
Evaluation of sweet potato flour as a wheat flour substitute in the development of edible spoons

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Abstract The study investigated the effect of substituting sweet potato flour for wheat flour in developing edible spoons. The results suggested that F2 (20% sweet potato flour substitution) had the most optimal properties. It has the highest sweet potato flour substitution, which showed no signs of sugar decomposition. Moreover, it has a good balance of good nutritional content, low water absorption, adequate relative hardness, and is readily biodegradable. Furthermore, consumers had a positive reception of its use as an alternative to plastic spoons.

Keywords: Edible spoon, Sweet potato flour, Wheat flour substitute

Introduction

The demand for disposable cutleries has risen over the previous years, especially with the rise of takeaway industries (Gu *et al.*, 2022). The recent COVID-19 virus has further catalyzed the reliance on these disposable cutleries to possibly prevent the transmission of the deadly virus (Cubas *et al.*, 2023; Janairo, 2021). Most disposable cutleries are plastic made with polystyrene or expanded polystyrene (Kabir and Hamidon, 2021). They are often not recycled and are immediately disposed of in sanitary landfills (Borg *et al.*, 2022). In other cases, because of the constraints in solid waste management, consumers would resort to non-environmental friendly practices, like open dumping and open burning, which leads to more significant environmental problems such as microplastic production, leachate production, and greenhouse gas and toxic gas emissions.

One alternative to plastic cutlery is edible cutlery. Edible cutlery is a baked cookie product resembling the shape of the actual cutlery that can be used for the same purpose but can be eaten afterward. If not eaten, there is a minimal

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risk of disposing of them as they are made with biodegradable materials, including wheat flour, grain flour, and root crop flour, and therefore can quickly decompose within a few days (Habla *et al.*, 2023).

The latest waste analysis and characterization of municipal solid waste generated in Ifugao State University Potia Campus found that plastic cutlery waste (primarily plastic spoons) was about 3.46% (4.85 kg) of the total municipal waste generated daily (Latugan *et al.*, 2024). This is expected to increase further as the number of student enrollees and employees on the campus increases. Hence, replacing these plastic spoons with edible spoons may be a good alternative in mitigating the rising plastic cutlery waste and promoting awareness of greener innovation among the campus constituents.

While some studies already explored the creation of edible spoons, most of these studies have used raw materials that are not native or not commonly found in the Philippines. Hence, this study will explore the use of flour from sweet potatoes, one of the country's widely found root crops. It is also one of the leading crops produced in the Philippines, reaching about 523.29 MT in 2023 (Statista, 2024). Sweet potatoes are known for their starchy texture and sweet taste. Sweet potatoes contain starch, sugars, vitamin C, pro-vitamin A, iron, minerals, and antioxidants (Laveriano-Santos *et al.*, 2022). When used as a substitute for wheat flour, sweet potato flour improved the nutritional status, color, and flavor of specialty bread (Hathorn *et al.*, 2008; Lu and Gao, 2011). Hence, sweet potato flour may also be used as a potential substitute for wheat flour in making edible spoons.

Hence, the general objective of this study was to use sweet potato flour (SPF) to substitute the commonly used wheat flour (WF) in creating edible spoons. Specifically, the effect of SPF substitution was investigated on the nutritional content, weight and sensory characteristics, water absorption, relative hardness, biodegradability, and consumer preference.

Materials and methods

Preparation of raw materials

The third class WF, SPF, refined white sugar, table salt, and distilled water used in creating the edible spoons were commercially bought to ensure consistency in the quality.

Preparation of edible spoons

A preliminary experiment showed that higher SPF substitution beyond 40% resulted in a very crumbly dough that was hard to mold and formed crumbly

edible spoons. Therefore, the resulting formulations were varied from 0% to 40% SPF substitution with an interval of 10%, as shown in Table 1.

