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Utilization of *Adlai (Coix lacryma-jobi L.)* Flour in Making Muffins

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Abstract

Aim: This study primarily aimed to formulate muffins made from *Adlai* flour. It also aimed to characterize the muffins, determine their consumer acceptability, shelf-life, as well as their cost.

Methodology: This study used a completely randomized design (CRD) wherein the samples were prepared in three batches as replication. There were five treatments used in the study including control, such as T_0- 0% *Adlai* flour, T_1- 25% *Adlai* flour, T_2- 50% *Adlai* flour, T_3- 75% *Adlai* flour and T_4- 100% *Adlai* flour as primary ingredient.

Results: The pH of muffins ranges from 7.03 to 7.46, water activity 0.78 to 0.83 and moisture content of 10.56% to 12.84% which falls under intermediate moisture foods (IMFs). Furthermore, it has no significant difference with the weight of muffins which ranges from 41.59 to 42.34 cm. However, there's an impact for top-diameter (53.10 to 53.79 cm) and height (31.73 to 41.11 cm) with sensory evaluation which revealed muffin (T_1-25% *Adlai* flour) is comparable and similar with control. Overall acceptability of muffin (T_1) was rated highest with 7.90 that fall under the "like very much". Consumer acceptability showed that 100% rated the sample as acceptable and comparable to the commercial muffin and 98% of the consumers were willing to buy the said product once marketed. Based on the real-time shelf-life study, it was noted that until Day 5 under ambient condition, conformed to the standard for physico-chemical and microbial analyses. For the cost, it is revealed that the price range of muffins ranges from ₱ 28.31 to ₱ 32.00.

Conclusion: Producing a muffin made from *Adlai* flour is feasible using the standard procedure and formulation. Muffins made with different Adlai flour ratios has an effect in its physico-chemical properties and physical properties. For general acceptability, muffin (T_1) garnered the most acceptable rating. It can last until 5 days at ambient condition and it cost ₱28.31 – ₱29.80 per piece.

Keywords: *Coix lacryma- Jobi L., Adlai,* intermediate moisture foods, sensory evaluation, shelf-life study

INTRODUCTION

Coix lacryma-jobi L., commonly known as Job's tears seeds or "*Adlai*" seeds are a tall grain-bearing tropical plant which belongs to *Poaceae* a grass family the same family to which wheat, corn, and rice belong. There are a number of varieties differing in plant size and seed structure. *Coix lacryma-Jobi L.* or Job's tears seeds are an indigenous crop abundantly growing in the country and are being cultivated since ancient times as staple food as an alternative to rice. For instance, seed of wild forms have a hard shell while some cultivated varieties are characterized by a soft-shelled seed (Arora, 1977). *Coix lacryma- Jobi L.* or Job's tears seeds are promising crop which has a lot of health benefits.

According to Corke, Huang and Li (2016), in comparison to other cereals such as wheat, maize and rice, higher protein to carbohydrate ratio was obtained in *Adlai*. *Adlai* (*Coix*) seeds have minerals (phosphorus, potassium, magnesium, sulphur, and selenium), vitamin E (γ-tocopherol and γ-tocotrienol) and carotenoid (β-carotene) pigment. It has been observed that comparing the two species (big particle and small particle) *Adlai* seeds, small particle contains higher amount of TDF and minerals such as Na, Ca, Mg, Fe, Zn, Mn and S than the big particle *Adlai* seeds (Liu et al. 2014). In the Philippines, *Adlai* has been neglected in the past years particularly in its suitability as a food product and also, it is one of the underutilized indigenous crop in the country, even if it is being cultivated since ancient time. Hence, despite recognised nutritional and health-promoting benefits, promoting it in a country where rice is considered as a

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staple food may be challenging. In order to optimize the utilization of *Adlai*, there is a need to conduct further study on its components to produce value-added products to increase awareness and preference of the Filipinos to this underutilized crop. Transforming *Adlai* into either flour or starch can increase its utilization since in this form it can be used as a vehicle for micronutrient fortification.

With the growing trend of people who are health conscious, children acquiring micronutrient deficiency and global economic crisis of wheat flour in the market. Consequently, there is a need to conduct further study in utilizing this underutilized indigenous crop, namely *Adlai* as a wheat flour alternative. In this sense, the purposed of this study is to utilized *Adlai* flour in muffin to produce a new variety of flour source in making baked goods in the market and somehow could contribute to the existing sources.

Objectives

The focus of this study is to formulate muffins utilizing of *Adlai* flour.

Specifically, this study sought answers to the following questions:

1. What is the standard formulation and procedure in producing muffins with *Adlai* flour?
2. What are the physicochemical characteristics of muffins with *Adlai* flour in terms of pH, water activity (Aw), and moisture content?
3. What are the microbiological qualities of the formulated muffins with *Adlai* flour in terms of Total Plate Count (TPC), *S. aureus*, coliform, *E. coli*, yeast and mold count and *Salmonella*?
4. What are the sensory properties of the developed muffins and which among the formulation of muffins with *Adlai* flour is the most acceptable?
5. What is the shelf-life of the best treatment of formulated muffins with *Adlai* flour?
6. What will be the cost of the formulated muffins made from *Adlai* flour?

Time and Place of the Study

The study was conducted at the Institute of Food Science and Technology, College of Agriculture, Food, Environment and Natural Resources (CAFENR), Cavite State University, Indang Cavite. This study was conducted from February 2022 to January 2023.

