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Research Article

# Development of Edible Straw from Apple and Durian Peel

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**ABSTRACT**

Over the past few decades, there has been a surge in the demand for plastic utensils, especially plastic straw which contribute to consumption of toxic chemicals. The use of plastic straws has led to plastic pollution crisis due to their non-biodegradability and lengthy decomposition periods. Currently, various kinds of edible straw have been developed to replace traditional plastic straw to reduce the environmental pollution, however the edible straw usually has weak structural integrity and becomes soggy when immersed in beverages. The purpose of this study is to develop the production of edible straw from fruit peel, such as apple and durian peel skin and investigate the physicochemical characteristics of the edible straw at different temperatures. The manufacturing process of edible straw using fruit peel can be categorized into 3 main steps, including preparation of fruit peel paste using fruit peel and distilled water at weight ratio 1:0.3, preparation of edible film as well as drying and demoulding of edible straw. Then, a series of tests including water absorption test, heat resistance test and swelling ratio test have been conducted to investigate the functionality of the edible straw in different kinds of beverages, including hot and cold liquids at temperature ranges from 5 °C to 65 °C. The observation suggests that durian peel edible straw has higher water absorption capability, heat resistance and swelling ratio when soaked in liquids compared to apple peel edible straw. Both the apple and durian peel edible straw are best for use at beverage temperature within 25 °C. Durian peel edible straw has better performance as it can be used for beverage temperature up until 65 °C while only 45 °C for apple peel edible straw.



## INTRODUCTION

Plastic is the third-highest source of waste in the world after food and paper wastes which constitute a global environmental problem that can impact human health since it is difficult to recycle (Kaza et al., 2018). The total amount of plastic waste growing in accordance with increases in the global population and per capita consumption. Malaysia has been the world's top importer of plastic waste since 2017. Malaysian households generate between 0.85 kg and 1.5 kg of garbage per person each day (Chen et al., 2021). Besides, Malaysia is the second-highest plastics solid waste producer in Asia, after the Philippines (Moh, 2014). In addition, Malaysia produced more than 0.94 million tonnes of improperly handled plastic waste annually, including 0.14 to 0.37 million tonnes may have been washed into the oceans by 2018.

There are several factors that can contribute to plastic pollution, but the waste generated through plastic straws is a significant one since it is commonly utilized by humans in daily lives. The demand on the plastic straw increases as the world's population continues to grow. The improper disposal of plastic straws can cause damage to the environment. The material used to make plastic straws is propylene, which is not typically accepted by domestic recycling operations. This is because the plastic straws are constructed from low-grade plastics, hence causing them nearly impossible to be recycled since the new product is likely to degrade fast and end up in landfills because 95% of recycled plastic has a lesser value than the original.

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Researchers have recently developed alternative materials for straw, particularly edible materials. Edible straws are intended to be a sustainable replacement for single-use plastic straws to minimize plastic waste and adverse environmental effects (Darmawan et al., 2022). Edible straw is food grade and chemical free which can be consumed along with the beverage in order to eliminate the need for disposal and decrease the quantity of plastic waste that enters landfills or the ocean (Petchimuthu et al., 2021). In general, edible straw provides the same function as a conventional plastic straw but in an environmentally friendly way (Yavagal et al., 2020). There are many natural and food resources that can be utilized to manufacture edible straw, for instance starch, rice, seaweed and fruit peel.

In this study, different kinds of fruit peel, such as apple and durian peel skin are utilized as raw ingredients to produce edible straw. After producing the edible straw, a few tests will be conducted to examine the functionality and performance of the edible straw in different types of liquids, including hot and cold beverages in order to investigate its temperature resistance, water absorption and swelling ratio.