Table 1. The edible spoon formulations

Ingredients	Formulations				
	F0	F1	F2	F3	F4
Wheat Flour (%)	100	90	80	70	60
Sweet Potato Flour (%)	0	10	20	30	40
Wheat Flour (g)	185.0	166.5	148.0	129.5	111.0
Sweet Potato Flour (g)	0.0	18.5	37.0	55.5	74.0
Refined White Sugar (g)	6.0	6.0	6.0	6.0	6.0
Table Salt (g)	1.0	1.0	1.0	1.0	1.0
Distilled Water (g)	100.0	100.0	100.0	100.0	100.0

The dough was prepared by mixing the proportions indicated using a stand mixer for approximately 5 minutes until the dough got firmer with good consistency and viscosity. Approximately 30.0 g of the prepared dough was pressed into a two-spoon molder (Habla *et al.*, 2023). The molded dough was baked at 160°C for 90 min. The baked edible spoons were cooled down and removed from the two-spoon molder. The edible spoons were stored in an air-tight plastic container until further use.

Estimation of nutritional content

The nutritional content of each edible spoon was estimated using the Menu Eval Plus program of the Food and Nutrition Research Institute (FNRI) under the Philippines Department of Science and Technology (DOST). Each edible spoon's protein, fat, carbohydrate, and energy content were recorded.

Measurement of weight and determination of sensory attributes

Each edible spoon was carefully laid in the analytical balance, and then the measured weight was recorded. The sensory attributes, including color and taste, were also inspected through visual and taste tests.

Measurement of water absorption

The water absorption of the edible spoon was measured using the water absorption test (Kabir and Hamidon, 2021; Rajendran *et al.*, 2020). The edible spoon was immersed in room temperature distilled water for 10 min. After 10 minutes, the immersed edible spoon was removed from the water, pat dried and

weighed. The water absorption test continued until reaching a total of 60 min. The water absorption was calculated using the formula:

$$\text{Water Absorption (\%)} = \frac{W_2 - W_1}{W_1} \times 100$$

where W_2 = weight after 10 min of water immersion
 W_1 = weight before 10 min of water immersion

Measurement of relative hardness

The relative hardness of the edible spoon was measured using a Shore D Durometer. The tip of the durometer was pressed onto the edible spoon sample, and the reading was recorded.

Measurement of biodegradability

The biodegradability of the edible spoon was measured using the soil burial test (Nissa *et al.*, 2019). The edible spoons were buried in moist compost soil at a 7.5 cm depth for 7 days. After 7 days, the buried edible spoons were unearthed, brushed off soil particles, and weighed. The weight loss was measured using the formula:

$$\text{Weight Loss (\%)} = \frac{W_2 - W_1}{W_1} \times 100$$

where W_2 = weight after 7 days of soil burial
 W_1 = weight before 7 days of soil burial

After another 7 days, it was found that the edible spoons had completely biodegraded; hence, only the weight loss from the initial 7 days was recorded.

Measurement of consumer preference

About 110 non-expert participants, including students and employees of Ifugao State University Potia Campus, were asked to test the edible spoons. Each participant was given a set of various edible spoon formulations and was asked to use and eat the edible spoons. The participants were given a questionnaire that asked two questions: "Assuming all edible spoon formulations are sold at the

same price, which of the formulations will you buy in the market?” and “Would you buy and use these edible spoons once out in the market?”.

Statistical Tools

Mean was used to summarize the measured weight, water absorption, relative hardness, and biodegradability of the various edible spoon formulations. The one-way ANOVA was used to compare the means of the various edible spoon formulations. Frequency was used to summarize the consumer preference count for each edible spoon formulation. The chi-square goodness-of-fit test was used to check the significant difference in the preference count of the various edible spoon formulations.

Results

Effect of SPF substitution on nutritional content

The edible spoon’s protein and fat content decreased, while the carbohydrate content increased as the level of SPF substitution increased (Table 2). On the other hand, the energy content of the edible spoons remained consistent with increasing SPF substitution.

Table 2. The nutritional content of the edible spoons

Nutrients[†]	F0	F1	F2	F3	F4
Protein (g)	2.8	2.5	2.3	2.1	1.9
Fat (g)	0.3	0.3	0.3	0.2	0.2
Carbohydrates (g)	15.7	15.9	16.1	16.3	16.5
Energy (kcal)	76	76	76	76	76

[†] per piece of edible spoon

Effect of SPF substitution on weight and sensory attributes

The average weights of the edible spoons decreased with increasing SPF substitution (Table 3). Moreover, it was found that the average weights of F0, F1, and F2 were not significantly different ($p>.05$) from each other (Table 2). Furthermore, these formulations were significantly heavier ($p<.05$) than F3 and F4. Regarding sensory attributes, the edible spoon formulations with higher SPF substitution, especially F3 and F4, had a higher degree of browning (Figure 1) and developed a burnt and bitter taste.