Scope and Limitation of the Study

The study included the utilization of *Adlai* flour in muffins in general and also, the study was limited only four (4) variations of *Adlai* flour as primary ingredient (25%, 50%, 75% and 100%). It was developed to determine the organoleptic characteristics and acceptability of the product which were evaluated by 20 semi-trained panelists that are Food Technology student at Cavite State University and 100 consumer panelists that are regular consumers of muffins studying at Cavite State University-Main Campus. Moreover, the treatments were only limited on the determination of physico-chemical such as pH, water activity (Aw) and moisture content it was compared to the plain muffin. It also aimed to determine microbiological of the muffins like Total Plate Count (TPC), *S. aureus*, Coliform, *E. coli*, yeast and mold count and *Salmonella*. Likewise, packaging, shelf-life, and cost were determined of the best treatment. However, the nutrient composition was not included and muffin application only is the focus of the study.

METHODS

Research Design

This study was arranged in Completely Randomized Design (CRD) wherein the samples were prepared in three batches to serve as replications. The following treatments were used in the study:

T0 – with no *Adlai* flour as primary ingredient
T1 – with 25% *Adlai* flour as primary ingredient
T2 – with 50% *Adlai* flour as primary ingredient
T3 – with 75% *Adlai* flour as primary ingredient
T4 – with 100% *Adlai* flour as primary ingredient

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Table 1
Different Test Formulation of Muffins made from *Adlai* flour

INGREDIENTS	T_0- 0% *ADLAI* FLOUR (CONTROL)		T_1- 25% *ADLAI* FLOUR		T_2- 50% *ADLAI* FLOUR		T_3- 75% *ADLAI* FLOUR		T_4- 100% *ADLAI* FLOUR	
	T%	QUANTITY (G)	T%	QUANTITY (G)	T%	QUANTITY (G)	T%	QUANTITY (G)	T%	QUANTITY (G)
All Purpose flour	31.53	315	23.65	237	15.77	158	7.88	79	-	-
Adlai Flour	-	-	7.88	79	15.77	158	23.65	237	31.53	315
Eggs	15.04	150	15.04	150	15.04	150	15.04	150	15.74	150
Palm Oil	13.83	138	13.83	138	13.83	138	13.83	138	14.47	138
Water (Hot)	16.25	162	16.25	162	16.25	162	16.25	162	12.69	162
Brown Sugar	12.13	121	12.13	121	12.13	121	12.13	121	12.69	121
Full Cream Milk Powder	9.70	97	9.70	97	9.70	97	9.70	97	10.15	97
Baking Powder	0.97	10	0.97	10	0.97	10	0.97	10	1.02	10
Salt	0.24	2	0.24	2	0.24	2	0.24	2	0.25	2
Butter Flavor	0.32	3	0.32	3	0.32	3	0.32	3	0.32	3
TOTAL	100.00	1000	100.00	1000	100.00	1000	100.00	1000	100.00	1000

Note: This formulation has some modification, and it is based on the study from Kutschera, M. and Krasaekoopt W. (2012) in which they added *Adlai* flour in butter cake and Andoy et. al (2019) in which they utilized *Adlai* flour in saltine crackers.

Muffin Formulation

The muffin formulation and procedure adapted from the study of Kutschera and Krasaekoopt (2012) and Andoy et. al (2019), with some modifications. The studies used different percentages of *Adlai* flour to substitute in all-purpose flour.

Preparation and weighing. Weighed and mis-en placed all the needed ingredients.

Mixing. First, dissolved the full cream milk powder with hot water. Placed all the wet ingredients inside the mixing bowl, then mixed until homogeneous. Then, placed all the dry ingredients, mixed gradually. Stop mixing, then scraped all the sides of mixing bowl. Mixed the batter until fully incorporated.

Scaling. Lined molded baking pans with 3-ounce baking cup liner. Weigh and scale 45 to 47 grams of batter per baking cup liner.

Baking. In a pre-heated oven to 180 °C (356 °F), baked for 18 – 20 minutes or until golden brown.

Cooling. Allowed to cool the muffins on the cooling tray for 10 minutes until it reaches 28 to 32 °C (82.4 to 89.6 °F).

Packing. The muffins were packed in an Oriented Polypropylene Cast-polypropylene (OPP-CPP) plastic.

Sealing and Storing. The packed muffins were sealed accordingly using impulse sealer and kept in refrigerator at 4 °C until further evaluation.

Procurement of Raw Materials

The *Adlai* grits (var. Tapul) were obtained from Bukidnon *Adlai* Store at Malaybalay, Bukidnon. Other ingredients were acquired from the All About Baking and Public Market at Trece Martires City, Cavite. After all the ingredients and equipment were prepared, the researcher started to prepare and bake the muffins.

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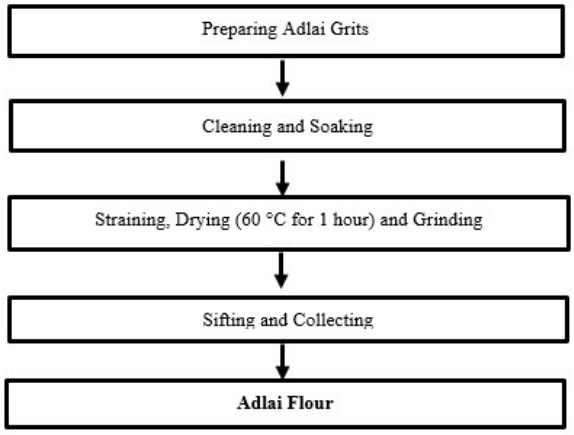

Fig.1 Process flow of *Adlai* flour [Adapted from Mulyono et al. (2019)].

Processing Technology of Muffin made *Adlai* flour

Production of *Adlai* Flour

Adlai flour production was prepared using the method described by Mulyono et al. (2019) with some modification not adding water in the process of grinding.

