Development of Non-Wheat Edible Spoon

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ABSTRACT

Plastics are convenient alternatives but have catastrophic effects on the environment. Based on data from international bodies, the Philippines is one of the biggest contributors of plastic waste in the ocean which mostly comprises single-used plastic such as packaging and single-use plastic cutleries. Currently, there's a growing trend in biodegradable and edible cutleries that help lessen demand for single-use cutleries. This study focuses on the development of a non-wheat edible spoon using locally produced or harvested natural food ingredients, raw cassava, and saba banana. Five mixture formulations in two different mixing methods and three different molding methods were conducted. Out of the total 30 trials conducted, two trials produced a product that possesses the quality of a functional and edible spoon. The product has the characteristics of a toasted bread or cookie or biscuit. Grated and kneaded 100% cassava mixture that was baked in a close molder have excels in the water absorption test with 38.89%, 10.53%, and 15.79% absorption rates at hot, cold, and ambient food serving temperature conditions for 30 minutes without losing its functionality as a spoon. The sensory evaluation further revealed that it was acceptable and can be eaten afterward, as both the two trials received a 9-point hedonic mean value > 7 in terms of appearance, smell, taste, texture, and hardness. Further analysis of the physicochemical characteristics of the mixture and product, shelf life and packaging, and development of a proper close molder are necessary for commercialization in the future.

Keywords: non-wheat edible spoon, plastic waste, starch gelatinization

INTRODUCTION

One of the 17 Sustainable Development Goals (SGDs) is the responsible consumption and production which targets, by 2030, to substantially reduce waste generation through prevention, reduction, recycling and reuse. Companies and business entities are encouraged to adopt sustainable practices in accordance to the national policies and priorities (United Nations, 2015). However, effective waste and resource management remains to be a challenge globally. In fact, 4.8 to 12.7 million tons of plastic leak into the oceans each year, with Asia contributing to over 80 percent of marine leakage. Philippines is the third largest contributor with an estimated 0.75 million metric tons of mismanaged plastic entering the ocean every year (GVR, 2019; World Bank Group, 2021.

With an estimated 0.75 million metric tons of plastic waste, Philippines is the third largest contributor plastic polluters. The low cost and convenience of plastics, has made the Philippines one of the world's leading plastic polluters (WWF-Philippines, 2018), and made the plastic pollution crisis worse year by year (SEA circular, 2020). Straws, stirrers, forks, knives and spoons are among the top-ten plastic trash recovered during the International Coastal Cleanup 2018 (Ocean Conservancy, 2019).

Several scientific investigations have shown that it takes 1000 years for plastic to degrade in a landfill as plastics just break up, over time. At every stage of its lifecycle, plastic poses distinct risks to human health, arising from both exposure to plastic particles themselves and associated chemicals (CIEL, 2019). When plastics are exposed to the sun, the heat slowly turn them into microplastics (Chamas, et al., 2020; Lindwall, 2020). Microplastics are small plastic pieces less than five millimeters long which can be harmful to the ocean and aquatic life (NOAA, 2021). Although some companies opt for biodegradable, plastics labeled such take a long time to break down (Lamb, 2019). Labelling plastics as biodegradable or compostable does not warrant for the plastic to be suitable for disposal in the open environment (Krieger, 2019). Plastic that is labeled as compostable is generally intended to be sent to an industrial or commercial composting facility which has higher temperatures and different breakdown conditions than those found in a typical homeowner's compost bin (EPA, 2020).

In 2010, an alternative to the disposable plastic cutleries was created. Narayana Peesapaty started BAKEYS and developed an edible spoon made of millet, rice and wheat flours (Beckman, 2016). Uniquely baked and is made for one time use, the "edible lunch spoon" can last for 20 minutes in hot liquid. However, when one doesn't want to eat them, these spoons can be thrown since they decompose within four to five days (Peesapaty, 2016). Munir (2016) explain that the lack of water, moisture, or fat in the product allows the spoon to have a long shelf life, that is two to three years, without the need for extra preservatives. As identified, the ingredients are sorghum flour, rice flour, and wheat flour. Using these, Lui (2018) explained that edible utensils limit plastic wastes and are completely biodegradable for they are made of safe-to-eat ingredients. Edible utensils are eco-friendly, functional, delicious, and nutritious. In fact, they are the perfect addition to soup, unlike normal crackers or croutons, since they won't become soggy.

