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Utilising Pineapple Peel as a Renewable Raw Material for Making Edible Cutlery

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Abstract

The growing environmental concerns associated with plastic waste, especially single-use plastic cutlery, have prompted the search for sustainable alternatives that are biodegradable and non-toxic. Among the various possibilities, the use of agricultural waste products, such as pineapple peel, has emerged as a promising approach to developing eco-friendly edible cutlery. Pineapple peel, which constitutes a significant portion of the fruit discarded during processing, is typically viewed as waste. However, recent studies have shown that it possesses a unique composition of cellulose, lignin, and other polysaccharides that can be exploited for various industrial applications, including the production of edible and biodegradable materials.

This research explores the potential of utilising pineapple peel as a renewable raw material for creating edible cutlery that could serve as a sustainable replacement for conventional plastic utensils. The study investigates the physical and chemical properties of pineapple peel, examining its structural integrity, moisture content, and texture, to determine its suitability for moulding into cutlery shapes. Additionally, the research evaluates various processing methods, such as enzymatic treatments, drying techniques, and blending with other natural fibres or food-grade additives, to enhance the material's strength, durability, and biodegradability. Moreover, the research examines the nutritional and safety aspects of edible pineapple peel-based cutlery, ensuring that the final product is both safe for consumption and aligned with food safety standards. The sensory properties, such as taste, aroma, and mouthfeel, are also assessed to ensure a pleasant eating experience for consumers. Environmental impact assessments are conducted to compare the carbon footprint and biodegradability of pineapple peel-based cutlery with traditional plastic cutlery, highlighting its advantages in terms of waste reduction and sustainability. The research also explores potential challenges, such as scalability in production and market acceptance, as well as the economic feasibility of using pineapple peel as a raw material on a commercial scale. In conclusion, this study aims to contribute to the development of a circular economy by transforming agricultural waste into valuable products that can help mitigate plastic pollution while providing a functional and safe alternative to single-use plastic cutlery. The findings of this research could pave the way for further innovations in sustainable packaging and waste utilisation, contributing to the broader effort of reducing environmental pollution and promoting sustainability in the foodservice industry.

Keywords: Anti-Bacterial, Bioactive Compounds, Cutlery, Quality

1. Introduction

Cutlery has been one of the most important yet useful production tools for eating all over the world. It is estimated that the spoon is one of the oldest tools used by humans. These were made from natural materials such as wood, animal bones and shells. The oldest example is of 1259 spoons in England. Forks and knives for eating were also introduced at the beginning of the 18th century.

Until the invention of stainless steel, silver was the metal of choice for cutlery as it did not react to most foods. Stainless steel has become the metal of choice for

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most cutlery as it is strong, durable and easy to maintain. With the introduction of plastic products to the market, cutlery became cheaper and easier. For example, glasses, plates, spoons, forks, knives and many more products are produced in various designs and sizes. Today, stainless steel cutlery is more expensive than plastic or edible cutlery[1].

Pineapple peels are safe for consumption and do not contain any harmful natural toxins or heavy metals. The principal allergen implicated is bromelain, an enzyme that can trigger mild adverse events in sensitive individuals, but anaphylaxis is rare[2]. Natural compounds such as saponins and flavonoids may cause some minor irritation, but this is rare. The peel can carry more pesticide residues than the inner fruit, since it is directly exposed during farming. This will cover different types of pest control, such as organophosphates and neonicotinoids. Although levels are generally within safe limits, they can be elevated based on how the fruit is grown. Following good farming practices will mitigate these dangers[3].

Various toxicological studies conducted to evaluate individual or combined use of pineapple by-products and/or residues, such as peel/crown, at different concentrations are non-toxic. For instance, the *Artemia salina* bioassay of the toxicity showed that the LD50 value (the lethal dose to 50% of the organisms tested) of pineapple residues was well above the threshold for a toxic substance, and therefore inactive and non-toxic for common food application[4]. In bodies that aren't allergic to any of the ingredients, current science and food safety evidence indicate that pineapple edible cutlery is safe for the general population, provided it's eaten in moderation (two to three utensils per food serving, for Adults). People with pineapple allergy should avoid this product as it causes allergic reactions (such as gastrointestinal problems). If large amounts or chronic habitual use is expected, or if coexisting medical or dietary problems exist, then a health professional should be referred to. Normal consumption is fine and safe for common use.