Cleaning and Soaking. The *Adlai* grits were washed and soaked in water overnight at room temperature, grain to water (3:1 w/w) – ratio.

Straining, Drying and Grinding. It was strained and drained then dried in an oven at 60 °C for 1 hour and ground until fine texture was achieved.

Sifting and Collecting. The *Adlai* flour was sifted with mesh 100 and the powder was collected and prepared for the next process which was the production of muffin. Collected *Adlai* flour was placed in a zip lock polyethylene bag and stored under ambient condition (25-30 °C).

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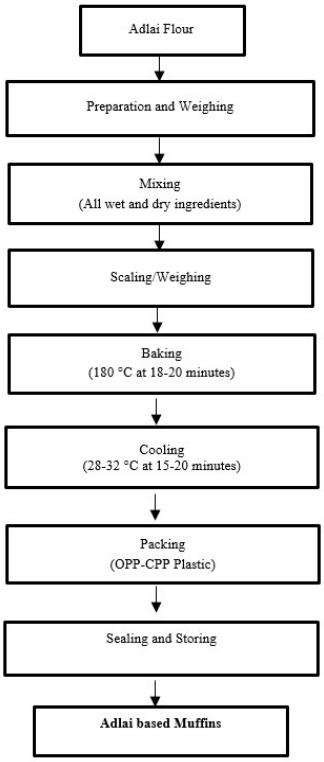

Fig.2 Process flow of muffins made from *Adlai* flour [Krasaekoopt W. (2012) and Andoy et. al (2019)].

Production of Muffins

Preparation and weighing. Weighed and mis-en placed all the needed ingredients.

Mixing. First, dissolved the full cream milk powder with hot water. Placed all the wet ingredients inside the mixing bowl, then mixed until homogeneous. Then, placed all the dry ingredients, mixed gradually. Stop mixing, then scraped all the sides of mixing bowl. Mixed the batter until fully incorporated.

Scaling. Lined molded baking pans with 3-ounce baking cup liner. Weigh and scale 45 to 47 grams of batter per baking cup liner.

Baking. In a pre-heated oven to 180 °C (356 °F), baked for 18 – 20 minutes or until golden brown.

Cooling. Allowed to cool the muffins on the cooling tray for 10 minutes until it reaches 28 to 32 °C (82.4 to 89.6 °F).

Packing. The muffins were packed in an Oriented Polypropylene/Cast-polypropylene (OPP-CPP) plastic.

Sealing and Storing. The packed muffins were sealed accordingly using impulse sealer and kept in refrigerator at 4 °C until further evaluation.

Physico-chemical Analyses

The produced muffins were characterized based on its physico-chemical properties. All tests were triplicated to ensure and validate the result gathered. The most acceptable sample underwent physicochemical analysis as well as the control.

pH Determination

The pH of the muffin was determined using a HSP digital pH meter. Samples were placed in a beaker then the electrode was placed in the sample until the readings were measured and recorded.

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Water Activity Determination (Aw)

Novosina is equipment that was utilized to determine the water activity for muffins. The equipment has a warmed-up period after turning it on. Any amount of sample was filled on the sample cup. Then, the chamber in the equipment was closed by until it locks, and the actual value was read in the display.

Moisture Content Determination

The moisture content of muffins was measured using automatic moisture analyzer. Five (5) grams of the mashed muffins were measured in the foil lid. Once done the analyzer were set to standard time and temperature which is 100 °C for 5 minutes. The samples were heated and analyzed. The collected data were jotted down for further computation.

Physical Properties Analyses

Physical properties of the muffins like the weight, top diameter and height were measured. All tests were triplicated to ensure and validate the result gathered. The most acceptable sample underwent physical analysis as well as the control.

Weight Determination

Each baked muffin sample was weighed using a weighing balance. The data was gathered and consolidated prior submitting to the statistician.

Top Diameter and Height Determination

The top diameter and height of each baked muffin were obtained by using a caliper. The data was gathered and consolidated prior submitting to the statistician.

Microbial Analyses

The most acceptable muffins alongside with the control were carefully packed and transported to PHILEXPORT Testing Laboratory at Farmtec Foods Inc., Silang, Cavite for total plate count, *Staphylococcus aureus,* yeast and mold count, coliforms, *E. coli* and *Salmonella* following the standards set by Philippine Food and Drug Administration (FDA-Circular-No. 2022-12 Guidelines on the Microbiological Requirements and Assessment of Certain Prepackaged Processed Food Products). These were both analyzed to check if there will be significant differences between the two samples.

Sensory Evaluation

Twenty (20) semi-trained panelists from Institute of Food Science and Technology, College of Agriculture, Food, Environment and Natural Resources, evaluated the product. Muffins were evaluated in terms of color, aroma, flavor, mouthfeel, and general acceptability. Nine-point (9) Hedonic Scale was used to evaluate the product, wherein the range of the scale to be used was in descriptive and acceptability form with corresponding numerical values where 9 is the highest and 1 is the lowest. The panelists rated the sample from left to right and they gave a score to the sample depending on how they perceived it in a small paper plate along with the score sheet (Appendix A). In addition, they rinsed their mouth with water to continue to the next sample. Distilled water was provided to serve as a palate cleanser for the evaluator.