Grand View Research (2019 reported that the global edible cutlery market size was valued at USD 22.6 million in 2018. The spoon edible cutlery accounted for a share of more than 35.0% in 2018. The household application segment is expected to expand at the fastest CAGR of 9.0% from 2019 to 2025. In the Asia Pacific, it is expected to be the fastest growing market for edible cutlery, expanding at a CAGR of 9.6% from 2019 to 2025. Companies around the world are developing and taking on this trend of edible cutleries, their primary ingredients are millet flour, sorghum flour, wheat flour, rice flour, corn flour, other market existing flours, and food grade starches.

Providing alternatives to single use plastic is one crucial step to fully eliminate the human dependency to single used plastic cutleries. Having greatly felt the responsibility to become agent of sustainable human development, the researchers took the opportunity to embark in developing a non-wheat edible spoon using locally produced or harvested natural food ingredients. As Philippines is known to be a non-wheat exporter (Lyydon, 2019), this study developed an edible spoon using cassava and saba banana. They are locally available that using them would increase the varieties of edible cutleries that are produced and made available locally.

According to the PSA statistics in 2019, cassava (Manihote esculenta) has a total volume production of 2,630,800.28 metric tons. About 120,000 hectares of agricultural land in the country is planted with cassava plants each year, producing about 1.8million tons of cassava roots. And based on the Department of Agriculture (DA) publication, cassava is a calorie-rich vegetable root crop that contains plenty of carbohydrates, key vitamins, and minerals, but has been criticized for its low, poor-quality protein content. It can be boiled, baked, steamed, grilled, fried, mashed, or added to stews. Its carbohydrate content ranges from 32 to 35% in fresh weight and about 80–90% in dry matter (Uchechukwu-Agua et. Al., 2015). Additionally, saba banana (Musa balbisiana) according to the DA has stands out as the most important fruit crop in the Philippines and among the many banana cultivars, Saba is considered as one of the leaders in terms of production and trade. In 2016, the Philippines had a production of 2.47 million tons of saba banana (PSA 2017). Primarily used for manufacturing banana chips and banana ketchup and in various food products such as snacks (boiled or raw) (Doloiras-Laraño, et al. 2018). The green banana pulp contains 70-80% starch on a dry weight basis (Zhang et. Al., 2005).

This study provides an alternative to disposable or single-use cutleries which is one of the most efficient way to create a safer environment. With the use of these locally produced foods as main ingredients of this edible spoon, the production and the market demands of saba banana and cassava might increase. Likewise, food manufacturers, cutlery producers, and food establishments will become more innovative and creative.

Purpose of the Study

The study aimed to develop a non-wheat edible spoon using the locally produced or harvested natural food ingredients. Specifically, the present study developed a mixture suitable for an edible spoon and a suitable molding method. The study also performed water absorption test on the developed spoon and determined the level of acceptability a long appearance, strength or hardness, aroma, taste, and texture. Lastly, the study performed the shelf-life study of the developed spoon through physical observation by which a production method or process was developed.

Methodology

Research Design

The research study adopted the experimental method to come up with the appropriate mixture and process suitable for production of edible spoons. Five mixture formulations, two types of mixing process, and three molding processes were involved in this study.

Raw cassava and saba banana were the primary ingredients for the development of edible spoon. The five mixture formulations were pure (100%) cassava mixture, pure (100%) banana mixture, and three varying formulations of cassava and banana (70% cassava & 30%banana, 50%cassava & 50%banana, and 30%cassava & 70%banana). The two mixing processes were kneading and pounding, resembling the process of nilupak and mochi making. The molding process involved the use of a stainless soup spoon as an improvised and alternative molder, thus the finished product more likely resembled a soup spoon rather than a common spoon. Three methods of using the molder were utilized to determine which produced the best quality spoon. The first method was an open mold using a single spoon molder; the second method was a pair of two-spoon molder which mixture was sandwich in between the molder, and the third method was a close mold that used a single spoon molder and then warped in aluminum foil to simulate a closed mold.

