Evaluating the Optimal Performance of Biodegradable Cutlery

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I. Abstract

This paper aims to understand how some properties of biodegradable spoons contribute to their overall quality and performance. The results from these tests may help future research on biodegradable cutlery by providing prior knowledge on how some different types of spoons hold up. This paper also might help those interested in biodegradable cutlery better understand how a wide variety of spoons on the market fare. This study compares four commercially available eco-friendly spoons and one homemade spoon with an original recipe, not available online. The purpose is to understand how certain properties of these spoons contribute to their performance in terms of water absorption, degree of swelling, and solubility. The results showed varying levels of water absorption, swelling, and solubility among the different spoons. The homemade spoons exhibited the lowest water absorption among the edible spoons while the others followed in the order of incrEDIBLE and then Bocado. But after that, Concession Essentials' disposable wooden cutlery proved preferable to all the flour-based spoons in terms of water absorption. The Veggie Straws' spoons, however, showed no change resulting in them showing the most outstanding results for the. The Veggie Straws' spoons had this result of no changes throughout all the tests. For length 1, The Veggie Straws had the lowest degree of swelling followed by Concession Essentials, Bocado, homemade, and incrEDIBLE. Length 2 went The Veggie Straws, Bocado, Concession Essentials, homemade, and incrEDIBLE. Lastly for degree of swelling, length 3 went The Veggie Straws, Concession Essentials, incrEDIBLE, Bocado, and then homemade. The next test, solubility, had a tie between Concession Essentials and The Veggie Straws for the lowest change in mass with both at 0%. Following this up, were the homemade spoons, Bocado, and IncrEDIBLE. The results of the tests for The Veggie Straws' showed no changes in swelling, solubility, or water absorption, leading us to believe that it works the best in liquids out of the spoons being tested.

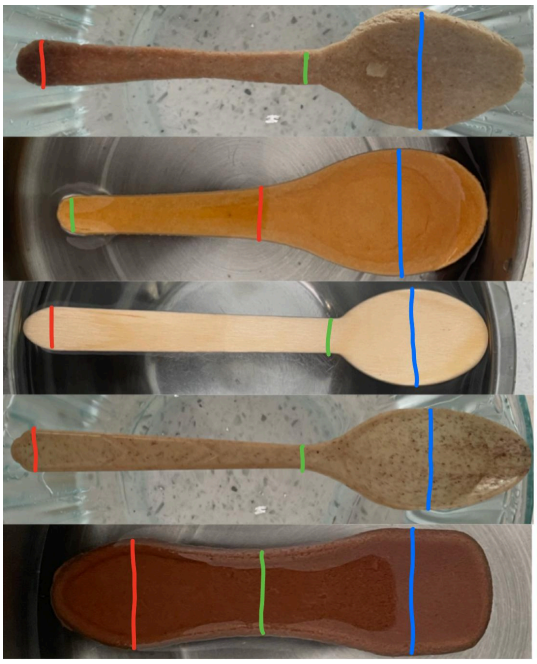
II. Introduction:

People have known that plastic is a useful material for decades, but it has also become widely known how much it contributes to pollution. Roughly 40,000,000,000+ pieces of plastic cutlery are thrown out annually [1]. Despite this, its uses are growing, and the production of plastic is increasing drastically. 70 years ago, the world only produced a mere two million tons of plastic compared to the over 450 million tons being made now [2]. This demand for plastic products is not something that can be easily dampened, which is why the idea of alternatives for plastic cutlery, packaging, straws, and bags has become so popular. Biodegradable and edible spoons have been researched for many years, with people creating many different types of this cutlery. Some spoons use bioplastics which are plastics made from some biological material rather than petroleum [3]. Bioplastics are often either compostable or biodegradable. Compostable means that, while they can break down, they require particular conditions; biodegradable, on the other hand, can break down freely in nature. These bioplastics are considered much better than plastic due to many advantages such as reduced pollution, lower carbon footprint, reduced fossil fuel usage, and faster decomposition [4], [5]. However, the production process of these bioplastics can harm the environment due to fertilizers and

pesticides used in growing agricultural products; ozone depletion; and land used for farming and turning organic material into plastic [5].