## MATERIALS AND METHOD

### Materials

Apple peel, durian peel, distilled water, acetic acid (4%) (Manufacturer: Supelco), coffee powder (Oldtown), carbonated drinks (CocaCola), tea, iced cubes, peeler, beaker, blender, hot plate, magnetic stirrer, filter cloth, baking parchment paper, stainless steel straw, oven (Manufacturer: Memmert), stainless steel tweezer, electronic balance (Manufacturer: A&D Company Limited), thermometer, cups, vernier calliper.

### Preparation of Fruit Peel Skin Paste

First, fruit peel skins were prepared where apple peel was prepared by peeling the outer surface of apple using peeler while durian peel was prepared using the endocarp of durian husk. The fruit peels were washed thoroughly to remove any dirt or residues and any remaining fruit flesh attached to the peel skin. Then, the fruit peels were cut into small pieces and put in a blender. Distilled water was added and the mass ratio of fruit peel to distilled water was approximately 1:0.3 (Petchimuthu et al., 2021). Next, the fruit peel pieces were blended using a blender for 5 minutes to form paste. The paste was heated at 80 °C using a hot plate until it boiled (Petchimuthu et al., 2021, Nasri et al., 2023). Lastly, the mixture was filtered using filter cloth to obtain fruit peel residue by removing excess water from the paste (Darmawan et al., 2022).

### Preparation of Edible Film

The fruit peel residue was taken out from a beaker. Then, all the residue was spread on the baking parchment paper, aiming for a width that is suitable for a straw, which is around 0.5 cm and 14 cm length (Petchimuthu et al., 2021). Few drops of acetic acid (4%) were added on the surface of the film for antifungal effect (Nasri et al., 2023). The residue was then rolled to form edible biodegradable straws with the aid of stainless-steel straw. The edges were overlapped to create a sturdy structure and secure the ends.

### Drying of Edible Film, Unmolding and Storage

The rolled edible film with 0.5 cm thickness and 14 cm length was heated inside an oven at 100 ℃ for 30 minutes (Darmawan et al., 2022). Next, unmold the edible straw from the stainless-steel straw and the baking parchment paper was removed using stainless-steel tweezer. The final products of edible straws were stored in a clean, dry, and airtight container to maintain their integrity until needed.

### Water Absorption Test

Four edible straws were first prepared. Initial weights of the straws were measured using electronic balance. Then, 4 beakers filled with water heated at different temperatures were prepared, which were 5 ℃, 25 ℃, 45 ℃ and 65 ℃ respectively (Darmawan et al., 2022). Each edible straw was put into each beaker for 10 minutes. Next, the final mass of the edible straw was measured using electronic balance. The data were recorded and the percentage changes were calculated (Mohd Ghazali et al., 2021).

$$Water\ Absorption = \frac{Final\ mass - Initial\ mass}{Initial\ mass} \times 100\%$$

### Temperature Resistance Test

Four edible straws were first prepared. Initial lengths of the straws were measured using vernier calliper. Then, 4 beakers filled with water heated at different temperatures were prepared, which were 5 ℃, 25 ℃, 45 ℃ and 65 ℃ respectively (Darmawan et al., 2022). Each edible straw was put into each beaker for 10 minutes. Next, the final length of the edible straw was measured using vernier calliper. The data were recorded and tabulated.

$$Temperature\ Resistance = \frac{Final\ length - Initial\ length}{Initial\ length} \times 100\%$$

### Swelling Ratio Test

Six pieces of edible straw are soaked in different types of liquid, such as carbonated drink, coffee and tea for 30 minutes. Then wiped using tissue paper to remove the excess liquids remaining on the surface of edible straw (Cui et al., 2023). Next, the thicknesses of the straws were measured using a vernier calliper. The swelling ratio was calculated.

$$Swelling\ Ratio = \frac{Final\ thickness - Initial\ thickness}{Initial\ thickness} \times 100\%$$

## RESULTS AND DISCUSSION

In this section, results of physical properties and functionality tests are presented and discussed.