Consumer Acceptability Test

The most acceptable treatment based from the evaluation of twenty (20) semi-trained panelists was subjected to a consumer acceptability test. The muffins were evaluated for consumer acceptability in comparison with the control. Total of one hundred (100) consumer panelists from Cavite State University Main were informed regarding the product such as allergen before the testing procedures follow. The genders of the consumers were also collected by filling in the questionnaire. The samples were prepared by packing the muffins in OPP/CPP sheets and given to each respondent along with the score sheets. The overall acceptance was evaluated by the participants using a 9-point hedonic scale (9-Like Extremely, 8-Like Very Much, 7-Like Moderately, 6-Like Slightly, 5- Neither Like nor Dislike, 4-Dislike Slightly, 3- Dislike Moderately, 2- Dislike Very Much, 1- Dislike Extremely) survey prepared by the researcher. This scale has labels at each end and in the middle and it ranges from 1-9 with corresponding verbal anchors. The participants rated the attributes of muffins depending on their liking by putting a check (√) on the score sheet provided. The hedonic scale determined how acceptable the product is by the consumer.

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Statistical Analysis

The data gathered during experimentation of physical and physico-chemical analysis results were recorded and statistically analyzed using F-test or One Way Analysis of Variance (ANOVA) was used to determine the significant difference and interpreted through Tukey's Honest Test. For the sensory evaluation, the data generated were recorded and statistically analyzed using Friedman's test with 5% of significance. The hedonic scores underwent data transformation for it to become non-parametric. Wilcoxon-Signed Rank Statistics was used to determine the acceptability of the most acceptable sample with the control among the consumer panelists. Frequency Distribution was also used to test the market feasibility of the best treatment. Lastly, for the physico-chemical properties under shelf-life study, a t-test for independent samples was used to compare two independent groups to determine if the means of the associated populations are significantly different.

Shelf-life Stability Testing

Shelf-life refers to a guide wherein it determines how long a product will be consumable before it will deteriorate. It also provides any storage conditions thaw must be followed to ensure the longevity of the product. Shelf-life ensures that the food product is safe to eat and keeps its appearance, flavor, odor, and texture intact.
Shelf-life is commonly estimated using two types of stability testing: the real-time stability test and the accelerated stability test. In real-time stability testing, a product is stored at a recommended storage conditions and monitored until it fails the specification. While in an accelerated stability test, a product is stored at elevated stress conditions such as temperature, humidity and pH.

Adapting from Bhise, S. & Kaur, A. (2014), the samples were undergone real-time stability test wherein the shelf life of best treatment as well as the control were analyzed, adding microbial analyses as part of modification since it's the usual practice in the food industry. Muffins were analyzed for moisture, water content, pH and overall acceptability under ambient temperature (30 ± 1 °C) and refrigerated temperature (4 – 6 °C) conditions also the microbial growth were being monitored periodically for 5 days.

Product Costing

The production cost was determined by recording the market prices and online price of the ingredients used in the study. Cost in electricity, gas, packaging and water is also considered.

RESULTS and DISCUSSION

Process Specifications

The process of the production of *Adlai* flour was adapted from Mulyono et al. (2019), with some modification of not adding water. For the incorporation of different *Adlai* flour to muffin, the process was adapted from Krasaekoopt W. (2012) and Andoy et al. (2019), with some modification to some ingredients used.

Table 2
Specifications in the Processing of *Adlai* flour and muffins made from different *Adlai* flour percentages

PROCESS	SPECIFICATIONS
Procurement, Washing, Inspection and Soaking ↓	Five kilograms sack of *Adlai* grits (var. Tapul) were received and inspected for damage and foreign matters. The *Adlai* grits were washed and soaked for 12 hours at room temperature.
Straining and Drying ↓	*Adlai* grits were strained and drained to remove foreign matters. It was placed in baking trays and dried in an oven at 60 °C for 1 hour.
Grinding and Sifting ↓	After it was dried, the samples were collected and pulverized with a grinder until powderized then sifted with Mesh #100 to collect the *Adlai* flour.

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Collection and Storing ↓	The produced *Adlai* flour was placed in ziplock PE Bag and stored in a clean, dry and ambient storage.
Weighing and Mis-en-placed ↓	All the dry ingredients, composed of *Adlai* flour, all-purpose flour, brown sugar, full cream milk powder, baking powder and salt; and wet ingredients such as eggs, palm oil, hot water and butter flavor, were weighed and mis-en placed.
Mixing ↓	First, dissolved the full cream milk powder with hot water. Placed all the wet ingredients inside the mixing bowl, then mixed until homogeneous. Next, placed all the dry ingredients and mixed gradually. Stop mixing, then scraped all the sides of mixing bowl. Mixed the batter until fully incorporated.
Scaling ↓	Lined molded baking pans with 3 ounce baking cup liner. Weighed and scaled 45 to 47 grams batter per baking cup liner.
Baking and Cooling ↓	In a pre-heated oven 180 °C (356 °F), baked 18 to 20 minutes or until golden brown. Pricked a tooth pick inside the muffins, when it came clean, it was baked already. Allowed to cool the muffins on the cooling tray for 10 minutes until it reaches 28 to 32 °C (82.4 to 89.6 °F).
Packing, Sealing and Storing	The muffins were packed in an Oriented Polypropylene/Cast-polypropylene (OPP-CPP) plastic. The packed muffins were sealed and kept in a refrigerator at 4 °C until further evaluation.

Physico-chemical Properties of Adlai Muffin

Physico-chemical analysis is important to perform since it is responsible for the final quality of the product. Muffins made from *Adlai* flour with different treatments were evaluated and compared, to determine which treatment are the best and highly acceptable. The treatment that uses 100% all-purpose flour served as the control. It is needed to set standards for the other treatments. Some of the physicochemical properties tested in this study pH, water activity and moisture content. These were also the common parameters tested in Food industries specifically for bakery products.

