AN OVERVIEW-NATURAL POLYMER CUTLERY, ALTERNATIVE TO NON-BIODEGRADABLE WASTE

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Abstract:
Plastics are the mixtures of organic polymers that contribute significantly to global environmental pollution. As a result of increased environmental concerns, development of biodegradable silverware from starch, guar gum, cellulose, psyllium and agar etc sources with various formulations is one of the strategies to decrease the waste generated by usage of plastics, single-use plastic packaging and utensils, particularly disposable plastics which are developed from synthetic polymers such as polyethylene, polyester, Teflon, and epoxy, etc. Biodegradable cutleries will be developed through several unit operations such as Waste collection, Composting, Raw materials, Pretreatment, Compression molding, Coating (optional), Food Companies, retails, Consumers. Biodegradable cutleries can be coat with different materials Beeswax, chitosan, Glycerol etc which can improve higher most the acceptability with good appearance and handling properties compared to the existing single use plastics. This review paper aims to present a thorough about the biodegradable cutlery and tableware materials and its development, production processes, characteristics, uses and environmental impacts which has potential to replace traditional waste products for our daily needs.

Keywords – Cutlery, Eco-friendly alternative, Toxicity, Waste management.

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1. Introduction

The rise of take-out services in the fast food and beverage sectors, together with the hectic lifestyle of today, has affected the expansion of the disposable tableware industry globally. (Wold J., Global Paper Cups market overview 2019). While single-use cups, bowls, plates, and silverware have become essential convenience items, the conventional materials they are composed of having a detrimental effect on the environment (Shen *et al*., 2020).

Cutlery is a term used to describe hand tools used for preparing, serving, and especially consuming food (Green *et al*., 2007). Cutlery that is edible has been taken into consideration in this essay. Examples taken into consideration in this essay are baked flour spoons and "puri(s)," which are offered with bhel-puri, a typical Indian snack (Narvekar., 2022).

Benefits due to edible containers and cutlery

Cutlery and Containers are often used in daily life. Typically, materials including stainless steel, aluminium, steel, iron, copper, brass, and other alloys are used to create them (Cutler., 2018). Theseare often cleaned and then used again. Butfrequently plastic containers and silverware are used in addition to these items. The issue arises from the fact that they are frequently discarded after only one use (Durr *et al*., 2011).

These mostly non-biodegradable plastic tableware and containers accumulate in the environment. Indians are thought to consume over 120 billion pieces of plastic cutlery each year, which puts the quantity of garbage in perspective (Com., 2020). About 40 billion people live in the United States. People typically resist recycling plastic cutlery because they believe it to be too little, too light, and contaminated (Weeks., 2010). There are existing initiatives to combat this, such as those urging consumers to refuse plastic utensils when ordering takeout. Additionally, single-use plastic is being outlawed by several governments (Tenenbaum., 2022). Along with these activities, the creation of plastic trash will be decreased if we switch to biodegradable containers.

Eating-related containers and utensils have various health advantages as well. When leaves are utilized as containers, they frequently include numerous health-improving compounds including antioxidants and alkaloids (Antolak *et al*., 2021). When food is put on a leaf, they are leached into the food, which is then ingested with it. These substances are intended to reduce risk for even severe disorders like diabetes and cancer (Onyeike &Series, 2012).

The idea of biodegradable cutlery is not new although to many it appears to be brand-new, it has been around since the early 1500s (Luchese *et al*., 2021). The bread dish was initially used to impress the British Duke in 1427. The Duke was so impressed with the invention that he granted the Irish nobleman who created it money to start a bread-bowl store in the area that is now known as Dublin (Natarajan *et al*., 2019). The Tosada bowl, which is also fashioned of stale tortilla, was invented in the 1930s. The contemporary bowl, which is an adaptation of a Mesoamerican design, has subsequently undergone several modifications, even a little Betty Crocker version. The Sourdough boule bowl was created later in the 1980s with the intention of selling San Francisco's clam chowder The bay area boosted popularity (O'Malley., 2019).

Plastic pollution is a global issue that is rising at an exponential rate as a result of increased consumerism and the use of more plastics in manufacturing has increased stuff that we utilize every day (Moshood *et al*., 2022). In 2018, over 380 million people Each year, tons of plastic are manufactured worldwide. From the 1950s through 2018, an estimated 6.3 billion tons of plastic were created globally, with an estimated 9% recycled and another 12% burnt. Studies indicate that 90% of seabirds have plastic debris in their bodies, which is a significant amount of plastic trash that is released into the environment (Wilcox *et al*., 2015). Through lowering plastic use, picking up trash, and encouraging plastic recycling, there have been considerable attempts in certain places to lessen the prominence of free range plastic pollution. According to some academics, by weight, there may be more plastic in the oceans by 2050 than fish (Awuchi.,2019). Plastic manufacturing and usage have increased globally for more than 50 years. Plastics have been produced and used more widely worldwide. A projected 299 million tons of plastics were produced in 2013, up 4% from the previous year and continuing the rising trend from the previous years. (World watch Institute, January 2017).