Table 3. The weight and sensory attributes of the edible spoons

Formulation	Weight [†]	Color	Taste
F0	18.6 ± 0.1 ^a	light brown	acceptable
F1	18.0 ± 0.1 ^a	light brown	acceptable
F2	18.7 ± 0.1 ^a	light brown	acceptable
F3	17.0 ± 0.1 ^b	dark brown	burnt and bitter
F4	16.2 ± 0.4 ^b	dark brown	burnt and bitter

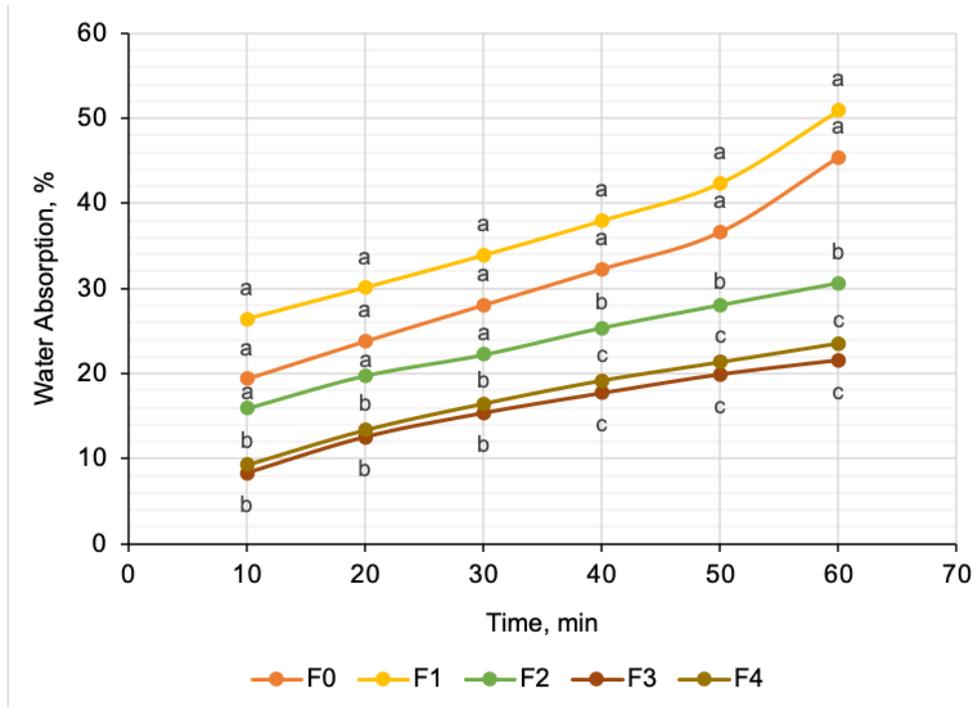
[†] mean values not sharing the same letter differ significantly at $\alpha = .05$, as the Tukey post hoc test indicates.



Figure 1. The edible spoons created from the various formulations

Effect of SPF substitution on water absorption

The water absorption of the edible spoon formulations increased as the water immersion time increased from 0 min to 60 min (Figure 2). Moreover, the water absorption plots of F2, F3, and F4 were nearly linear, showing a uniform degree of water penetration from 0 min to 60 min. On the other hand, while F0 and F1 started with linear water absorption plots from 0 min to 30 min, the water absorption exponentially increased from 40 min to 60 min, showing a higher degree of water penetration. It was also observed that as the level of SPF substitution increased, the water absorption of the edible spoons decreased, with F3 and F4 having significantly the lowest ($p < .05$) water absorption among the formulations.



Data labels not sharing the same letter differ significantly at $\alpha = .05$, as the Tukey post hoc test indicates.