1.1 Plastic Waste Effects on the Environment

Plastic pollution alters habitats and natural processes, reduces the ability of the ecosystems to adapt to climate change, and directly affects livelihoods, food production and clean drinking water for millions of people. The work of the United Nations Environment Program shows that the air pollution problem does not exist in a vacuum. The world is facing a global plastic problem. About 79% of the 8.3 billion tons of plastic produced since 1950 ended up in landfills or leaked into the environment.

1.2 Solid Waste and Its Disposal

Waste disposal is another major problem in the current industry. Due to rapid urbanisation and population growth, serious solid waste management problems have emerged in many countries. Waste products formed as a result of human activities and industrial processes, especially plastics, increase rapidly in volume, harm the environment and threaten ecology. Disposal of waste close to the shore can have a serious impact, especially when plastic enters the food supply through bioaccumulation. Plastic products have always been popular for their convenience and economic benefits, but have increased the amount of non-degradable waste products that are a concern. To solve this problem, researchers and entrepreneurs developed new food and flatware or cutlery using bio-based raw materials. However, due to the high cost of bio-based materials, their application is limited to specific businesses with environmental considerations. So, in this case, it's a good idea to create cheaper edible flatware, which uses cheap underutilised food by-products of the process. Food waste and by-products are important because of proteins, lipids, starches, micronutrients, bioactive compounds, dietary fibre containing moisture and ash content and all quality last. All organoleptic properties of the fruit, for example, taste, are determined by the tissue fat content. Food cutlery or coated films based on these plant materials can be an alternative to food products that contain colour-potential antioxidants and polyphenols. This research work mainly focuses on the reduction of value-added edible and biodegradable cutlery, which can potentially replace single-use plastic cutlery, along with the utilisation of solid waste value-added products. Safety cutlery, particularly that which is edible, has garnered significant attention for employing more intelligent, secure, and eco-friendly plastic options[5]. Established in 2011 by scientist Narayana Peesapathy, Bakeys aims to offer a sustainable substitute for conventional plastic utensils.

This initiative, launched by Peesapathy, manufactures functional kitchen utensils (such as white spoons, forks, and even chopsticks) made from rice, alongside dried millet (sorghum or sorghum). Utensils like chopsticks and spoons remain unaffected by food and liquids.

Consuming meals might become simpler with these since they tend to sell out in roughly 10 to 15 minutes.

2. Materials and Methodology

Pineapple peel is used as a base material. Pineapple peels are used to make cutlery and are added in a concentration of 8%, 10%, and 15% to evaluate their effect on the properties of edible cutlery. Icing sugar and refined wheat flour are used as binding agent to improve their structural properties.

2.1 Sourcing of Plant Material

Ananas comosus peel was collected from the Solan district in Himachal Pradesh. Fresh *Ananas comosus* were used for the preparation of the extract. Before using the pineapple peels, it was thoroughly washed to remove any dirt or residues. Then rinse the peels under running water and gently scrub them with a soft brush or sponge.

2.2 Wheat Flour

Wheat flour is a powder made from the grinding of wheat used for human consumption. Wheat flour is the major ingredient and consists mainly of starch (ca. 70–75%), water (ca. 14%) and proteins (ca. 10–12%)[6].

2.3 Icing Sugar

Icing Sugar is a type of finely powdered sugar that is commonly used in baking. To make edible cutlery using icing sugar, mix icing sugar with water to create a smooth and pliable dough. Once the dough is ready, you can shape it into the desired shape of your cutlery using moulds or by hand.

2.4 Pre-Treatment of Pineapple Peels

Ananas comosus peel was collected from the Solan district in Himachal Pradesh. Fresh *Ananas comosus* were used for the preparation of the extract. Before using the pineapple peels, they were washed thoroughly to remove any dirt or residues and gently scrubbed with a soft brush or sponge.