Our global plastic consumption was predicted to be 260 million tons in 2008, and according to a 2012 assessment by Global Industry Analysts, plastic consumption is expected to reach 297.5 million tons by the end of 2015 (Das, S & Das, B. 2017). Furthermore, because they do not biodegrade rapidly into the environment and require hundreds or thousands of years to do so, they limit the use of natural resources for future generations. Therefore, reducing the use of plastic must be one of the top concerns, especially for the equipment and utensils that are directly used for eating (Bonaventura &

Johnson 1997). One-time cutlery is in great demand; the United States, for example, uses 40 billion plastic ones per year (Munir., 2017). While India discards 120 billion pieces of plastic cutlery annually According to statistics provided by the Digital Journal, the worldwide demand is 640 billion per year, and the market for plastic cutlery was valued at US$2.62 billion in 2017 and is predicted to reach US$3 billion by 2025 Digital Journal, 2019 (Reddy, B. D., 2016). According to a 2018 National Geographic research, China contributes 29% of the world's total plastic manufacturing volume, while Asia accounts for 50% of all plastics manufactured worldwide (Parker., 2018).

Table 1. Plastic Vs Biodegradable Cutleries

1. Material Source

	Plastic	Biodegradable	Reference
Material Source	Derived from non-renewable resources like petroleum or natural gas	Derived from renewable resources like cornstarch, sugarcane, or plantbased materials	Dordevic *et al* .,2021.

2.

2. Toxicity

	Plastic	Biodegradable	Reference
Toxicity	May contain harmful chemicals, such as BPA or phthalates	Typically, free from harmful chemicals and safer for human use and the environment	Malafi *et al.*,1994

3. Biodegradability

	Plastic	Biodegradable	Reference
Biodegradability	Takes hundreds of years to decompose	Decomposes within a few months to a few years, depending on environmental conditions	Kliem, S *et al.*,2020

4. Durability

	Plastic	Biodegradable	Reference
Durability	Highly durable, Long-lasting and resistant to Degrading	Degrades more quickly, making them less suitable for long- term use	Iqbal *et al.*,2023

5. Carbon footprint

	Plastic	Biodegradable	Reference
Carbon Footprint	Higher carbon footprint due to resource extraction, production, and waste disposal	Lower carbon footprint due to the use of renewable resources and faster decomposition	George *et al.,* 2023

6. Marine Pollution

	Plastic		Reference
Marine Pollution	Contributes to marine plastic pollution, harming marine life, and Ecosystem	Less harmful to marine life and ecosystems due to faster decomposition	Bhuyan *et al.,* 2021

7. Waste Management

	Plastic	Biodegradable	Reference
Waste Management	Contributes to landfill waste and plastic pollution	Reduces landfill waste and plastic pollution due to faster decomposition	Evode *et al.,* 2021

8. Consumer Perception

	Plastic	Biodegradable	Reference
Consumer Perception	Often associated with environmental harm and Pollution	Generally perceived as more ecofriendly and sustainable	George *et al.*,2023

Factors responsible for Biodegradable cutleries

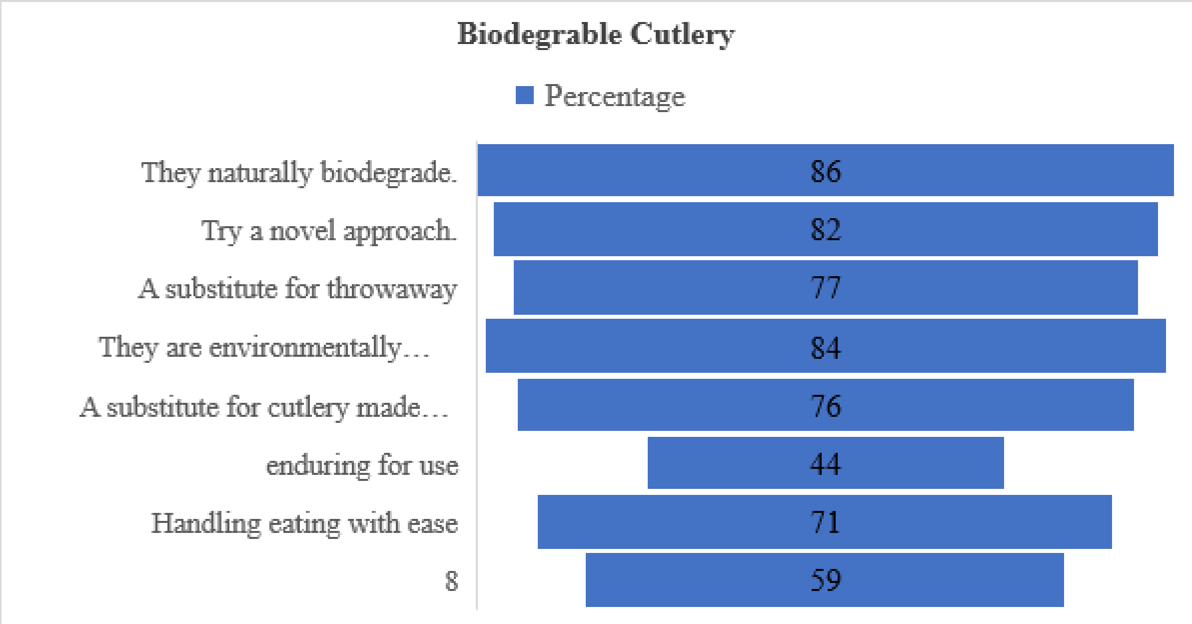


Fig 1. Demonstrates that customers are aware that eco-friendly and biodegradable cutlery is available. Additionally, it reveals that customers are still uncomfortable eating with edible. It cannot serve as a substitute for metal cutlery (Patil *et al.*,2018).