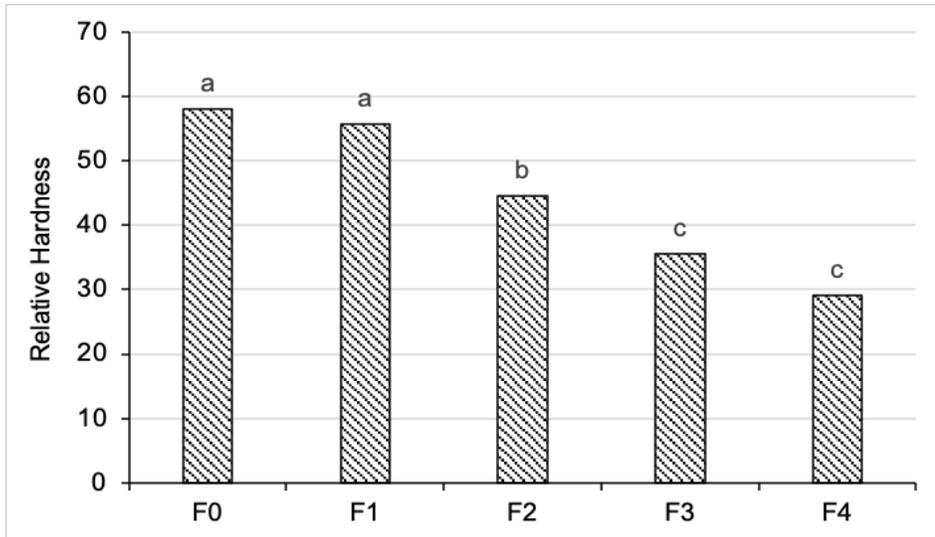
Figure 2. The water absorption of the edible spoons

Effect of SPF substitution on relative hardness

The relative hardness of the edible spoons was found to decrease with increasing SPF substitution (Figure 3). In particular, F0 and F1 were significantly the hardest ($p < .05$) among the five formulations. Moreover, it was found that F2 was significantly harder ($p < .05$) than F3 and F4.

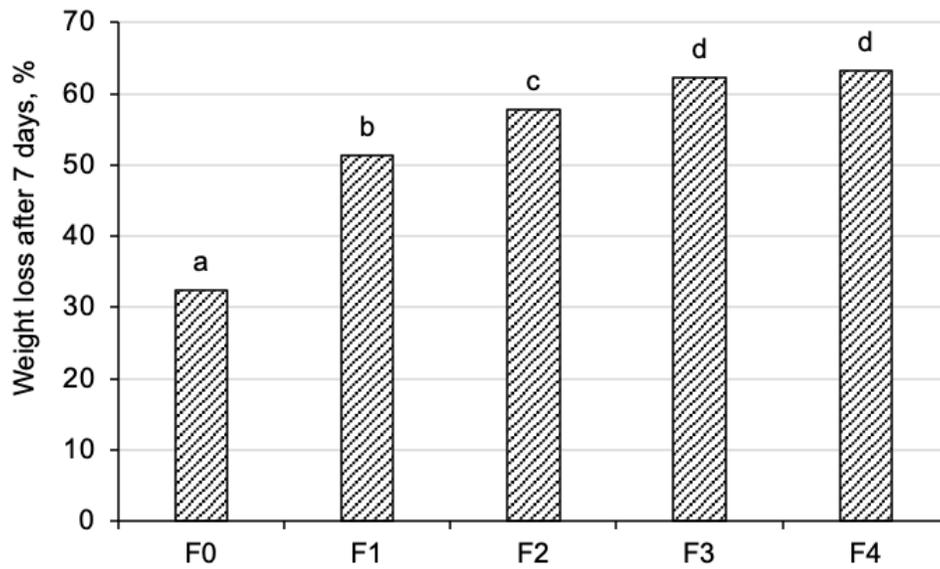
Effect of SPF substitution on biodegradability

The weight loss of the edible spoons was found to increase as SPF substitution increased (Figure 4). Among the five formulations, F3 and F4 were found to have significantly the highest ($p < .05$) weight loss after seven days of soil burial. This was also evident in the physical appearance of the unearthed edible spoons (Figure 5), which showed that F3 and F4 appeared to have the most advanced state of biodegradation among the edible spoon formulations. Moreover, F3 and F4 exhibited a softer and more pliable texture than the other formulations.



Data labels not sharing the same letter differ significantly at $\alpha = .05$, as the Tukey post hoc test indicates.