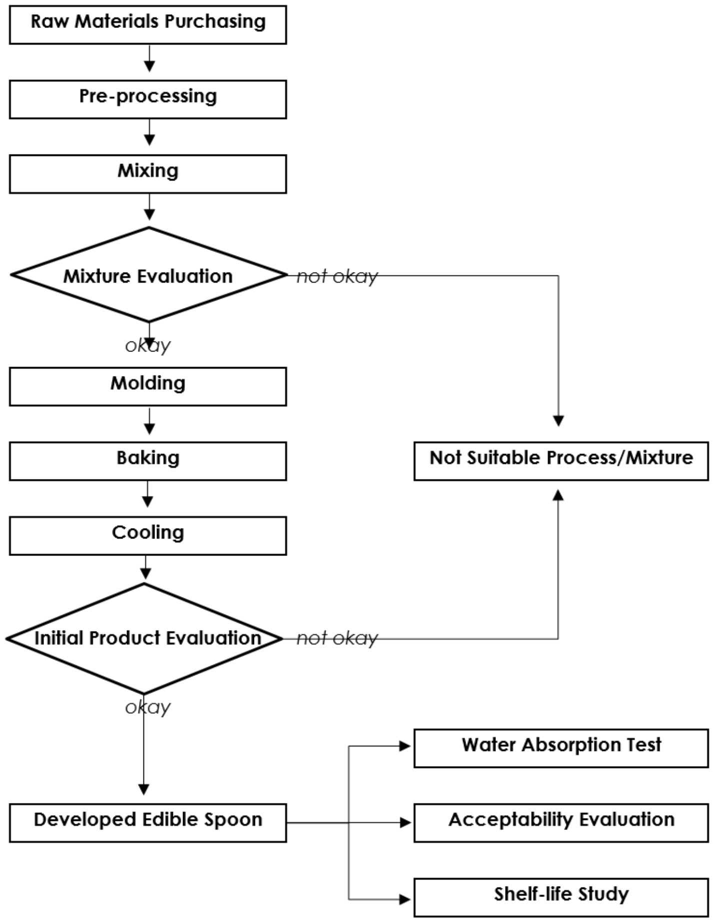

Figure 1: Process Flow of the Edible Spoon Product Development

Figure 1 shows the process flow of the different processes during the development of the product. Starting with the raw materials, they were purchased from both the local market and farmer. Cassava and banana went to pre-processing of peeling and washing. For the kneading mixing method, both cassava and banana were freshly grated, and for the pounding mixing method, cassava and banana were boiled first. A 0.5% of salt was added to each of the mixtures for flavor and taste. Different mixture evaluations were done to determine the mixtures suitability for the next process of molding. The general criteria considered for the evaluation were chemical and physical characteristics. The researchers observed whether the mixture could be handled with ease and be properly molded. Observed physical characteristics of the mixture were also recorded and taken into consideration.

Each mixture that passed the evaluation are then molded in three different ways. Molded mixtures were baked at 150℃ until they were toasted. Products were then allowed to cool and physically evaluated. When the products manifested the characteristics if a spoon, which means that the product maintained its form and used according to its expected function. Recording of the physical characteristics of the products was systematically done. The trial products that passed all the physical evaluation were produced in quantity and submitted for acceptability evaluation made by the panel of sensory evaluators.

Samples were also subjected to a water absorption test in three different food temperature serving conditions: hot, cold, and ambient. The test measured the amount of water that the developed spoon can absorb for a minimum of 30 minutes. Hot serving temperatures was 60°C or hotter, while cold serving temperature was 5°C or colder (FSANZ, 2021). The safe food ambient temperature ranges from 15°C -25°C (Lewis, 2019).

For the shelf-life study, samples of the developed products were kept in an air-tight container and a non-air-tight container to determine the best storage condition. The samples were observed physically and sensory evaluated from time to time. This direct method of monitoring of the product evolution in regular intervals of time (BTSA, 2019) was practiced by the researchers all through the product analysis.