The author discovered after doing a literature review that a wide range of materials are utilized to create biodegradable cutlery. Here, the author has attempted to emphasize the information found in the prior section.

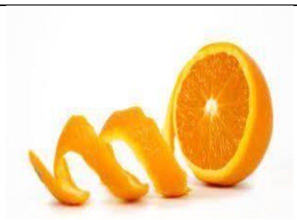
Table 1.2 Indicative list of Biodegradable cutleries and Table wares			
Sl.No	Cutlery/Company	Description	Reference
1	Rice Husk Table ware	One of the most resilient types of biodegradable cutlery that can sustain temperatures of more than 1000C without breaking is rice husk dinnerware. The smooth, glossy surface of this reusable dinnerware is 100% natural and derives from the wax found in rice husks. An entirely natural extract that is devoid of toxins and dangerous byproducts is the end result of the production procedure. These might be a viable replacement for everyday use storage, such as tiffin boxes and other containers, as they are sturdy, smooth, portable, and reusable.	http://www.ecoideaz.com/showcase/biodegradable-cutlery-for-the-eco-sensitive-foodie)
2	Bagasse Cutlery	The bagasse plant, a source of natural fiber, is used to produce sugarcane. For many years, bagasse has been used to make durable paper and food packaging. Additionally, it is relatively light, making it a fantastic option for eating on the move. Additionally, because it entirely decomposes, it won't contribute to the issue of expanding landfills. Last but not least, Bagasse silverware is a great substitute for plastic cutlery if you wish to be environmentally friendly.	(https://climaterealtalk.org/best-eco-friendly-disposable-cutlery/)
3	Bambu's Bamboo Cutlery	A US-based firm called Bambu provides a variety of environmentally friendly goods, including bamboo cutlery, a sort of biodegradable silverware that should only be used once before being thrown away. Bamboo from Bambu is used to make their cutlery, and it is an organic material that can be composted. The bamboo	(https://climaterealtalk.org/best-eco-friendly-disposable-cutlery/)

		cutlery from Bambu is also devoid of harmful chemicals and suitable for use with food. Forks, spoons, and knives made of bamboo are available from Bambu and may be used with both hot and cold meals.	
4	Eco Quality Cornstarch Cutlery	Cornstarch and other biodegradable materials are mixed to make Eco Quality cornstarch cutlery. Eco Quality cornstarch cutlery is also free of harmful chemicals and can be used with hot and cold foods.	(https://climaterealtalk.org/best-eco-friendly-disposable-cutlery/)
5	We Are Straw Cutlery	Their wheat straw cutlery is made from the leftovers of wheat crops, which would otherwise be discarded as waste. It's biodegradable and compostable, making it a more sustainable alternative to traditional plastic cutlery. We Are Straw's wheat straw cutlery is available in various shapes, including forks, spoons, and knives, and it is used for hot and cold food. The cutlery is also microwave and dishwasher-safe.	https://climaterealtalk.org/best-eco-friendly-disposable-cutlery/)
6	Wood able Disposable Wooden Cutlery	Wooden disposable cutlery is a type of eco-friendly disposable cutlery made from wood, usually from forests that are managed in a way that doesn't harm the environment. One of the best things about disposable wooden cutlery is that it is biodegradable and compostable.	(https://climaterealtalk.org/best-eco-friendly-disposable-cutlery/)
7	Earth Suds Disposable Cutlery	EarthSuds disposable cutlery is made from plastic and wood that have been reused or recycled. The brand's cutlery is safe for food because it does not contain chemicals or toxins. Also, they can be used for both hot and cold food.	(https://climaterealtalk.org/best-eco-friendly-disposable-cutlery/)
8	Bio Futura Disposable Cutlery	The cutlery made by Bio Futura is made of potato starch, The cutlery is strong and will last longer than regular plastic cutlery. The organic potato starch used to make the cutlery comes from small European farms. It is also better for the environment than plastic cutlery.	(https://climaterealtalk.org/best-eco-friendly-disposable-cutlery/)
9	Areca Leaf Cutlery	Cleansed, heated, and then chopped into the necessary solid forms, the dried sheaths from fallen betelnut trees or areca palm leaves. The entire process is chemical-free, leaving a negligible carbon footprint. They are an excellent substitute for caterers and event planners who care about the convenience of their clients and the environment at the same time.	(Boro et al., 2020)
10	Pineapple leaf pulp	Overall, the findings show that pineapple leaf pulp may be utilized to replace plastics in biodegradable packaging. In addition, this value-added utilization of natural fibers minimizes the waste stream and landfill impact.	(Mahatme et al .,2018)
11	Leaves as dining plates, food wraps and food packing material:	The emphasis has switched to the use of disposable plates manufactured from plant leaves, which are abundant in antioxidants and have therapeutic benefits. Serving meals on eating plates made of leaves is a long-standing custom in India with distinct cultural, religious, therapeutic, and social significance. In the Indian states of Odisha, Madhya Pradesh, Chhattisgarh, Andhra Pradesh, and Telangana, tribal people make their living by sewing leaf plates. To provide Naivedyam, leaves and leaf plates are utilized.	(Kora.,2019).
12	Malay Traditional leafen art food packaging	Traditional food packing, particularly those made of leaves and other plant parts, biodegradable. Products including bags, plates, cutlery, and bowls are now created from materials that decompose naturally	(Ibrahim et al., 2007)