Figure 3. The relative hardness of the edible spoons



Data labels not sharing the same letter differ significantly at $\alpha = .05$, as the Tukey post hoc test indicates.

Figure 4. The biodegradability of the edible spoons



Figure 5. The edible spoons after 7 days of soil burial test

Effect of SPF substitution on consumer preference

It was found that while F2 had the highest preference count, it was not significantly different from the preference count for F0 and F1 (Table 4). Hence, the participants preferred all three formulations equally.

Table 4. The consumer preference for the edible spoons

Formulation	Preference Count	χ^2	p-value	Decision
F0	36	1.38	0.501	Fail to Reject
F1	32			Ho
F2	42			

When asked, “Would you buy and use these edible spoons?” all the participants answered “Yes.”

Discussion

The protein and fat contents of the edible spoons decreased with increasing SPF substitution. Similar observations were found in other studies that substituted SPF for WF including the study of Onabanjo and Dickson (2014) on cookies, Dako *et al.* (2016) on bread, Mitiku *et al.* (2018) on bread, Edun *et al.* (2018) on bread, Roshana and Mahendran (2019) on muffins, Oyinloye *et al.* (2022) on bread, and Nor *et al.* (2021) on cookies. Root crops, such as sweet potatoes, generally have low protein content (Mitiku *et al.*, 2018). Moreover, SPF also contains significantly lower protein than WF (Dako *et al.*, 2016; Ewunetu *et al.*, 2023; Olatunde *et al.*, 2019; Roger *et al.*, 2022; Meenakumari *et al.*, 2023).

Hence most of the protein content of the edible spoons was contributed by WF. Previous reports have also shown that both SFP and WF generally have a low fat content; however, SPF has significantly lower fat content than WF (Dako *et al.*, 2016; Roger *et al.*, 2022; Meenakumari *et al.*, 2023). Therefore, the decrease in the protein and fat contents of the edible spoons was brought about by the decreasing amount of WF with increasing SPF substitution.

On the other hand, the carbohydrate content of the edible spoons was found to increase with increasing SPF substitution. Previous reports have shown that SFP has significantly higher carbohydrate content than WF (Dako *et al.*, 2016, Roger *et al.*, 2022). Hence, even if the WF decreased, the increasing substitution with SPF increased the carbohydrate content of the edible spoons. The energy content of the edible spoons remained consistent with increasing SPF substitution. This is because even if the protein and fat content decreased from the removal of the WF, the carbohydrate content increased with the addition of the SPF.

The resulting weight of the edible spoons was negatively affected by SPF substitution, especially those with higher SPF substitution (F3 and F4). Similar observations were found in other studies that substituted SPF for WF, including the study of Dhaka and Sangeetha (2017) on bread and Toan and Anh (2018) on biscuits. The lower average weights of both F3 and F4 edible spoons can be attributed to the observed browning caused by the decomposition of the sugars. As SPF generally contains more sugars than WF (Kolawole *et al.*, 2020; Edun *et al.*, 2018), increasing the SPF substitution increased the sugar content of the edible spoons, making them more susceptible to sugar decomposition, given that the baking process occurred at a high temperature and long baking time. This was also reflected in the observed taste of the edible spoons, as both F3 and F4 had a burnt and bitter taste compared to the rest of the formulations. While F3 and F4 can still be used as spoons, they may be less likely to be eaten afterward due to their taste. Thus, F3 and F4 can be marketed as simply biodegradable spoons, instead of edible spoons.

Low water absorption is an ideal characteristic of an edible spoon, making it usable longer (Habla *et al.*, 2023). The water absorption test showed that the water absorption of the edible spoons decreased with increasing SPF substitution. However, this was contrary to the results of other studies that substituted SPF for WF, including the study of Taneya *et al.* (2014) and Yadav *et al.* (2014) on noodles. The high fiber content in the SPF (Dako *et al.*, 2016; Olatunde *et al.*, 2019; Ewunetu *et al.*, 2023) should have helped increase the water absorption of the edible spoons, especially for formulations with higher SPF substitution (F2, F3, and F4), as fiber contains many hydroxyl groups that can hydrogen bond with water (Liu *et al.*, 2019); however, this was not the case.