Respondents

The panels of evaluators for the sensory evaluation to determine the acceptability of the developed spoon in terms of appearance, taste, aroma, and texture were chosen through purposive sampling. The respondents were composed of 30 members, 10 of them were in-house panels of evaluators. They were chosen because they possessed the ability to discriminate and they expressed willingness to participate in the evaluation process, as such they , manifested their interest, integrity, and healthy work attitude. Most importantly, these evaluators were in good health conditions and demonstrated stability that they showed a high sensitivity to certain sensory qualities that they observed slightest differences between samples.

Research Instrument

To determine the acceptability of the developed edible spoon sensory evaluation was conducted using the 9-point hedonic scale.

Data Collection and Procedures

Trial products that passed the initial evaluation were distributed to the chosen panelist and they have been provided with sensory evaluation form where their responses were recorded. The evaluators have been briefed and instructed to first use the product in an assortment of different beverages in different serving temperatures before actually tasting the product, since the developed spoon is too hard to bite on as it is.

Statistical Treatment of Data

Hedonic scaling was used to determine the degree of likeness or dislikeness of the developed products. The results were tallied and tables were constructed, analysis and interpretation of data was made. Frequency and weighted mean were used to compute the average value of samplings in different trials.

RESULTS AND DISCUSSION

The Mixtures

Five mixture formulations have passed the mixture evaluation phase of the development. Two of the mixtures, Mixture 1- 100% cassava and Mixture 2- 70% cassava and 30% used the kneading mixing method. As to physical characteristics, the pure cassava mixture was a little bit crumbly but can be formed and molded when handled properly. Mixture 2, the 70% cassava, and 30%banana mixture had a much desirable texture. The slimy characteristics of the freshly grated banana helps it to form a firm dough that didn't crumble easily.

The other three mixtures used the pounding mixing method. They were Mixture 3, 4, and 5. The combination of pounded cassava and banana had the best dough in terms of workability. They were smooth, easy to be rolled out, a little bit sticky to cut, but can easily be formed in the molder, though requires a little dusting of starch (rice starch) to prevent them from sticking. The cooking process ensures that the starch in the ingredient is cooked and the pounding process makes the starch to become stickier that helps the mixture to clump up and form into a smooth dough. As pounding adds air bubbles to the mochi (same process of the study) which contributes to its gooey, stretchy texture (Francisco, 2017).

Mixture Number	Mixture Formulation	Mixing Process	Physical Characteristics Observed
Mixture 1	100 % Cassava	Kneading	a little crumby
Mixture 2	70% Cassava 30% Banana	Kneading	firm and a little sticky
Mixture 3	100% Cassava	Pounding	
Mixture 4	70% Cassava 30% Cassava	Pounding	
Mixture 5	50% Cassava 50% Banana	Pounding	

Table 1: Composition of the mixture formulation, process, and physical characteristics

The starches of the ingredients have the key role in the process. Generally, plant starch contains two strings: the amylose which accounts to 20% to 30%, and amylopectin that makes up about 70% to 80% of the starch compound (Edwards, 2017). Cassava's average amylose content is 20.7%, ranging between 15.2% and 26.5% (Sánchez et al., 2009). While the plantain and cooking bananas viz, Nendran, Monthan and Saba recorded >34% of amylose (Ravi and Mustaffa, 2013). Amylose is an insoluble component of starch that easily separate from water, while amylopectin is the soluble component that tends to absorb water more (Francis, 2017). Amylose is also less sticky when cooked while amylopectin is sticky when cooked (Francisco, 2017).

While trials that utilized 100%, 70%, and 50% of freshly grated banana are deemed not suitable for the preparation of edible spoon, this is due to the slimy texture of the freshly grated banana, which makes the mixtures un-formable and un-moldable. The slimy texture is a noticeable characteristic of banana (DeVoe, 2017).

And lastly, the pounded boiled banana is crumbly and don't clump up together to form a workable dough. Thus, mixtures that utilize a higher percentage (70% and 100%) of pounded banana are also deemed not suitable for the preparation of edible spoon. The reason for this crumbly texture is the banana's high amylose content which does not absorb much water during cooking that should make it sticky.