13	Biodegradable disposable paper cup from pineapple peels, orange peels and Mauritian hemp leaves with beeswax coating	The production of paper cups from agro-waste using less water, energy, and raw materials could therefore be a way to boost a country's economy by turning these wastes into added-value products while minimizing deforestation and the amount of waste reaching the landfill. This study demonstrated that fiber extraction from fruit peel wastes and hemp leaves.	(Buxoo *et al* ., 2020)
14	Moringa Pod Husk cutlery	Biodegradable cutlery developed from moringa pod husk which has rich source of cellulose, fiber, hemicellouse pod husk cannot be consumed served as a waste material since biodegradable cutlery is a short time period it serve as a promising alternative for the convectional plastic cutlery.	(Kumbhar *et al.*,2020)
15	Envi green	Envigreen produces items manufactured with vegetable oil and natural starch derivatives as well as vegetable scraps. These goods are non-toxic. harmful to plants, animals, and the environment. Envigreen contains absolutely no traditional plastics. Envigreen operates as objective to eliminate plastic from the earth via efforts in the South-east Asian and Middle Eastern nations.	(http: //envigreen. In)
16	Edible utensils:	Using utensils that can be eaten after eating food or beverages is a novel notion. The types of edible cutlery include spoons, forks, soup spoons, and ice cream sticks. Millet and other common food ingredients are utilized to make these products. Food components of plant origin can be used to color and flavor edible cutlery with a variety of Flavors. The edible cutlery is appropriate for all climatic conditions and distant locations, and it can tolerate contact with fluids.	(https: //ediblepro. com/pages/ about - us\)
17	Dharaksha Eco solutions	An ecologically responsible start-up company that specializes in biodegradable packaging material is called Dhar Aksha Eco solutions minimizes the burning of agricultural waste by developing sustainable and biodegradable substitutes for Styrofoam that are produced chemically. Established businesses like Dabur, Kraft Packaging, and Barosi have already employed this material since it is reasonably priced and of high quality.	[https: //www.dharaksha. com].

Table 1.3 Raw materials used for Producing biodegradable cutleries

Sl. No.	Natural resources	Composition	Uses	Reference
1	Banana stem 	Cellulose (50%) Hemicelluloses (30%) lignin(18%) pectin (5%) Water soluble material (3%)	Health benefits Biodegradable cutleries Bioplastic Textile industry Compost Decorate items Livestock feed Ritual and tradition	(Mohiuddin *et al.*, 2014).
2	Pineapple leaves 	Cellulose 82% Hemicellulose18.80% Lignin 15.4% Pectin 3% Fat and wax 4.2%	Fiber extraction Eco friendly packing Medical use Biofuel production Bioplastic Weaving	(Coppola G *et al.*, 2021).
3	Orange peels	Cellulose Lignin	Flavouring beverage Culinary Infusion	(Katiyar., 2017).

		Hemicellulose Moisture 10.30%	Cooking and Flavouring Cosmetics Bioplastics Biodegradable cutleries	
4	Mauritian hemp leaves 	Moisture 6-7% Cellulose 51.6% Hemicellulose 27.0% Lignin 28.0% Soluble compounds 29.4% Ashes. 8.8%	Medical use Suitable packing Bioengineering Fiber production Soil erosion control Home Decore	(Aldalbahi *et al.*, 2021)
5	Corn husk 	Cellulose 29.3% Hemicellulose 39.7% Lignin 11.4% Moisture content 7.81	Bridgeable cutleries Packing and wrapping Corn husk tea Garding Animal beading	(Boachie. ,2015).
6	*Sugar palm* 	Cellulose 43.88 Hemicellulose 10.1 Lignin 33.24 Moisture content 6.45	*Artistic and culinary creation* *Baked goods* *Morden candy varieties* *Poetry and literature* *Cutleries* *Biodegradable*	(Pericu *et al.*, 2021).
7	Wheat straw 	Cellulose 39% Hemicellulose30% Lignine16% moisture content	Mushroom cultivation Bioenergy and biomass Composting and erosion control Artistic projects Biodegradable packing	(Ogbu & Okechukwu. ,2023).
8	Barley straw 	Cellulose 43% Hemicellulose33% Lignine 9% moisture content	Science experiments Animal comfort Mushroom cultivation Bioenergy and biomass Algae control	(Voloshin *et al.*, 2016)
9	Rice straw 	Cellulose 34.7% Hemicellulose 29.3% Lignine 19% Moisture content	Mushroom cultivation Biodegarble cutlaries Art and sculpture Bioplastic Biofule production	(Mohanty *et al.*, 2021)
10	Moringa pod 	Cellulose 40.5% Hemicellulose 65.5% Lignine 20.5% moisture content	Biodegrable cutlaries Nutrition and health programe Cultaral dishes Oil production Water treatment Moringa tea	(Gonsalves., 2016).