### Physical Properties of Edible Straw

**Figure 1** shows the apple peel edible straw. The edible straws made of apple peel produced have an average mass of 2.0 g and the average length is 14 cm. Besides that, the average thickness of edible straws made of apple peel is 1.93 mm and has an average diameter of 8.50 mm. **Figure 2** shows the durian peel edible straw. The edible straws made of durian peel produced have an average mass of 1.3 g and the average length is 13.5 cm. In addition, the average thickness of edible straws made of durian peel is 0.80 mm and have an average diameter of 7.00 mm.

The paste of the durian peel produced after blending was extremely fine and smooth while the paste of the apple peel was coarse and grainy as depicted in **Figure 1** and **Figure 2**. The water absorption ability of durian peel is greater than

apple peel hence making the cell swollen. However, the final product of apple peel edible straws has a smoother surface when compared to durian peel edible straws as shown in **Figure 3** and **Figure 4**. This is because there is a great deal of fibre contained in the durian peel which causes the surface of the straw to become coarser due to loss of water content during drying process using the oven. **Table 1** shows the Physical properties of edible straw.

**Table 1** Physical properties of edible straw (n=7).

| Type of edible straw | Apple Peel | | Durian Peel | |
|---|---|---|---|---|
| | Mean | SD | Mean | SD |
| Mass, w (g) | 2.10 | 0.2231 | 1.29 | 0.1558 |
| Length, *l* (cm) | 13.93 | 0.6770 | 13.50 | 0.3295 |
| Thickness, *l* (mm) | 1.96 | 0.0904 | 0.83 | 0.1030 |
| Diameter, d (mm) | 8.44 | 0.0495 | 7.03 | 0.1030 |

**Figure 1** Apple peel film

**Figure 2** Durian peel film

**Figure 3** Image of edible straws made from apple peel

**Figure 4** Image of edible straws made from durian peel

**Water Absorption of Edible Straw**

**Figure 5** shows the water absorption of edible straw which indicated by mass changes of edible straw versus water temperature. In the water absorption test, 4 temperatures were selected to test the edible straw, which were 5 ℃, 25 ℃, 45 ℃ and 65 ℃ because these temperatures are suitable for human tongue to drink beverages. During the test, the edible straws undergone mass changes as the result of the net flow of water into the cells. Water moves from a level of high concentration to a level of lower concentration across a partially permeable membrane and down a concentration gradient.

According to data obtained, the mass changes percentages of apple and durian peel edible straws increased when the temperature of water increased. When the edible straws were soaked in water, the cells absorb the water and gain volume hence causing the swelling of the edible straws. This contributed to the final expansion of cells and increasing mass of edible straw after dipped in water. Moreover, durian peel edible straws had higher water absorption capacity than the another since they absorbed more water when immersed in water as they had higher mass changes percentages in comparison with apple peel edible straws. This is due to the higher hemicellulose content in the durian peel. The hydrophilic nature is associated with hydroxyl groups of hemicelluloses, cellulose and lignin which is the main constituent of cellulosic fibres, which hold the water molecule by hydrogen bonding. On top of that, hemicellulose is the main cause of water absorption in the cellulosic fibres followed by amorphous cellulose, lignin and crystalline cellulose (Sahu et al.,2020).

However, the mass changes percentage of apple peel edible straw showed a decrease trend at the water temperature 65 °C. The decreasing trend was caused by the partial disintegration of edible straw at elevated temperature as it cannot resist the elevated temperature. Therefore, it can be summarized that apple peel edible straw are able to be used to drink beverages with temperature ranges approximately between 5 °C and 45 °C, while durian peel edible straw can resist temperature up until 65 °C. Both type of edible straws best suit at room temperature to medium high temperature.

