are roughly 0.05 to 0.1 mm thick, whereas this composite film had a thickness of 0.07-0.09 mm. The thickness of the film differed from place to place because the surface of the non-stick pan was not perfectly plain.

The non-biodegradable plastic bags and polythene are generally insoluble in water, whereas this composite film is soluble in water. That's one of the deficiencies of this film. Thus, if a bag or food package is made with this film, the package cannot be wetted. As the most used component while making this composite film was water, the moisture content of this film was higher than the plastic bags or polythene of the market.

The polybags currently available are primarily non-biodegradable. But this composite film was not only biodegradable but also edible to cattle.

During biodegradability determination, when the mass of the film was taken, some soil adhered to the film, which could introduce measurement errors. Thus, the calculated value of the biodegradability of the film might differ from the actual one. The melting point temperature could also differ because of the impurities in the film.

In the end, despite the lack of lab facilities and economic issues, the biodegradable and cattle-edible composite film was developed successfully with slight impurities.

6. Conclusion and Future Recommendations

In this experimental paper, The Single use plastic consumption pattern around the globe and in Bangladesh was observed. Based on feasible criteria, a suitable alternative to food packages was selected. The development of the desired product was done as economically as possible. Upon analysis, the characteristics of the product were found to be in line with the requirements needed to meet. Finally, a biodegradable cattle edible food package was obtained by which chocolate and other foods could be wrapped. But more research should be done to make this film user-friendly and cost-effective. Industrial mass production and process optimization can reduce the cost considerably.

The characteristics of the film can also be improved further by changing the amount of materials used. Cross-linking is a very effective technique for increasing the mechanical strength and barrier qualities of the film. Proteins can be utilized in a variety of functional groups to achieve this. This utilization is accomplished by functional groups working with their reactive side groups.

Chemical processes using acid, alkali and cross-linking agent can also be employed to improve film properties. Increased tensile strength can be attained when chain structure expands and protein interaction increases.

Besides, further testing can be done to approximate the viability of this product, such as tensile strength measurement, water solubility, and other properties. Finally, extensive experiments should be executed to produce a more general alternative to single use plates and glass.

7. Acknowledgement

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NOMENCLATURE

T(d) : Time, day
T(m) : Time, minute
m : Mass, gram
Δm : Mass loss, gram