2.5 Soaking and Drying

Submerge the pineapple peels in the water for 1 hour. After soaking, the peels were rinsed under running water to remove any dust or residues. Once rinsed, the pineapple peels were allowed to drain and air dry. They were then placed on clean, absorbent towels or racks to facilitate drying and made sure they were completely dry before proceeding with further processing.

2.6 Processing Techniques (e.g., Drying, Grinding, Moulding)

Firstly, the pineapple peels were cut into small pieces. The peels were then spread evenly on drying trays or racks and placed in a dehydrator at 55°C for 20 hours[7].

2.7 Grinding

Once the pineapple peels were fully dried, they were ground into a fine powder using a blender or milling machine. The grinding time and speed were adjusted to achieve the desired texture and fineness of the pineapple peel powder. The powder is used to remove any coarse particles or fibres, ensuring a smooth and uniform consistency.

2.8 Mixing and Forming

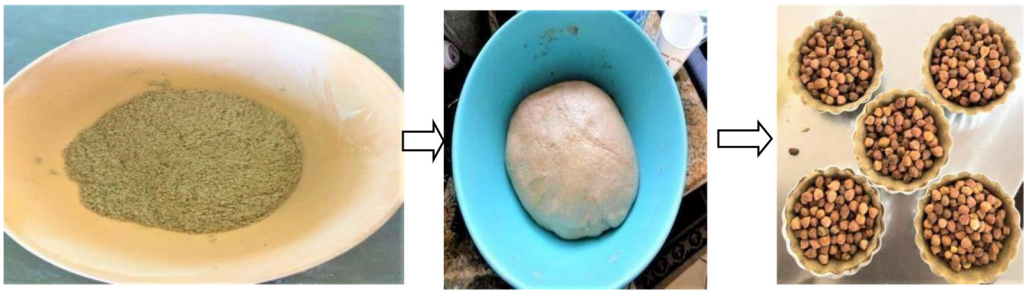
In a mixing bowl, combine the pineapple peel powder with other ingredients, such as flours (e.g., wheat flour) and sugar. Gradually add water or other liquid ingredients while stirring to form a dough-like consistency.

2.9. Shaping and Moulding

Take small portions of the dough and roll them into a ball or a log shape. Use a rolling pin to flatten the dough into a thin sheet of desired thickness. Cut out shapes using cookie cutters or specialised moulds for spoons, forks, or other utensil designs. The flow chart for the preparation to make cutlery is shown in Figure 1.

3. Drying and Curing

The mould is placed in a baking dish sheet. The cutlery is placed in the oven at 170°C for 25 minutes. A controlled drying environment is maintained to prevent excessive moisture loss or cracking. The drying time is monitored to achieve the desired level of hardness and structural integrity. After drying, the cutlery is exposed to the air for further curing, ensuring it becomes sturdy and durable.



Preparation of ingredients **Preparation of Dough** **Moulding**

Figure 1. Flow chart for the preparation to make cutlery.

3.1 Composition of Samples

To find out which composition of ingredients is best, 4 samples were prepared using ingredients in different ratios as given in Table 1 below.

Refined icing sugar is used in a ratio of 30, while the concentration of pineapple peel powder varies. The cutlery was baked at 170^0 C for 25 minutes. It was taken out of the oven and evaluated for different parameters. The final fabricated cutlery is shown in Figure 2.

4. Results and Discussion

4.1 Water Holding Capacity

The water holding capacity is an important parameter for edible cutlery, which checks how long the liquid can be kept in it. To evaluate the capacity of cutlery to hold water, 10ml of cold water was kept in it until it leaked.