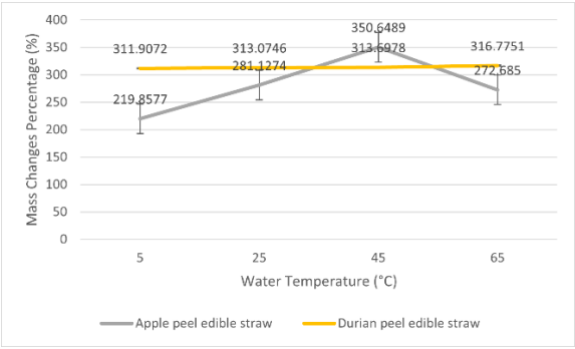


**Figure 5** Mass changes percentage vs water temperature

**Heat Resistance of Edible Straw**

**Figure 6** shows length changes percentage of edible straw versus water temperature. In the heat resistance test, temperatures selected to test the edible straws were the same as the water absorption test, which were 5 ℃, 25 ℃, 45 ℃ and 65 ℃. During the test, water molecules tend to enter the cells via osmosis, causing the edible straw to swell, resulting in the final expansion of cells and increasing length

of edible straw after immersed in water. At the same time, the edible straw absorb heat from water and become soggy after some time.

Furthermore, the edible straw partially disintegrated in the water especially in high temperature of water. Water temperature 20 °C to 80 °C will be the ideal temperature resistance range for the edible straws (Darmawan et al., 2022). In heat resistance test, the tested temperature is in the range 5 °C to 65 °C as this temperature range is safe for human tongue to withstand. On the basis of these considerations and on the totality of the evidence, extremely hot beverage consumption above 65 °C considered as "probably carcinogenic to humans" (Loomis, et al., 2016).

Based on the result collected, the apple peel edible straw showed an increasing trend of length changes percentage followed by a drastically decrease where the edible straw disintegrated and cracked when the temperature reached 65 °C as illustrated in **Figure 6**. On the other hand, the length changes percentage of durian peel edible straw showed a continuously increasing trend indicating the durian peel edible straws did not disintegrate easily and able to withstand the high temperature at 65 °C. Thus, it can be concluded that durian peel edible straws have higher heat resistance and excellent mechanical stability than apple peel edible straw that can be used by consumers when enjoying hot drinks. This is caused by the higher cellulose content in durian peel in which cellulose is a water-insoluble polymer with a rigid linear structure. Cellulose is the main structural component of the cell wall (Festucci-Buselli et al., 2007) and it was found to maximize stiffness and strength of the material (Nasri et al., 2023). **Table 2** shows the composition of apple and durian peel.

**Table 2** Composition of apple and durian peel

| Type of Fruit Peel | Apple Peel | Durian Peel |
|---|---|---|
| Composition | - Lignin (15.3-23.5%)<br>- Cellulose (7.2-43.6%)<br>- Hemicellulose (4.26-24.4%) | - Lignin (15.45%)<br>- Cellulose (60.45%)<br>- Hemicellulose (13.09%) |
| Reference | Dhillon et al., 2013 | - Charoenvai et al., 2005<br>- Aimi et al., 2014 |

From the findings, both the apple and durian edible straws have better heat resistance at water at cold to room temperature. The result of the heat resistance test is in accordance with the study of A'yun (2020), which claims that an initial temperature of about 25 °C and a percentage of 65.19% produce the best results for the temperature resistance test compared to 93.66% at 4 °C cold water and 293.96% at 80 °C hot water. The edible straw can retain its durability when dipped in water and maintained its structural integrity as well as did not dissolve or disintegrate prematurely during the test. In short, durian peel edible straw is more heat tolerant compared to apple peel edible straw where it can be used to drink cold and hot beverages with temperature below 65 °C.