Table 3
Physico-chemical properties of muffins

PHYSICO-CHEMICAL PROPERTIES	T_0- 0% *ADLAI* FLOUR (CONTROL)	T_1- 25% *ADLAI* FLOUR	T_2- 50% *ADLAI* FLOUR	T_3- 75% *ADLAI* FLOUR	T_4- 100% *ADLAI* FLOUR
pH** (6.8-7.4)	7.05 c	7.03 c	7.17 bc	7.25 b	7.46 a
Water Activity* (0.81)	0.75 d	0.78 cd	0.79 bc	0.82 ab	0.83 a
Moisture Content** (10.0-17.0%)	16.19 a	12.84 ab	11.69 b	10.96 b	10.56 b

Means followed by a common letter are not significant at 5% Tukey's Test
Legend: (ns) Not Significant (*) Significant (**) Highly Significant
(Figures inside parentheses are typical values of Batter Cake type Bakery goods based on Bakerpedia.com)

pH. It is observed that pH of the samples rises as the amount of *Adlai* flour increases. pH in chemically leavened baked goods is a sign of Sodium bicarbonate neutralization efficiency. This means that the samples become

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more neutral as *Adlai* flour increases in the treatments. T_4- 100% *Adlai* flour is the most neutral among the treatments. Low pH could lead to microbial growth and early staling of baked goods. 7.05 pH reading for muffin with T_0- 0% *Adlai* flour (Control) is within the range for the usual pH of muffin. Typical pH values of bakery products fall on the batter cake type category ranges from 6.8 to 7.4. Above table, presented that the pH is highly significant which means that some of the samples are not comparable to the control or to the other treatment. However, muffin with T_1- 25% *Adlai* flour is statistically similar to muffin with T_0- 0% *Adlai* flour (Control).

Water Activity (Aw). Patil (2022) mentioned that the water activity is important to determine as the water available affects the microbial growth, chemical and biochemical reactions. Patil (2022) also added that the water activity of low moisture food should be <0.60, 0.60- 0.85 for intermediate moisture foods (IMF) and >0.85 High Moisture foods. The table above shown the range of water activity on different treatments (0.75-0.83). It can be noted that as *Adlai* flour increases, the water activity of each treatment also increases. All treatments were falls under intermediate moisture foods (IMFs). Primary objective of IMF foods is to be stored safely in an ambient condition. Though the food is not sterile, since some microorganisms such as *Staphylococcus aureus* and yeast and molds can grow in ambient condition for that reason, said microorganism indicator was also controlled in the entire study.

Moisture Content (MC). Moisture content of the food can influence the taste, texture, weight, appearance, and shelf life of product. Based on the table, moisture content decreases as *Adlai* flour incorporation increases (16.19-10.56). It was an indication of shelf-life and overall stability, that lower moisture content has lower enzymatic activities and microbial growth reduced. A sign of economic value can be depicted since as the lower it is, the higher it's solid contents (protein, starch, fat, sugar and ash) and the higher it's value. Furthermore, IMFs have moisture contents between 15 and 50%. Most of the water that the food contains is in unavailable form and cannot be used for chemical reaction and microbial growth. This is the principle used in the preparation of IMFs.

Physical Properties of Muffins made from Different Percentages of Adlai flour

Physical properties like the weight, top-diameter and height of muffin made from varied percentages of *Adlai* flour were measured and assessed to distinguish which treatment are the best and to know the effect of said *Adlai* flour variations into the muffin. The control which used 100% all-purpose flour. It was needed to establish standards for the other treatments. Weight, top-diameter and height were tested in this study.

Table 4
Physical properties of muffins

PHYSICAL PROPERTIES	T_0- 0% *ADLAI* FLOUR (CONTROL)	T_1- 25% *ADLAI* FLOUR	T_2- 50% *ADLAI* FLOUR	T_3- 75% *ADLAI* FLOUR	T_4- 100% *ADLAI* FLOUR
Weight^{ns}	41.85	41.59	41.92	41.82	42.34
Top-Diameter**	55.10 a	53.79 b	53.66 b	53.10 b	53.13 b
Height**	44.13 a	41.11 b	37.71 c	33.13 d	31.73 e

Note: Means followed by a common letter are not significant at 5% Tukey's Test
Legend: (ns) Not Significant (*) Significant (**) Highly Significant

Weight. Based on the table below, different treatments range from 41.59 cm to 42.34 cm. Muffin with T_4-100% *Adlai* flour obtained the highest in terms of weight across all treatments. It happened to be no significant difference across all treatments, thus, resulting to being comparable to the muffin with T_0- 0% *Adlai* flour (Control). Weight change factors can be either negative like food loses moisture during cooking or positive like a dried legume absorbs water during boiling. It's essential to determine in which of the treatments were most likely to have to impact as *Adlai* flour increases.

Top-diameter. 53.10 cm to 53.79 cm were the range of muffins with different level of *Adlai* flour. Among treatments, muffin with T_1-25% *Adlai* flour obtained the highest value. All samples were highly significant with each

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other, since as *Adlai* flour increases the density of the batter increases yielding dense, tough or deflated baked goods. However, muffin with T_1-25% *Adlai* flour was observed to be statistically similar to the muffin with T_0- 0% *Adlai* flour (Control). Top-diameter in baked goods was important since it indicates that among treatments which were have an effect as *Adlai* flour increases.