Two trials have passed the initial product evaluation, they are the 100%cassava mixture and the 70%cassava and 30%banana mixture. Both are of the kneading mixing method and also both are of the close molding process.

The Molding Methods

Mixture Formulation	Mixing Process	Molding Process	Physical characteristics observed
100% Cassava	Kneading	Close	hard, even color, not chalky, maintain its shape
70% Cassava 30% Banana	Kneading	Close	hard, even color, not chalky, maintain its shape

Table 2: Product that passed the Initial Evaluation

Both trials have produced a hard and sturdy product which can be used as a functional spoon; they possess dry and hard cookie and biscuit-like characteristics without the richness of shortening (fats & oils).

The close molding methods have ensured the proper starch gelatinization of the mixture during the baking process which resulted in a properly baked product, as the water vapor from the mixture are trapped within the molder. Starch gelatinization is the process where starch and water when subjected to heat causes the starch granules to swell and gradually absorb water in an irreversible manner (The BC Cook Articulation Committee, 2015). Initial and final gelatinization of cassava starch occurs at 60°C and 80°C, respectively (Wheatley, et Al, 2003). And banana starch has an onset gelatinization temperature of 73.64°C, a peak gelatinization temperature of 76.98°C, and an endpoint gelatinization temperature 80.69°C (Thanyapanich, N., et Al. 2021). Proper gelatinization of the starch is necessary before it starts to lose the water during the baking process, the bonded gelatinized starch will form the structural strength of the develop edible spoon since cassava and banana lacks in protein (DA, 2013).

However, excessive heating may cause evaporation of the water and shrinkage of the gel (The BC Cook Articulation Committee, 2015), this results in a chalky/starchy product exhibited by the open and pair molding method. Since the open and pair molder exposes the mixture to a continuously high temperature, which did not permit the proper swelling of the starch, instead water within the mixture rapidly evaporates and shrinks the gel quickly.

On the other hand, regardless of the molding method used, pounded 100% cassava mixtures have produced a puff-upped product, this is due to the incorporation of air during the pounding process. Francisco (2017) explained, that pounding adds air bubbles to the mochi (same process of the study). The tiny air bubbles trapped in the mixture expanded when heated, creating millions of little air pockets, giving a well-risen baked product (Institute of Food Science + Technology, 2017).

While pounded 70%cassava and 30%banana mixture and pounded 50%cassava and 50%banana mixture have produced a product that has a rubbery or gummy (can bend without breaking) characteristics. The addition of pounded boiled banana is the major contributing factor for these rubbery characteristics, as banana contains higher amylose percentage. A correlation analysis showed that the quinoa samples with higher amylose content tended to yield harder, stickier, more cohesive, gummier, and more chewy texture after cooking (Wu et. Al., 2017).

The identified product of the formulated mixture, mixing process and molding process that passed the process of mixture and initial product evaluation phase of the development have undergone water absorption test and sensory evaluation. From here on, product of the kneaded and close molded 100% cassava mixture has been designated as ES1 (Edible Spoon 1) and the kneaded and close molded 70% cassava and 30%banana mixture as ES2 (Edible Spoon 2) for much easier identification.

Water Absorption test

ES1 and ES2 have been subjected to water absorption tests by soaking them for 30 minutes on three different water temperature conditions that simulate different food and beverage serving temperatures. All samples on these tests are able to maintain their form.