11	Oat straw 	Cellulose 35% Hemicellulose26% Lignine 15% moisture content	Herbal Medicine Organic matter Mulching and garding Pet bedding Biofuels Biodegarble cutlaries	(Havstad., 2020).
12	Corncobs 	Cellulose 41% Hemicellulose36% Lignine 15% moisture content	Insulation Birds feeder Biofuel Education and scince Abrasive material	(Shogren., 2019)
13	Sorghum straw 	Cellulose 35% Hemicellulose27% Lignine 21% moisture content	Live stock forage Soil improvement Cultural and trditional use Building materials Oraganic mater Biodegarble cutlaries	(Ammar., 2023).
14	Potato peels 	Cellulose 8.3% Hemicellulose 7.41% Starch 23.01% Moisture 5.26%	Food production Startch extraction Fertilizer Biodegarble packing Bioplastics Animal feed	(Khodaei *et al* .,2021).
15	Mango kernel 	Cellulose 25.2% Hemicellulose 34.06 % Lignin 32.88 Moisture 5.26	Natural Binders Dyeing fabric Mango kernal oil Flavouring beverage Paintings Art and craft	(Snodgrass. ,2012).

Manufacturing techniques are essential for producing biodegradable packaging and dinnerware products. To guarantee that ecologically appropriate alternatives to single-use plastics are widely adopted, these methods must be effective, economical, and efficient. The discussion of the production processes for biodegradable dinnerware.

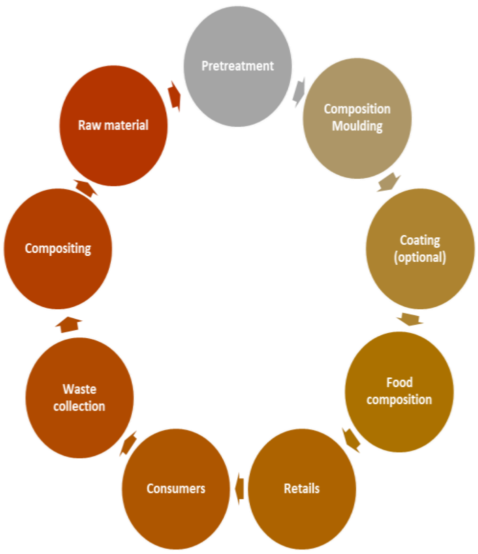


Fig No – 2. Flow Chart for Manufacturing of biodegradable cutlery

2. Raw material preparation

Before drying at room temperature, Raw material leaves were washed in water to remove dirt and soil particles the leaves were divided into tiny, 5 cm-long pieces. (Sibaly & Jeetah.,2017). These were cut the pulping of raw material (Pineapple leaves, cornhusk, fruit peels etc) using chemicals (soda) the ratio of raw material leaves (kg wet weight) to pulp is 1 to 4. 10% solution of sodium hydroxide (Farhata *et al.,* 2017).

To find the ideal amount of time for the leaves to break down into pulp, the raw material were cooked for 120, 150, or 180 minutes (Aremu *et al.*, 2015). The pulp was then extensively rinsed under running water to get rid of the remaining chemicals. The pulp was then pressed to remove water and weighed into dosages of 200, 250, and 300 g for paper production (Hailu., 2020).

2.1 Making paper from the fibrous pulp

A 50 g/L starch solution was added to each pulp, and the mixture was stirred for 5 minutes. To create a paper sheet, the mixed materials were put on a mesh frame with dimensions of 40:40 cm. The paper sheet was then heated to 65 degrees Celsius and dried for 6 hours (Yusof *et al.,* 2012). In order to test packaging formation, a paper sheet was cut to a size of 20 x 20 cm and placed on a compression molding machine (VDU-100 type LCC-144) that was set to 200 °C and 200 kg/cm^2 of pressure for 10 minutes. This process is referred to as "hot pressing" (Wei *et al.,* 2016)

3. Experimental Procedures

3.1 Physical and Mechanical property testing

3.1.1 Thickness and grammage

The thickness of the paper was determined using a Vernier caliper. Eight locations on each sample were measured, and the mean thickness was determined with an accuracy of ± 0.001mm. The grammage of paper was determined according to ISO 536 (Iewkittayakorn *et al* .,2020). Whenever possible, each test piece shall have an area of not less than 500 cm2 and not more than 1000 cm^2. 20 test pieces were weighted on a balance and masses were recorded to three significant figures.

The grammage in grams per square meter was calculated as follows:

$$g = \frac{m}{A} \times 10000$$

where m is the mass of the test piece (g) and A is the area of the test piece (cm^2). ISO 536 Determination of grammage (Chungsiriporn *et al.*, 2022).