Height. Various treatments range from 31.73 cm to 41.11 cm. Muffin with T_1-25% *Adlai* flour obtained the highest value. Height of muffin made from different percentages of *Adlai* flour were highly significant among all treatments, subsequently due to *Adlai* flour as its incorporation increases, the denser batter it became. This hurdle on the aeration of cake batter resulting from highest to lowest range of height. Although muffin with T_1-25% *Adlai* flour, was noted to be statistically similar to the muffin with T_0- 0% *Adlai* flour (Control). The height of baked goods was essential since it has to be sign how much will the cake batter rise or aerate, thus resulting to distinguish in which of the treatments were most likely to have to impact as *Adlai* flour increases.

Sensory Evaluation

It has been defined by the Sensory Division of Institute of Food Technologists (IFT, 1981b) that sensory evaluation is a scientific discipline used to evoke, measure, analyze, and interpret human reactions as perceived by sight, smell, taste, touch and hearing. It is a significant component of a food research project or product development. Moreover, it may be utilized in product development, research, quality control, and shelf-life studies. Sensory evaluation can be used as the foundation of decision-making. Total of 20 semi-trained panelists that are consumer of muffins evaluated the product. This was utilized to determine the acceptability and preference of the panels upon evaluating all the treatments. Sensory properties of muffins were analyzed in terms of color, aroma, flavor, mouth feel and general acceptability. Results were presented in Table 5 and 6 below.

Color. Color is one of the most important factor used by consumers to determine the quality of products. Based on the results of descriptive rating (Table 5), all treatments appeared to be highly significant different with one another in terms of color intensity level. Muffin with T_1-25% *Adlai* flour, muffin with T_3-75% *Adlai* flour and muffin with T_4-100% *Adlai* flour were statistical similar to muffin with T_0- 0% *Adlai* flour (Control) except muffin with T_2- 50% *Adlai* flour since mean was preceded by b letter only. The muffin color intensity varies across all treatments due to Maillard reaction. Maillard reaction, also known as carbonyl-amine reaction, is the responsible of non-enzymatic browning which results of desirable colors and flavors in baked products and other thermally-processed foods. Since amino acids and reduced sugars reacted with a multifaceted series of reactions depending on factors like pH, temperature, available moisture and etc (Bakerpedia and Manley, 2011). Furthermore, in terms of acceptability rating (Table 6), all samples were observed to be no significant difference with one another. It can be implied that all treatments are acceptable to the semi-trained panelists.

Aroma. Aroma of baked good products is essential since it will attract potential consumers. Aroma is the first cousin of taste. Aroma is strongly associated taste since formulating any kind of food and beverages are more than just one's sense of taste (Anthony, 2007). As *Adlai* flour added to each treatment, the aroma attributed perceived varies. Based on the results of descriptive rating (Table 5), all treatments were significantly different with one another. However, muffin with T_1-25% *Adlai* flour was noted to be closer in values and statistically similar to muffin with T_0-0% *Adlai* flour (Control) among other treatments. While in acceptability rating (Table 6), across entire treatments were alike and no significant difference, thus, all treatments are acceptable to the semi-trained panelists.

Flavor. Flavor is defined to be the sensory impression of a food or other substance primarily determined by the chemical senses of mouth and nose. Flavor is the by-product of odor and taste (Nunez, 2020). Flavor is one of the most important attributes of muffin. Results from Table 7 shows that all treatments appeared to be similar in terms of flavor intensity since no significant difference was noted. It can be inferred that butter flavor incorporated complement with different percent level of *Adlai* flour on the muffins. However, in terms of acceptability rating (Table 8), it can be implied that all samples were highly significant with each other. But muffin with T_1-25% *Adlai* flour obtained the highest rating in terms of acceptability among the other treatments.

Texture/Mouthfeel. The physical attributes of the food are processed by the brain during mastication is called texture. Mouthfeel is associated to texture that it signifies as the relations between mouth surfaces in the mouth and

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the food, which is significant to baked goods (The Benefits of Texture Analysis in Food Production. (n.d.) Mecmesin.com from https://www.textureanalyzers.com/publications/benetits-of-texture-analysis-in-food-production). In Table 7, there were no significant difference noted across all treatments and the denseness intensity of the muffins were all similar as perceived by the semi-trained panelists. However, for the acceptability rating of this attribute (Table 6), it can be entailed that all treatments were highly significant which means preference of each treatment to the semi-trained panelists varied. As explained, muffin with T_1-25% *Adlai* flour and muffin with T_2-50% *Adlai* flour were statistically similar to muffin with T_0- 0% *Adlai* flour (Control). While muffin with T_3- 75% *Adlai* flour and muffin with T_4- 100% *Adlai* flour were dissimilar to muffin with T_0- 0% *Adlai* flour (Control) due to the letter precedent on the data.

Table 5
Mean score of sensory descriptive quality attributes

DESCRIPTIVE QUALITY ATTRIBUTES	MUFFINS WITH DIFFERENT LEVEL OF *ADLAI* FLOUR (TREATMENTS)				
	T_0- 0% *ADLAI* FLOUR (CONTROL)	T_1- 25% *ADLAI* FLOUR	T_2- 50% *ADLAI* FLOUR	T_3- 75% *ADLAI* FLOUR	T_4- 100% *ADLAI* FLOUR
Color**	8.00 ab	8.65 ab	8.70 a	8.10 ab	8.10 b
Aroma*	7.05 ab	7.20 ab	6.55 b	7.60 a	7.55 ab
Flavor^{ns}	7.35	7.55	6.95	7.35	7.25
Mouthfeel/Texture^{ns}	6.45	6.95	6.45	6.25	6.65