4.2 Water Absorption

Samples of each combination were tested for water absorption. The initial weight of the cutlery was recorded. 10ml of water was kept in it for 20 minutes. The remaining water was then decanted, and excess water was removed from the surface. The final weight of cutlery was recorded, and then the percentage absorption was calculated. The figure below shows a water absorption test conducted on cutlery. The given formula calculates the percentage of water absorption-

$$\%Water\ Absorption = \frac{Final\ weight\ of\ cutlery - Initial\ weight\ of\ cutleryx}{Initial\ weight\ of\ cutlery} \times 100$$

Table 1. Composition of edible cutlery samples

SAMPLE NO.	WHEAT FLOUR	ICING SUGAR	PINEAPPLE PEEL POWDER
C	70gm	30gm	-
T1	62gm	30gm	8gm
T2	60gm	30gm	10gm
T3	58gm	30gm	12gm
T4	55gm	30gm	15gm



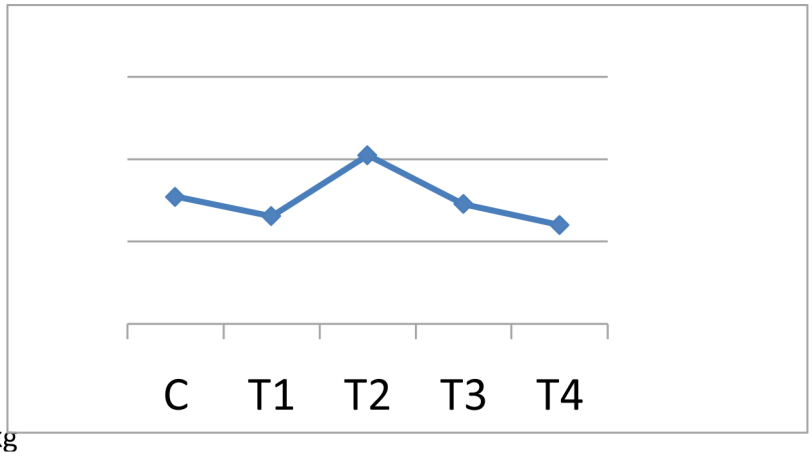
Figure 2. Fabricated cutlery.

4.3 Texture Analysis

A texture analyser is the source of ultimate objective quantification of whether the food is crispier, firm, sticky, etc., as a result of a new technique or the addition of certain ingredients to the formulation. The texture analyser present in the lab at Bhai Gurdas Institute of Engineering and Technology, Sangrur (P.B.), is used to check the hardness in the sample, which is calculated to analyse the strength of cutlery and how much force is required to chew it. Triplicates of each sample were taken for this test. The texture profile analysis was presented in Graph 1.

4.4 Biodegradability

The biodegradation term indicates degradation of material by the action of microorganisms. The



Graph 1. Texture profile analysis

4



Figure 3. Soil Buried test for cutlery samples

biodegradation test is done to check the biodegradability rate of the samples. The microorganism present in the soil acts on the biomaterial and degrades it completely[8]. Therefore, the best method to check the biodegradation rate is of cutlery is to keep it in soil and allow microorganisms to degrade it for a few days. Edible cutlery samples were kept in the soil as shown in Figure 3, and the weight was recorded regularly (7-14 days) to check the rate of biodegradation.

4.5 Water Retention Capacity

The cutlery samples were analysed for water holding capacity, and results concluded that the samples could hold water up to Thour without leakage. Also, they can hold food up to 20-40 minutes without turning soggy, as shown in Figures 4-6. The cutlery was turning soggy due to the presence of bio-based flours in it.

4.6 Water Absorption

Water absorption percentage for all the samples was evaluated by putting cold water in them. The trend for water absorption is shown in Figure 7 with the help of Graph 2. The trend is as follows: Control sample $1>S2. S3. Cutlery with the highest percentage of pineapple peels shows minimum water absorbance; this trend is observed due to the presence of fibres in pineapple peels[9].

4.7 FTIR (Fourier Transform Infrared)

Characteristic peaks between 2943 and 3240cm^{-1}, signifying = C-H stretching, because of the presence of wheat flour, were noticed in all analysed samples of edible pineapple peel cutlery. Peaks also signifying O-H(acids) functional group between 2500 and 3300cm^{-1} were observed in the cutlery. The FTIR report of cutlery was presented in Graph 3.