Time (mins)	Hot			Cold			Ambient		
	ES1	ES2	Temp	ES1	ES2	Temp	ES1	ES2	Temp
0	0.00%	0.00%	76°C	0.00%	0.00%	5°C	0.00%	0.00%	25°C
5	22.22%	33.33%	64°C	10.52%	29.41%	5°C	5.26%	29.41%	26°C
10	33.33%	38.89%	57°C	10.53%	29.41%	4°C	10.53%	29.41%	27°C
15	33.33%	50.00%	52°C	10.53%	29.41%	4°C	10.53%	29.41%	28°C
20	33.33%	50.00%	47°C	10.53%	29.41%	6°C	15.79%	35.29%	28°C
25	38.89%	50.00%	45°C	10.53%	29.41%	7°C	15.79%	41.18%	28°C
30	**38.89%**	50.00%	44°C	**10.53%**	35.29%	8°C	**15.79%**	41.18%	28°C

Table 3: Percentages of Water Absorption

Shown in table 3 is the percentages of the water absorbed by each trial product samples every 5 minutes for a total of 30 minutes on three different temperature conditions. And ES 1 samples have the overall least amount of water absorbed through the different water temperature conditions for the duration of 30 mins. Which is 38.89% at hot, 10.53% at cold, and 15.79% at ambient temperature. While ES 2 sample absorbed water about 50% of its weight at hot, 35.29% at cold and 41.18% at ambient temperature.

Quality Characteristics	Weighted Mean	
	ES1	**ES2**
Appearance	7.87	7.50
Hardness	8.00	8.00
Smell	7.77	8.10
Taste	7.60	7.20
Texture	7.40	7.10
Overall	**7.73**	**7.58**

Table 4: Acceptability or Sensory Evaluation Result

This result is comparable to the study of Rajendran et. Al. (2020), for edible spoon made of 50.12 % wheat flour, 26.18 % barnyard and 0% of pearl millet flour with water absorption of 49.76%, 35.93% and 41.09% for 10°C, 29°C, 50°C respectively. The least water absorbed means that the edible spoon can be used for a longer period of time before it disintegrates or loses its form and functionality as a spoon. Sensory evaluation results shown in table 6 have hedonic mean values of greater than 7, it implies that ES1 and ES2 are both accepted in all parameters described. Comparing the result of the two trials, the appearance mean value of ES1 7.87 is higher than ES2 7.50, comments from the evaluators describe it as a spoon resembling a wooden spoon and much improvement is suggested to improve the overall appearance. In terms of hardness, both trials are at the same mean value of 8.00, meaning that the hardness of the developed edible spoons are accepted for its functionality to be used as a spoon. In terms of smell, ES2 mean value of 8.10 is higher than ES1 7.77, one reason that ES2 scores higher than ES1 is that the smell of banana is much more enticing. In terms of taste, ES1 mean value of 7.60 is higher than ES2 7.20, the powdery banana taste of ES2 is the major contributor for this result. And in terms of texture, ES1 mean value of 7.40 is higher than ES2 7.10, the slimy texture of the soaked banana is one of the contributing factors for this result. Overall ES1 or the pure cassava mixture is much liked than ES2 or cassava and banana mixture, but ES2 banana aroma is much more appreciated.

A mean liking score of 7 or higher on a nine-point scale is usually indicative of highly acceptable sensory quality; hence, a product achieving this score could be used confidently as a good illustration of 'target' quality (Everitt, 2009).

Shelf-Life Study

With the direct method of determining the shelf-life of the product. The study is currently at a minimum of three months shelf-life study, where samples of the two trials have been kept and stored in a sealed reusable container. Sensory evaluation has been done and performed by the researchers, and has observed a little to no changes to the overall quality of the product. Developed edible spoons have also been left in an unsealed storage container for a minimum of one week and observe little to no change to the overall quality of the product. Even when exposed to air for that amount of time, staling or degradation of its crunchiness/hardness was not observed.

The absence of water/moisture, fats and oil in the developed edible spoon guaranteed it to have a much longer shelf life than those of ordinary baked goods. Excess water in a food product can cause an increase in the rate of microbial growth (Moore, 2020). Another major cause of deterioration in the quality of food and food products is caused by the reaction of fats and oils with molecular oxygen leading to off-flavors that are generally called rancidity (Ahmed, et Al, 2016).