3.1.2 Absorbency

The absorbency was measured by placing a paper sample on top of a cavity. 0.01 cm3 (10L) of water was dropped on top of the paper using a micropipette. A stopwatch was immediately started when the preset volume of water was dropped on the paper, and it was stopped when the water droplet was completely imbibed into the paper. This test was repeated five times at different locations on each type of sample (Sibaly *et al.*, 2017).

3.1.3 Water absorptiveness

The Cobb method was used to determine water absorptiveness of the paper according to ISO 535 (ISO 535 Determination of water absorptiveness). Five samples of each type of bio-coated paper were kept in the conditioning atmosphere throughout the test. After weighing, the samples were slowly immersed in 100 ± 5ml water (or proportionately less for a smaller test area) in a cylinder providing 10mm head space, and the timer was immediately started. Fresh water was used for each determination. The samples were taken out of the liquid, blotted with an absorbent paper to remove excess water, and weighed again. The procedure was repeated until reaching equal masses in two consecutive measurements (during 4 days), and the absorption capacity of the paper was calculated using Eq (Sibaly *et al.,* 2017).

water absorptiveness = (m2 − m1) F (2)

where m^2 is the wet mass of the test piece (g), m1 is the dry mass of the test piece (g) and F is 10,000/test area (for a typical test apparatus this is 100 cm2)

3.1.4 Tensile strength

Tensile strength was tested on an Instron Testing System Model UTM-5582 equipped with a 1 kN capacity load cell. A total of 8 representative test pieces, 25 ± 1mm wide and 180 ± 2mm long, were cut from each type of paper and tested to obtain the tensile properties, namely elongation at break, force to break, force at break, time to failure, strain at break and stress at break, from which the tensile strength was determined. The rate of elongation (crosshead speed) was set to 5mm/min ± 2.5mm/min (Sibaly *et al.*, 2017).

3.1.5 Burst strength

Twenty pieces of bio-coated paper samples (2.5 × 2.5 in.) were used to test burst strength in accordance with (ISO 2758 Determination of bursting strength). The specimens were securely clamped in position, with overlap at all points. Hydrostatic pressure was increased as specified until the specimen ruptured, and the maximum pressure was registered. If any movement of the unclamped margin of the specimen was observed, that test run was rejected and clamping pressure was increased. If, however, excessive clamping pressure damaged the specimen, the test result was also disqualified and the clamping pressure was reduced. Each side of the paper was tested ten times (ISO 2758 Determination of bursting strength).

3.1.6 Drop test
Sample cups with no cracks were dropped from a height of 0.8 m and were there after analyzed for cracks or splits after impacting on a level cement floor The drop test gives an early indication of the strength properties of the Cutleries. Those which cracked after the drop test shows that no big force was necessary to rupture the bonds between the lignocellulosic fibers.

3.1.7 Internal tear resistance of paper (Elmendorf-type method)
The tear resistance of paper was determined from the average tearing force in accordance with the Elmendorf method (ISO 1974. Paper-Determination of tearing resistance). The test pieces were first conditioned in a controlled atmosphere. The two sides of the paper were distinctly marked for distinguishing between them. The bio-coated paper was cut to four rectangular sheets of the same size, between 50 ± 2mm and 76 ± 2mm wide and 43 ± 0.5mm long. A pendulum (with augmenting mass) was used to regulate the energy input and to show the remaining energy by swing amplitude. The mean readings were arranged to within the range 20% to 80% of the full-scale reading by adjusting the mass and the number of sheets tested in a single run. The tear resistance was determined as follows (ISO 1974. Paper-Determination of tearing resistance).

$\mathrm{F} = Fp/n$

F is the tearing resistance (mN), F is the mean scale reading (mN), p is the number of sheets torn simultaneously for which the pendulum scale has been calibrated to give a direct tearing resistance reading (mN), and n is the number of sheets torn simultaneously

3.1.8 The surface morphology analysis by scanning electron microscopy
Scanning electron microscopy (SEM) was employed to analyse the morphological properties of the paper and the bonding quality between the pineapple leaf fibers and the bio-coating. The surface morphology of uncoated and coated paper was investigated from Scanning Electron Microscope (SEM, JSM5800 LV, JEOL; Japan) imaging. The surface of the sample was carbon coated and then gold coated for conductivity, and the SEM accelerating voltage used was 20 kV.

3.1.9 X-ray diffraction (XRD)
This test was performed to obtain information about the crystallinity of the produced CA by using an X-ray diffractometer to collect (at room temperature) XRD patterns of the prepared cellulose acetate sample. By using a Philips powder diffractometer with Cu Ka radiation (k = 0.154 nm), X-ray diffraction (XRD) patterns of the samples were recorded in the range 2h = 4–80^{0}. The instrument was operated at 40 kV and 40 mA. The spectra were recorded with a 2h step of 0.02box at a scanning rate of 2h/min. (Mostafa *et al.*, 2018).

3.1.10 Fourier Transform Infrared (FTIR)
FTIR was used to confirm the structure of cellulose acetate. By using a Nicolet IS-10 FTIR instrument with KBr discs, FTIR spectroscopy measurements were made. The peaks, as given in the chart, indicated that the functional groups were present in the CA sample (Mostafa *et al.*, 2018).