4.8 Moisture Analysis by Oven Dry Method

To measure the dry weight of the cutlery samples, they were first dried in an oven at 110°C for 120 minutes. After



Figure 4. After 15 minutes.



Figure 5. After 30 minutes.



Figure 6. After 45 minutes.

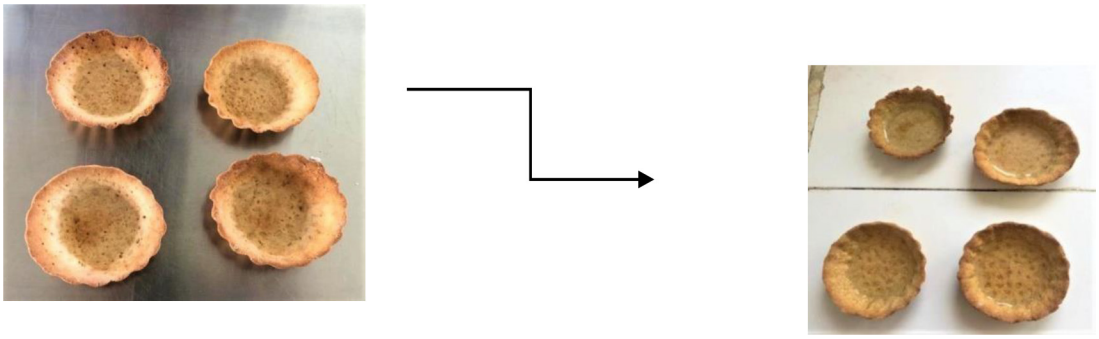
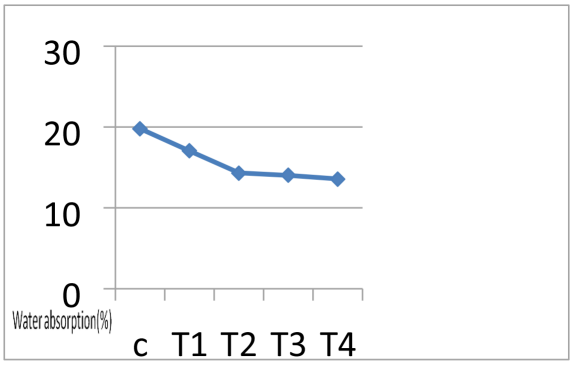


Figure 7. Water absorption- initial and after 20 minutes.