Developed Production Process

Based on the process performed during the development phase of non-wheat edible spoons, the researchers have come up with the above (Figure2) production process for quantity production with strict implementation of quality control in key stages of the production. Quality control starts at the purchasing of raw materials, inspection of fresh cassava and banana is carried out to ensure freshness and avoid any

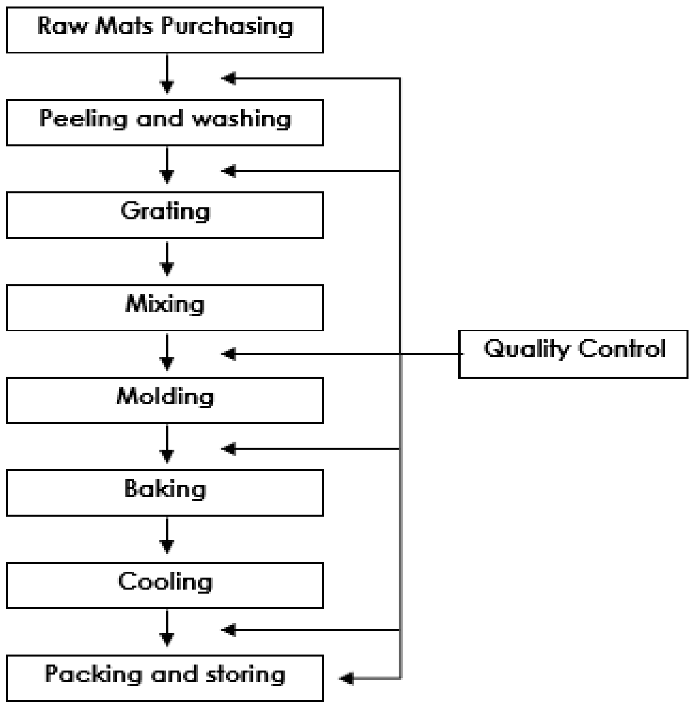

Figure 2: Developed Production Process Flow

spoiled or rotten items, this is further carried out during peeling and washing. At the mixing method stage, quality control will ensure a consistent mixture to produce consistent quality product. To maintain consistent product weight and size, strict quality control is done during shaping and forming in the molding stage. And to verify that every batch of edible spoon produced is of the right quality, strict final quality control after the cooling stage is performed.

Hayes 2021 added that quality control seeks to ensure that product quality is maintained or improved, it involves testing units and determining if they are within the specifications for the final product.

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CONCLUSIONS AND RECOMMENDATIONS

Based on the findings of the study, the researchers concluded that non-wheat edible spoons can be produced from a starchy natural food ingredient, formulated at 100%cassava (freshly grated), and 70%cassava&30%saba banana (freshly grated). This mixture formulations have the suitable characteristics needed to produce the intended product, the mixtures are both formable and moldable, which is made possible by the characteristics of the ingredient's starchy components. Also, the addition of the slimy grated banana has increased the ease in workability of the mixture. But a close molder is necessary and appropriate in the molding process, as it will help to properly gelatinized the starch within the mixture by trapping the moisture and delaying the evaporation of the steam during the baking process and this will result to a properly baked product with all its desirable quality characteristics.

Its further concluded that the developed edible spoon can be offered as an alternative with regards to the demand for single-use plastic spoons or to the increasing current demand for edible cutleries. The water absorption test conducted results in a highly useable and functional spoon that maintains its functionality for the 30 minutes it has been soaked, with the 100% cassava mixture(ES1) absorbed the least amount of water, averaging 38.89% in hot, 10.53% in cold, and 15.79% in ambient food serving temperatures. And through the sensory evaluation its edible qualities are further supported as it scored an overall mean of greater than seven, an indication of a highly acceptable sensory qualities.

Further study of the physicochemical characteristics of the mixture and the product is highly needed in order to much better standardize every production process. A proper close molder for commercialization and quantity production in the future is highly recommended. Further study for its shelf life with micro analysis and the use of air tight and environmentally friendly packaging for commercialization is also recommended.

It is further recommended that studies should be conducted on the utilization of other starchy food ingredients or underutilized root crops available in the locality such as palawan (*Cyrtosperma merkusii*), lima-lima (*Dioscorea pentaphylla*), taro (*Colocasia esculenta*), baribaran (*Dioscorea esculenta (Lour.) Burkill*) and many others, for production of edible spoons/cutleries.

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