The observed trend can then be attributed to the decomposition of the sugars in the edible spoons, especially for formulations with higher SPF substitution, resulting in the formation of a carbonized layer on the surface of the edible spoons, which reduced the porosity and acting as a physical barrier that slowed down the penetration of water into the edible spoon's interior. While low water absorption in edible spoons is ideal for maintaining their structural integrity and functionality (Siddiqui *et al.*, 2023; Habla *et al.*, 2023), it must also be balanced with the sensory attributes. As previously discussed, the edible spoon formulations with higher SPF substitution (F3 and F4) have the lowest water absorptions. However, these formulations showed visible signs of sugar decomposition (dark brown color and burnt and bitter tastes), making them usable as a spoon but not fit to be eaten.

The hardness of the edible spoons should be adequate in that they are hard enough to maintain their form but also not too hard when eaten (Lauková *et al.*, 2019). It was found that as the SPF substitution increased, the relative hardness of the edible spoons decreased. Similar observations were found in the studies that substituted SPF for WF, including the study of Meng *et al.* (2022) on bread, Nor *et al.* (2021) on cookies, Lauková *et al.* (2019) on cookies and crackers, and Meenakumari *et al.* (2023) on biscuits. This can be attributed to the gluten content and fiber content, which were reported to affect the hardness of cookie products (Hussain *et al.*, 2019; Yang *et al.*, 2020; Nor *et al.*, 2021; Meenakumari *et al.*, 2023). Since SPF contains almost no gluten (Menon *et al.*, 2016, Meng *et al.*, 2022) and has significantly higher fiber content than WF (Dako *et al.*, 2016; Olatunde *et al.*, 2019; Ewunetu *et al.*, 2023), increasing the SPF substitution resulted in decreased gluten-forming components and increased fiber content. The increased fiber content may have further disrupted the formation of gluten from the remaining WF (Chouaibi *et al.*, 2019; Han *et al.*, 2019), resulting in the decreased relative hardness of the resulting edible spoons.

As consumers may opt not to eat the edible spoons after using them, then the edible spoons must also possess the capability to biodegrade when composted. It was found that as the SPF substitution increased, so did the weight loss of the edible spoons during the soil burial test. This can be attributed to the increasing fiber content with increasing SPF substitution, as previously mentioned. Several studies have observed that increasing the fiber content improves biodegradability (Rajesh *et al.*, 2015; Gunti *et al.*, 2016; Yulianto *et al.*, 2020). The increased fiber content may have contributed to the increased available carbon source for microbial biodegradation (Abdullah *et al.*, 2019). Additionally, the fiber content may have allowed the easier absorption of water and microorganisms from the soil (Huang *et al.*, 2018), thus further helping in the biodegradation process.

The edible spoon formulations (F0, F1, and F2) were found to be equally preferred by the participants. The participants also had a positive reception of using edible spoons as an alternative to plastic spoons as all of the participants answered “yes” to buying and using edible spoons since it supports the “Bawal ang Plastikan” (translation: using plastic is prohibited) program of the Ifugao State University, where the study was conducted. Overall, F2 gave the most optimal results regarding the aforementioned properties among the five formulations. F2 had the highest SPF substitution with no trace of sugar decomposition as it retained a light brown color and had no burnt and bitter taste. It also had the right balance of low water absorption and adequate relative hardness. Moreover, it is also readily biodegradable. The consumers also had a positive reception on using and buying them.

As the current study only explored the effect of SPF and WF composition on the edible spoons, follow-up studies may also examine the impact of process parameters, including baking temperature and time. As previously mentioned, both F3 and F4 showed visible signs of sugar decomposition from prolonged exposure to high baking temperatures. Hence, if higher SPF substitution is desired, the baking temperature and time can be adjusted to avoid sugar decomposition. Future studies can also look into improving the design parameters of the edible spoons. In terms of thickness, the edible spoons created were thicker than conventional spoons, as a simple two-spoon molder was used. Hence, better molder designs can be used to reduce the edible spoon’s thickness without compromising its ability to hold food and withstand the forces of eating. For water absorption, applying kappa carrageenan as an additive can also be explored to decrease the water absorption of edible spoons (Agustin *et al.*, 2020).

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Conflicts of interest

The authors declare no conflict of interest.

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