In addition to biodegradables, people have also started making flour-based edible cutlery. To explore this alternative further, previous research was conducted intending to create flour-based edible spoons. The finalized recipe for the cutlery entailed mixing flour and water into a batter and then flattening the batter into a circular, flatbread shape. A metal spoon that would be used as the mold was then prepared by covering the top with oil so that it didn't stick when the dough was placed on top of it. After the dough is laid on top the shape of the spoon is traced with a knife and the shape of the edible spoon is formed. After covering the top of the dough with oil so the spoon stays intact, they are baked at 350 degrees for 15 minutes. This spoon was entered into a competition called the Build A Better World Challenge where it tied for first place. The scope of this research is to compare this flour-based spoon to four other commercially available spoons to test for water absorption, solubility, and degree of swelling. The purpose of testing for water absorption is mainly to quantify how resistant the cutlery is to manipulation by water. The solubility test is for simulating biodegradability while also seeing how these spoons will fare in water. While solubility doesn't wholly represent and relate to biodegradability, it does contribute to part of it. It also helps facilitate bacterial decomposition of the cutlery. High solubility, while hinting at a potentially better biodegradability, also means it won't last for too long in water. The degree of swelling is meant as a more specified measure of water absorption, instead of the change in mass it's a change in length at three points. The swelling is another measure of how resistant the cutlery is to water. The spoons in this experiment consist of three flour-based spoons including mine, one wooden spoon, and a final spoon made from bioplastic. Comparing these five spoons will help us understand how the tested water properties (water absorption, solubility, and degree of swelling) affect the overall performance of the edible cutlery. From this research, future edible spoons may be made with a better focus on the most important design aspects.

III. Methods:



Spoon Name	Number Identifier
Homemade Flour Based	Spoon #1
Concession Essentials' disposable wooden cutlery	Spoon #2
Bocado's food presentation spoons	Spoon #3
Veggie Straws' biodegradable spoons	Spoon #4
IncrEDIBLE's edible cutlery	Spoon #5

For the water absorption test, the spoons were dried in sunlight for 24 hours and then weighed to obtain their initial weight. They were then submerged in distilled water for 24 hours and reweighed to determine the percent increase in weight. For example, a percent increase of 0% would mean no water was absorbed.

$$\frac{\text{soaked weight} - \text{dried weight}}{\text{dried weight}} \cdot 100\%$$

To measure the degree of swelling, the width of the spoons was measured at three points after drying in the same way as for water absorption. After soaking in distilled water for 24 hours, the spoons were re-measured to calculate the percent increase in width for those 3 points. A score of 0% here would refer to no change in length between dried and soaked.

$$\frac{\text{soaked length 1} - \text{dried length 1}}{\text{dried length 1}} \cdot 100\%$$

For the solubility test, the initial weight of the dried spoons was recorded. The spoons were then soaked in distilled water for 24 hours and re-dried in rice for another 24 hours followed by 1 hour in the oven at 175 degrees Fahrenheit. The final re-dried (post-dissolved) weight was measured to calculate the percent decrease. A 0% change in mass between dried and re-dried would mean that the spoon did not dissolve at all.

$$\frac{re\text{–dried weight} - \text{dried weight}}{\text{dried weight}} \cdot 100\%$$

Lastly, the spoons will also be observed and have their visible changes noted by the changes in their structure as they are soaked. They were all soaked simultaneously and visually evaluated to ascertain how their structures changed throughout.

*Length values for degree of swelling are written in the format (biggest length on the spoon's bowl, biggest length on the handle of the spoon, smallest length on the spoon's handle) and simplified to (length 1, length 2, length 3). This format is also used for the percent increase in length in the results section.

IV. Results

	Spoon #1	Spoon #2	Spoon #3	Spoon #4	Spoon #5
Water absorption	133.33%	100.00%	250.00%	0.00%	183.33%
Degree of Swelling	(19.54%, 20.00%, 149.47%)	(10.26%, 11.87%, 13.21%)	(13.93%, 6.95%, 35.62%)	(0.00%, 0.00%, 0.00%)	(26.45%, 27.61%, 26.03%)
Solubility	-6.67%	0.00%	-25.00%	0.00%	-33.33%

Table 1: quantified spoon results

Spoon #1 had dried lengths (1.438 in, 0.625 in, 0.188 in) and a dried weight of 15 grams. After soaking, their weight increased to 35 grams and the soaked lengths were (1.719 in, 0.75 in, 0.469 in) inches. The re-dried weight was 14 grams. By the end, the spoons had almost returned to being the dough and were completely unusable, however, they were the last of the edible spoons to do so with spoon #3 becoming unusable first.