Means followed by a common letter are not significant at 5% level
Legend: (ns) Not Significant (*) Significant (**) Highly Significant;
Color: 9-Earth Yellow, 8-Soft Brown, 7-Caramel, 6-Cinnamon, 5-Pecan, 4-Dark Walnut, 3-Philippine Brown, 2-Temptress and 1-Black; Aroma and Flavor: 9-Extremely Perceptible, 8-Very Perceptible, 7-Moderately Perceptible, 6-Slightly Perceptible, 5-Neither Perceptible nor Imperceptible, 4-Slightly Imperceptible, 3-Moderately Imperceptible, 2-Very Imperceptible and 1-Extremely Imperceptible; Mouthfeel/Texture: 9-Extremely Dense, 8-Very Dense, 7-Moderately Dense, 6-Slightly Dense, 5-Neither Dense nor Loose mass, 4-Slightly Loose mass, 3-Moderately Loose mass, 2-Very Loose mass and 1-Extremely Loose mass

The last two attributes weren't included in sensory descriptors, since flavor is already part of the descriptive rating. It were incorporated in acceptability rating to determine the tolerance level or the preference level of consumers upon consuming the muffins.

Overall Flavor. It is the whole release flavor of one product once tasted. On the data tabulated, all treatments were highly significant with the control since the precedent letter was b only. It can be established that the preference or acceptability of semi-trained panelists across treatments varied (Table 6).

Off-flavor. It is the undesirable flavor that may affect the consumer's acceptance to the product. The excessive heat and different percentage level of *Adlai* flour in the muffin can induced an off-flavor such as burnt sugar, earthy and grassy flavor. Chambers (2013) mentioned that Hexanal has been found in a variety of food products including meats and processed meats, fruits, processed fruits, as well as dairy and grain products. More specifically, hexanal often has been associated with green/grassy aromatics in fruits and vegetables. It was observed that all samples were not significantly different across treatments (Table 6).

General Acceptability. Food acceptability is driven by many factors, which may linked to the individual, the food or the environment in which the food is devoured. Acceptability is a subjective measure based on hedonics (pleasure), which in turn is affected by the sensory properties of the food, previous exposure to it subsequent expectations, contextual factors, an individual's culture, physiological status and many other factors. It refers to the overall acceptability of the product. It is determined through the use of 9-point hedonic scale which has a corresponding verbal anchor. (Baxter & Murray, 2003). It is observed in Table 6 that upon evaluating all the treatments in terms of its organoleptic properties were highly significant difference with each other. But, muffin with T_1-25% *Adlai* flour were closer and acceptable to muffin with T_0- 0% *Adlai* flour (Control). Sensory attributes or organoleptic properties are important factors that determine consumer's acceptability of new product. Statistically, muffin with T_1-25% *Adlai* flour

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obtained the highest rating across all samples (7.90) as it falls to "Like Moderately". The muffin with T_1-25% *Adlai* flour and muffin with T_2-50% *Adlai* flour were observed to be statistically similar and comparable to muffin with T_0- 0% *Adlai* flour (Control), except the remaining two, muffin with T_3-75% *Adlai* flour and muffin with T_4-100% *Adlai* flour, were noted to be highly significant to muffin with T0- 0% *Adlai* flour (Control).

To sum it up, for the sensory descriptive and acceptability rating, muffin with T_1-25% *Adlai* flour as primary ingredient, garnered closer, comparable statistical value to muffin with T_0- 0% *Adlai* flour (Control) and obtained highest acceptable rating among other treatments.

Table 6
Mean score of sensory descriptive quality attributes

ACCEPTABILITY QUALITY ATTRIBUTES	MUFFINS WITH DIFFERENT LEVEL OF *ADLAI* FLOUR (TREATMENTS)				
	T_0- 0% *ADLAI* FLOUR (CONTROL)	T_1- WITH 25% *ADLAI* FLOUR	T_2- 50% *ADLAI* FLOUR	T_3- 75% *ADLAI* FLOUR	T_4- 100% *ADLAI* FLOUR
Color^{ns}	8.30	7.60	7.75	7.85	8.05
Aroma^{ns}	8.20	7.90	7.55	8.05	7.85
Flavor**	8.45 a	7.90 ab	7.40 ab	7.30 b	7.25 b
Mouthfeel/Texture**	7.80 a	6.80 ab	6.90 ab	6.15 b	6.35 b
Over-all Flavor**	8.70 a	7.50 b	7.55 b	7.10 b	7.30 b
Off-flavor^{ns}	5.95	5.75	6.15	5.65	6.10

Means followed by a common letter are not significant at 5% level

Legend: (ns) Not Significant (*) Significant (**) Highly Significant; Color, Aroma, Flavor, Texture/Mouthfeel, Overall Flavor, Off-Flavor, General Acceptability: 9-Like Extremely, 8-Like Very Much, 7-Like Moderately, 6-Like Slightly, 5-Neither Like nor Dislike, 4-Dislike Slightly, 3- Dislike Moderately, 2-Dislike Very Much and 1-Dislike Extremely

Consumer Acceptability

The consumers of the samples were students from Cavite State University- Main Campus ages 19-35 years old. The participants were untrained panels that are regular consumer of muffins. It is observed that some of the participant rated the sample as moderately acceptable as they mentioned that it is whole rounded flavor release, thus affecting their perception to the product. Also, as the product was very dense in nature and it also affects the acceptability of the sample. Some of the participant also mentioned that they liked the innate aroma more thus giving a very acceptable and extremely acceptable rating. For some participants, they rated the product as slightly acceptable for the reason that they don't usually consume muffin.

Table 7 shows the tabulated data for the degree of acceptance for muffin made from *Adlai* flour using Wilcoxon signed-rank test, a non-parametric version of the paired samples t-test, to show if there's significant difference between muffin with T_1-25% *Adlai* flour and muffin with T_0- 0% *Adlai* flour (Control).