3.1.11 Antioxidant Activity
DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging ability of the extracts was evaluated as described by AOAC method. A portion of the extract (1 mL) was mixed with 1 mL of the 0.4 mM ethanolic solution of DPPH radicals, incubated for 30 min, and the absorbance was measured at 517 nm (Najjar *et al.*, 2022). Free radicals scavenging ability was expressed as percentage (%) inhibition. DPPH radical scavenging activity (%) = (1- $absorbance\ of\ sample$X100 $absorbance\ of\ contro$) ÷ 100

3.1.12 Moisture Content
To determine the moisture content of leaves, obtain fresh leaves, weigh them, then dry them in a hot oven. Take readings of the dried leaves until the weights are equal. The moisture content of the leaves can then be calculated by subtracting it from the freshly leaf weight. The moisture content is found by dividing the result by the weight of dry leaves.
Test Methods: Annex B of IS: 15271-2003 RA2013 Ed 1.1 (2006-02)

4. Microbial Analysis
4.1 Total Yeast and Mould count
A high yeast and mould count in food goods is not desired and shows that insufficient plant sanitation management, inappropriate packaging, and faulty storage were the contributing causes throughout product manufacture. The sample for microbiological inspection should be handled with caution and should be truly delegated of the lot. IS 5404 must be followed for this object. Preparation

of poured plates with an identify choose media and an identify quantity of the test sample if the starting product is liquid, or an identify suspension if the starting product is other.
Test Method: IS 5403: 1999 RA 2018

4.2 Coliform count

Bacteria that produce distinctive colonies in gentian violet neutral red bile lactose agar under the test circumstances specified within this International Standard at the required temperature (i.e. 30°C, 35°C, or 37°C, as agreed). Prepare two stream plates, hire a solid choose medium, and hire a set quantity of the test sample if the starting product is liquid, or hire a certain quantity of an initial suspension if the starting product is another. Other pairs of stream plates are prepared under similar conditions, using decimal dilutions of the test sample or the starting suspension.
Test Method: IS 5401(Part 1): 2012 RA 2018

4.3 Escherichia coli (E-Coli Detection)

This standard (Part II) specifies the method for isolating, validating, and counting *Staphylococcus aureus* and *Fusarium spp* in foods. The samples for microbiological research should be handled with care. IS :5404-1969t will be used for this object. This standard describes the method for locating and estimating important microorganisms that cause food-borne illnesses.
Test Method: IS: 5887(P-1): 1976 RA 2018

4.4 Salmonella (Detection)

Methods for examining Bacteria that are responsible for gastrointestinal disorders. The moola head's outermost leaves were removed since they were unsanitary, and only the Centre 2–3 leaves were used for the practical. The leaves were unsanitary, so cut them into 3 x 3 cm pieces with a sterilized scalpel, as previously recommended.
Test Method: IS:58887(P-3): 1999 RA 2018

4.5 Biodegradation Tests

Biodegradation by composting. Samples (5 g) of the produced CA were vacuum dried for 24 h at 45^0C, weighed precisely and, next, buried into the municipal solid waste mixture. Then, they were examined for possible biodegradation. The mixture consisted of leaves, paper waste, cow manure, food waste, composting seeds, urea, wood waste and water (Muller., 2005). The mixture was kept in an oven at 55^0C, at which the maximum growth of thermophilic microorganisms occurred. The samples were weighed every three days in order to determine the percentage of weight loss (Mostafa *et al.*, 2018).

5. Applications of Biodegradable Cutleries

Biodegradable Cutleries have become increasingly popular as a sustainable alternative to traditional plastic cutleries. Helping reduce plastic waste and promote eco-friendly practices. Here are some examples of biodegradable Cutleries.

Food Service Industry: Biodegradable cutleries is widely used in restaurants, cafes, and fast food Chains as an alternative to traditional plastic utensils. It reduces plastic waste and contributes to the overall sustainability efforts of food service industry (Perrigot *et al.*, 2021).

Events and Gatherings: Biodegradable cutlery is a popular choice for events such as parties, weddings, conferences and outdoor gatherings. It offers the conveniences of disposable utensils without the negative environmental consequences of single-use plastics (McCallum., 2018).

Takeout and Food Delivery: Many food delivery services and takeout restaurants are adopting biodegradable cutlery to provide customers with a greener option for utensils. This helps minimize the environmental impact associated with food packaging waste (Wongprapinkul., 2021).

Fast Food Chains: Many fast food chains are adopting biodegradable cutlery to align with sustainability goals while maintain the efficiency of their operations (Perrigot *et al.*, 2021).

Cafeterias and Institutions: Schools, offices, and institution that provide meals can opt for biodegradable cutlery to promote responsible waste management and environmentally conscious practices (Cheng., 2016).

Outdoor Activities: Campers, hikers, and outdoor enthusiasts can be benefit from bride gradable cutlery as it offers a light weight, disposable option that doesn't harm the environment (Fleckenstein., 2016).

Food Packaging: Biodegradable cutlery can also be integrated into eco-friendly food packaging solutions, minimizing the environment impact of the entirely packaging system (Roohi *et al.*, 2018).