For Spoon #2, the dried lengths were (1.219 in, 0.531 in, 0.469 in), with a dried weight of 2 grams. After soaking, the weight increased to 4 grams, and the soaked lengths were (1.344 in, 0.594 in, 0.531 in). The re-dried weight returned to 2 grams. These spoons never became fully unusable, however, they were the second to become semi-unusable after spoon #3 and stayed that way for the rest of the test. After only a bit in the water, the bowl of the spoon flattened out causing the spoon to become difficult to use.

Spoon #3 had dried lengths of (1.563 in, 0.906 in, 0.438 in), and a dried weight of 4 grams. The soaked weight increased to 14 grams, with soaked lengths of (1.781 in, 0.969 in, 0.594 in). The re-dried weight was 3 grams. This was the first spoon to become completely unusable, after a short period in the water they had become floppy and completely unusable.

Spoon #4 had dried lengths of (1.344 in, 0.531 in, 0.313 in), and a dried weight of 3 grams. After soaking, both the weight and lengths remained the same. This spoon did not change throughout all the tests because it was made out of bioplastic.

Spoon #5 showed dried lengths of (1.063 in, 0.906 in, 0.719 in), and a dried weight of 6 grams. After soaking, their weight increased to 17 grams, and the soaked lengths were (1.344 in, 1.156 in, 0.906 in). The re-dried weight was 4 grams. This spoon was the second to become completely unusable and did so soon after Spoon #2 became semi-unuseable. After becoming floppy like Spoon #3, it also inflated with water, popping after being pressed on slightly. It also became somewhat doughy partway through the drying process.

V. Analysis/Discussion

This study found that the spoons showed very different results with some showing a high aptitude for use in liquids. Firstly, Spoon #4 had no water absorption, degree of swelling, or solubility. Spoon #1 absorbed a surprising amount of water, though it lasted longer than the rest of the edible spoons before becoming doughy and losing its structure. Spoons #2 and #5 both exhibited moderate performance but #5 became unusable under moist conditions while #2 only became difficult to use. Spoon #3 absorbed the most water and became unusable first making it the least usable for liquid foods. During the soaking, all the spoons except #4 eventually became some degree of unusable, but for the first 1-2 hours they all were reasonably sound.

However, #3 became unusable within the first half hour meaning it may break in usage. These results show that bioplastic spoons are the most reliable for use in wet or moist environments/ liquid foods. They do not absorb water, swell, or dissolve meaning they keep their structure despite being in water. In contrast, flour-based spoons absorb much more water, leading to swelling and loss of structure. Wooden spoons seem to also have a decent water absorption and degree of swelling without the issue of dissolving or completely losing their structure. Compared to the rest of the edible spoons specifically, #1 seems to have been the best in all categories except the degree of swelling where only length 3 was outstandingly large. These findings are important because they help provide information on how different types of biodegradable cutlery perform. Specifically, this study focused on usability in water. Bioplastic spoons performed very well as opposed to the rest of the spoons meaning they are a good alternative to plastic spoons. They also perform outstandingly well in liquids when compared to the rest of the spoons. However, there are environmental trade-offs of using bioplastics; for example, the use of agricultural inputs and land should be considered. Additionally, while flour-based spoons are a great alternative as well, their limitations give cause for future research to improve the water survivability of these spoons. Lastly, the wood spoons were a very promising option performing decently in all the tests; however, they did become difficult to use quite a bit before the majority of the flour-based spoons became impossible to use.

VI. Conclusion

The results of the tests showed Spoon #4 had no changes in swelling, solubility, or water absorption. These characteristics give us reason to believe that it works the best in liquids out of the spoons being tested. These characteristics allow the spoon to remain functional even after being used in liquids repeatedly. Three experiments were done to compare the five various spoons' water resistance. Notes were also taken on the spoons' structure during these tests. Future research could investigate methods of improving the water resistance of flour-based and wooden spoons and test how biodegradable different types of biodegradable spoons are.

This study only looked at water absorption, degree of swelling, solubility, and basic structural integrity, because of this, the scope is limited. It didn’t test other factors such as biodegradability, potential to release harmful substances, or user preference. Future studies using this project could explore ways to improve the water properties of flour-based spoons, potentially by experimenting with different materials, coatings, or preparation methods. Research can also be done into the environmental impacts of biodegradable spoons in other conditions. User preference can also be researched in terms of taste, texture, and usability.

References

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