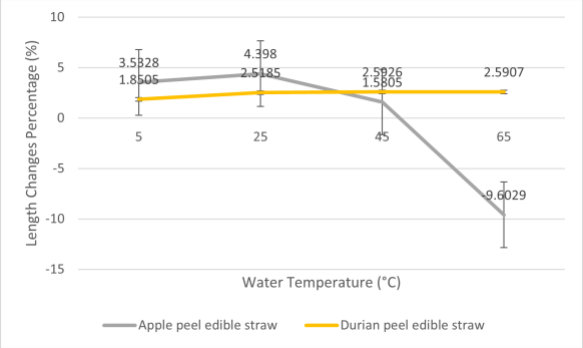


**Figure 6** Length changes percentage vs water temperature

**Swelling Ratio Test**

**Figure 7** shows the swelling ratio of edible straw versus different types of beverages. Swelling ratio test depends on the difference of thickness of edible straw before and after immersing in various types of beverages. The changes of the thickness were caused by the absorption of liquid molecules of the edible straw. Different types of beverages have different particle sizes that enters the cell of edible straw hence causing different degree of swelling. Water absorption and swelling caused an increased in the water content of the straws, resulting in a decreased hardness. On top of that, the swelling ratio of edible straw also increased with the temperature of beverages as the coffee has highest swelling ratio due to highest temperature, which is 45 °C among the tested beverages. A similar result was obtained by Cui (2023), when the straw is immersed in high temperature liquid, its swelling degree increases significantly. This shows that the mechanical properties and water resistance decline at medium to high temperatures, hence it can be concluded that the use of the edible straws in hot beverages will be dependent on the temperature.

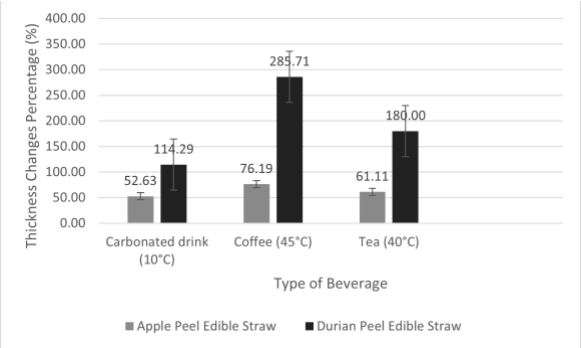


**Figure 7** Thickness changes percentage vs type of beverages

## CONCLUSION

Edible straw produced from apple and durian peel are successfully formulated with average mass of 2.0 g and 1.3 g for apple and durian peel edible straw respectively. Furthermore, the average length of the apple peel and durian peel edible straw are 14.0 cm and 13.5 cm each while the average thickness of edible straws made of apple peel and durian peel are 1.93 mm and 0.80 mm, respectively. In addition, the apple peel and durian peel edible straw have average diameter of 8.50 mm and 7.00 mm, respectively. Moreover, the water absorption of edible straws increases with liquid temperature in which durian peel edible straw has higher water absorption capacity due to higher hemicellulose content. Then, the ideal temperature range

for the edible straws is from 5 °C to 45 °C for apple peel edible straw and 5 °C to 65 °C for durian edible straw. The better performance of durian peel edible straw at higher temperature is caused by the higher cellulose content. Besides that, the swelling degree increased significantly in high liquid temperature in which durian peel edible straw has higher swelling ratio due to higher water absorption capacity.

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**References**

A'yun S. N. et al. (2021). Pengaruh Formulasi Bioplastik Berbahan Dasar Karagenan dan Gelatin Pada Pembuatan Edible Sedotan Terhadap Daya Tahan Air. Skripsi, Universitas Airlangga.

Aimi NN, Anuar H, Manshor MR, Nazri WW, Sapuan SM. 2014. Optimizing the parameters in durian skin fiber reinforced polypropylene composites by response surface methodology. *Industrial Crops and Products.* 54:291–295.

Charoenvai, S., Khedari, J., Hirunlabh, J., Daguenet, M., Quenard, M., 2005. Impact of rice husk ash on the performance of durian fiberbased construction materials. In: 10th DBMC International Conference on Durability of Building Materials and Components, Lyon, France, Retrieved from http://www.cstb.fr/fileadmin/documents/publicationsScientifiques/DOC00003448.pdf.