Graph 2. Graphical Representation of Water Absorption

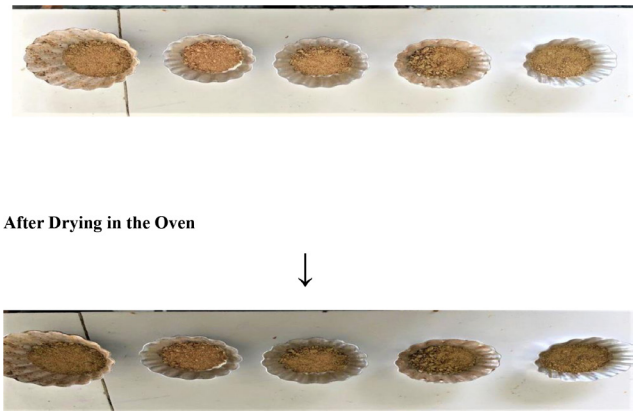
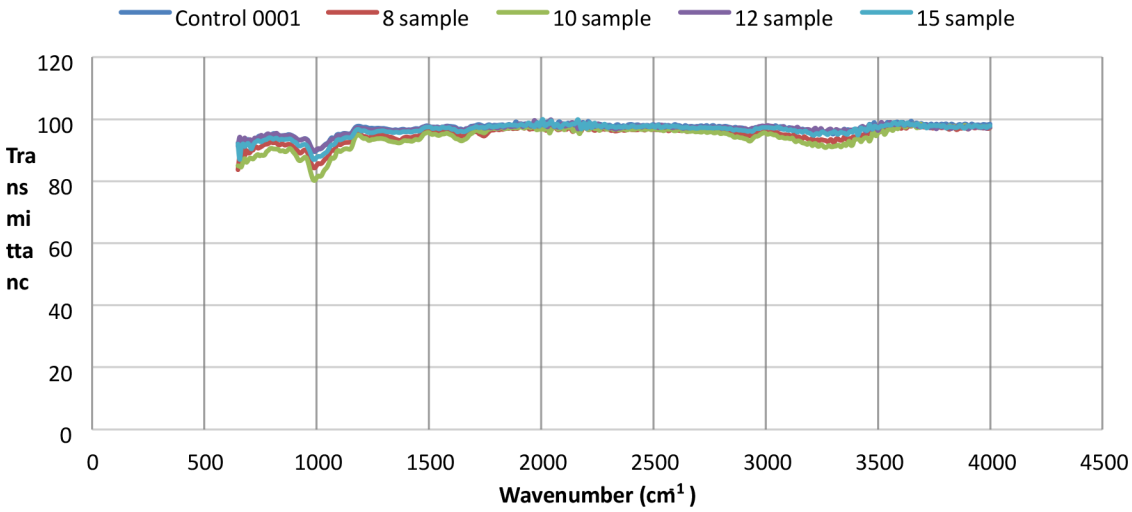
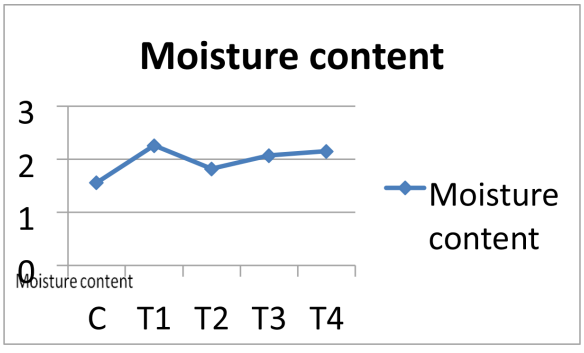


Figure 8. Cutlery samples before and after drying.



Graph 3. FTIR Report of cutlery



Graph 4. Graphical representation of the moisture content of cutlery

drying, to get the final weight, the samples were weighed once more. The cutlery samples before and after drying were shown in Figure 8, and the moisture content of the samples was presented in Graph 4.

5. Conclusion

In conclusion, this research project has explored the potential of utilising "*Ananas comosus*" peel as a sustainable solution for edible cutlery. The research conducted has demonstrated that this tropical fruit peel possesses several advantageous properties, making it an ideal candidate for creating eco-friendly and biodegradable utensils. Through the analysis of various parameters such as mechanical strength, durability, and sensory attributes, it has been established that "*Ananas comosus*" peel-based cutlery can effectively substitute traditional plastic utensils. Its inherent strength and rigidity, coupled with its appealing texture and taste, make it a viable alternative for single-use plastic cutlery, contributing to the reduction of plastic waste and environmental pollution. Overall, the findings presented in this project strongly suggest that "*Ananas*

comosus" peel can be effectively utilised as a sustainable alternative to plastic cutlery. The development and implementation of edible cutlery made from pineapple peels has the potential to significantly reduce plastic waste and promote a more environmentally conscious approach to food consumption and waste management. By embracing such innovative and eco-friendly solutions, we can strive towards a greener and more sustainable future for our planet. As the concept of edible and biodegradable cutlery is not new, and there were start-ups in India as well as in other countries who are working and manufacturing on the concept of edible cutlery, and they have such a wide range of products like cups, spoons, plates and bowls. Therefore, it has a scope for scale-up process as it doesn't involve any complicated procedure, nor does it require any sophisticated machinery. Further research can be done to increase the moisture and water resistance of cutlery to make it hold liquid food for longer periods. Also, more nutrient-rich biomaterials can be incorporated into cutlery to make it nutrient-rich. Waste utilisation, like the use of fruits and vegetable peels and pomace, can be used to make cutlery. Different natural flavouring and colouring agents can be used to improve its sensory attributes. Research should be done to make cutlery cost-effective so that it can be affordable for all classes of people.

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