Home use: Individuals are also choosing biodegradable cutlery for personal use at home. This reduces are overall demand for conventional plastic utensils and contribute to a more sustainable lifestyle (Rabiu & Jaeger-Erben., 2024).

Government Regulations: As governments worldwide implement stricter regulations on single-use plastics, the demand for biodegradable cutlery could increase across various sectors to comply with these policies (Vadera & Khan 2021).

Hospital and health care Facilities: In healthcare settings, where hygiene is a paramount, b biodegradable cutlery can be used for patient meals and other food services. It can be deposed of safely without contributing to the plastic waste stream (Tellier *et al.*, 2017).

Airline Catering: Biodegradable cutlery can be used by airlines to reduce plastic waste during in-fight meal services, contributing to their sustainability initiative (Lönnqvist., 2022).

Composting: Biodegradable cutlery is designed to break down naturally, some communities have composting Facilities that can process these utensils along with other organic waste, further the environmental impact (Song *et a.*, 2009).

6. Conclusion

The usage of edible cutlery and biodegradable cutlery is widespread across their popularity is expanding quickly over the world. This is shown by the high number of manufacturers. And the ever-growing number of creative goods obtainable from the market.

Cutlery and food containers unquestionably aid in reducing plastic waste. But one thing to consider is if disposable cutlery and containers are more environmentally friendly than reusable ones. Cutlery and edible items frequently come packaged in plastic. Additionally, there are several processing procedures and transportation steps required to create edible containers and utensils, which are ultimately consumed (either eaten or thrown away) all at once. Given this, it is clear that, while edible containers and cutlery are undoubtedly preferable than single-use plastics, we must utilize reusable containers and cutlery wherever feasible. Only when using single-use containers and cutlery is necessary for some reason should edible containers and utensils be used. For instance, due to logistical considerations

The way people treat food containers and utensils has to alter, just as people are used to cleaning fruits only after eating them. This will undoubtedly take place gradually and progressively. In the future, individuals may be able to select edible pods of food in the same way as they do now when picking fruits that are stored in stores without packing. If the product is unaffected by a single wash with water, they might be used without the requirement for external packaging. We should make an effort to make sure that no one discards food containers or silverware. This is because utilizing biodegradable or compostable containers and cutlery that need fewer processing stages is preferable if these edible containers and utensils are simply going to be tossed away.

Containers and cutlery that are readily edible to animals but not to humans offer another option if individuals prefer to discard edible containers and cutlery after using them owing to palatability or hygiene concerns. This could be the result of a number of factors, including hardness and resistance to being wet with water. While these qualities make containers and cutlery useful, they may make them safe for using by people.

While biodegradable cutlery offers several benefits, it's essential to recognize that their environmental impact is not without complexities. Factors such as proper disposal methods, industrial composting facilities, and the overall carbon footprint of production need to be taken into account. In cases where these utensils end up in standard waste streams or are improperly discarded, they might not fully biodegrade and could still contribute to pollution.

In the broader context, while biodegradable cutlery can play a part in reducing plastic waste, it's just one aspect of a more comprehensive strategy to address environmental issues. Ultimately, a combination of responsible consumption, waste reduction, recycling, and advancements in sustainable materials will collectively contribute to a cleaner and healthier planet. To maximize the positive effects of biodegradable cutlery, education and infrastructure are key. Public awareness campaigns can help educate consumers about the proper disposal methods, while governments and industries should invest in composting infrastructure to ensure these products break down efficiently. Additionally, ongoing research and innovation are vital to improving the durability, cost-effectiveness, and overall sustainability of biodegradable materials.

7. Future Prospects for the Research and Development of Biodegradable, Ecofriendly, Sustainable Materials and Applications

With continued technological breakthroughs and growing worldwide awareness of environmental concerns, the future prospects for research and development (R&D) of biodegradable, environmentally friendly, and sustainable materials and applications are positive. Key areas of concentration and future expansion include:

New materials: New biodegradable materials made from renewable resources, such as plant-based polymers, fungus mycelium, and algae, are constantly being researched and developed by scientists. In a variety of uses, from packaging to consumer products, these materials might replace traditional plastics in an environmentally beneficial way.

Improved biodegradability: The goal of R&D is to make current materials more biodegradable so that they decompose more quickly and with less harm to the environment. This entails reducing the production of toxic byproducts, optimizing degradation rates, and making sure materials can be recycled successfully recycled or composted.

Waste-to-resource Technologies: Innovative techniques are being developed by researchers to transform waste goods, such as agricultural wastes, into useful biodegradable materials with this strategy, waste is not only reduced but a sustainable supply of raw materials for biodegradable goods is also made available.

Collaborative efforts: The creation and use of biodegradable, environmentally friendly materials can be facilitated by international partnerships between researchers, business, and regulators. These collaborations can aid in determining research goals, information and resource sharing, and the development of regulatory frameworks that are favorable to sustainable materials.

Advanced manufacturing techniques: To make biodegradable and environmentally friendly items more effectively and with less waste, new production techniques like 3D printing and additive manufacturing are being investigated. These methods can also make it possible to create intricate shapes and structures that were previously unimaginable. (George *et al.,* 2023)

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Conflict of interest

The authors state that they do not have any conflicts of interest.

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