Chen H. L., Nath T. K., Chong, S., Foo V., Gibbins C., Lechner A. M. (2021). The Plastic Waste Problem in Malaysia: Management, recycling and disposal of local and Global Plastic Waste. SN Applied Sciences, 3(4). https://doi.org/10.1007/s42452-021-04234-y

Cui C., Zhao S., Zhang Z., Li M., Shi R., & Sun Q. (2023). Preparation and characterization of corn starch straws with strong mechanical properties by extrusion and retrogradation. *Industrial Crops and Products*. *191*, 115991. https://doi.org/10.1016/j.indcrop.2022.115991

Darmawan, M. S., Daeni, F., Kurniawan, T. S., & Listiaji, P. (2022). Preparation and characterization of edible straw made from dragon fruit peel to solve the problem of plastic waste. *Journal of Environmental and Science Education*, *2*(2), 106–110. https://doi.org/10.15294/jese.v2i2.60717

Dhillon, G. S., Kaur, S., & Brar, S. K. (2013). Perspective of apple processing wastes as low-cost substrates for bioproduction of high value products: A Review. *Renewable and Sustainable Energy Reviews*. *27*, 789–805. https://doi.org/10.1016/j.rser.2013.06.046

Festucci-Buselli, R. A., Otoni, W. C., & Joshi, C. P. (2007). Structure, organization, and functions of cellulose synthase complexes in higher plants. Brazilian *Journal of Plant Physiology*. 19(1), 1–13. https://doi.org/10.1590/s1677-04202007000100001

Kaza S, Yao L, Bhada-Tata P, Van Woerden F (2018) What a waste 2.0: a global snapshot of solid waste management to 2050. The World Bank

Loomis, D., Guyton, K. Z., Grosse, Y., Lauby-Secretan, B., El Ghissassi, F., Bouvard, V., … Straif, K. (2016).Carcinogenicity of drinking coffee, mate, and very hot beverages. *The Lancet Oncology. 17(7), 877–878.* doi:10.1016/s1470-2045(16)30239-x

Moh YC, Manaf LA (2014) Overview of household solid waste recycling policy status and challenges in Malaysia. *Resources, Conservation and Recycling*. 82:50–61

Mohd Ghazali, J., Abdul Halim, M. H. A., Balqis Norazman, N., & Azani, N. A. A. (2021). *Edible-Base Drinking Straw Coated of Carnauba Wax at Low Rate of Absorption in Banning Plastic Straw*. https://doi.org/https://doi.org/10.30880/mari.2021.02.02.021

Nasri, K., Loranger, É., & Toubal, L. (2023). Effect of cellulose and lignin content on the mechanical properties and drop-weight impact damage of injection-molded polypropylene-flax and -pine fiber composites. *Journal of Composite Materials*. 57(21), 3347–3364. https://doi.org/10.1177/00219983231186208

Petchimuthu P. Petchimuthu R, Raj A. A., Kumar V. K., Sivasankarapandian S., Ganesh N. (2021). Production of cost-effective biodegradable straw. *International Journal for Research in Applied Science and Engineering Technology*. 9(VII), 3710–3713. https://doi.org/10.22214/ijraset.2021.37096

Sahu P, Gupta M. (2020). Water absorption behavior of cellulosic fibres polymer composites: A review on its effects and remedies. *Journal of Industrial Textiles.* 2022;51(5_suppl):7480S-7512S. doi:10.1177/1528083720974424

Yavagal, P. S., Kulkarni, P. A., Patil, N. M., Salimath, N. S., Patil, A. Y., Savadi, R. S., & Kottursheettar, B. B. (2020). Cleaner production of edible straw as replacement for thermoset plastic. *Materials Today: Proceedings*, *32*, 492–497. https://doi.org/10.1016/j.matpr.2020.02.667