Table 7
Mean score of consumer acceptability for muffin with *Adlai* flour

PARAMETERS	TREATMENTS	MEAN
Consumer Acceptability	T_0- 0% *Adlai* flour (Control)	7.91
	T_1- 25% *Adlai* flour	7.82

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Alongside with figure 3 depicted, muffin with T_1-25% *Adlai* flour and muffin with T_0- 0% *Adlai* flour (Control) were both 50% with one another and 100% on Wilcoxon signed-rank statistics. It signified that no significant difference between the two samples, in which control serve as the market or commercial muffin recipe.

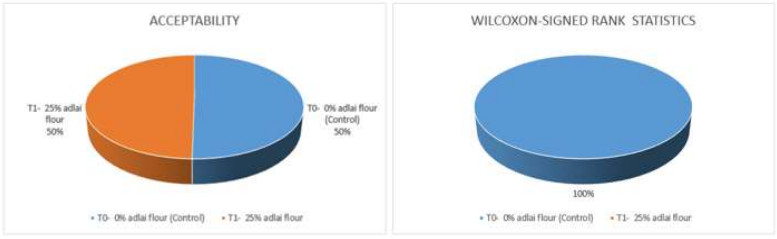

Fig.3 Percent distribution of the rating given by the consumer panels based on Wilcoxon signed-rank statistics

Moreover, Figure 4 shown the data for the willingness to buy the muffin with T_1-25% *Adlai* flour using frequency distribution. It can be concluded that 98% of the consumers wanted to buy muffin made from *Adlai* flour.

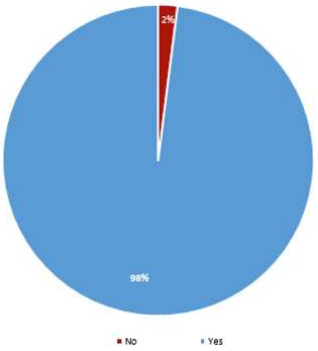

Fig.4 Percentage of consumers willing to buy muffin with *Adlai* flour

Shelf-Life Study and Microbiological Analyses of Muffin made from Adlai flour

The muffin made from *Adlai* flour with the best treatment and highly acceptable, which is muffin with T_1-25% *Adlai* flour undergone shelf-study alongside muffin with T_0- 0% *Adlai* flour served as the control. It was needed to set standards for the other treatment.

Below tables (Table 8 and 9) were arranged data for the shelf-life study of muffin made from *Adlai* applying the methodology of Bhise, S. & Kaur, A. (2014) with adding microbial growth analysis as additional food manufacturing industry practice. For physico-chemical properties, from Day 1 muffin with T_0- 0% *Adlai* flour and muffin with T_1-25% *Adlai* flour samples were relatively adjacent while for Day 5 it can be observed that water activity and moisture content were gradually apart in values except for pH. It can also infer that based on statistical analysis, there's no significant difference between the two treatments on Day 1 and Day 5 (Table 8).

To summarize, the control and the trial its aged, the moisture content decreases as the water activity increases accordingly. The exact relationship depends on whether the material being assessed is undergoing hydration (e.g. the absorption of water by starch) or dehydration (e.g. drying or baking). Though, the two samples slightly have a closer values in moisture content their water activities can be quite different. The greater the difference in water activity, the faster the rate of diffusion of the moisture will be (Cauvain, 2010). While for the pH, from day 1 to day 5 it gradually decreases. However, Cauvain, 2010 stated that it is not always possible with baked products to achieve changes in pH that will be enough to have greatly inhibiting effect on microbial activities. In some circumstances, the nature of the ingredients themselves make it challenging to achieve pH changes because they may interact with acids or they may provide a buffering effect.

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Table 8
Mean result for physico-chemical shelf-life study of muffin made from *Adlai* flour

PARAMETERS	TREATMENTS	DAY 1 MEAN	DAY 5 MEAN
pH^{ns}	T_0- 0% *Adlai* flour (Control)	6.37	6.44
	T_1- 25% *Adlai* flour	6.46	6.43
Water Activity^{ns}	T_0- 0% *Adlai* flour (Control)	0.764	0.888
	T_1- 25% *Adlai* flour	0.769	0.948
Moisture Content^{ns}	T_0- 0% *Adlai* flour (Control)	24.89	21.01
	T_1- 25% *Adlai* flour	24.86	23.02

Note: Triplicate samples
Legend: (ns) Not Significant

Based on Philippine Food and Drug Administration Circular No. 2022-012 on the guidelines on the microbiological requirements and assessment of certain prepackaged processed food products stated that under baked goods (e.g. breads, cakes, pie crust, pastries and fried doughs), yeast should be within m=<10 and M=10^3 (CFU/g); molds should be within should be within m=<10^2 and M=10^3 (CFU/g); aerobic plate count should be within should be within m=10^4 and M=10^5 (CFU/g); Coliforms should be within m=<10 and M=10^2 (CFU/g) and *Salmonella* per 25 grams should be within not detected or absence. So for microbiological parameters (Table 9), muffin with T_1- 25% *Adlai* flour was within and comparable with the standard which is muffin with T_0- 0% *Adlai* flour (Control), from Day 1 until Day 5. This is a good indication that microbiologically, muffin can last until 5 days despite having high percentage of eggs in the formulation, and also the physico-chemical properties its compasses as its aged. Moreover, both samples conformed on the Food and Drug Administration standards as stated previously. It's a good sign that the products were processed in Good Manufacturing Practices.

Table 9
Summary of result for microbial growth shelf-life study of muffin made from *Adlai* flour

TREATMENT	DAY	TEST/MICROORGANISM					
		TPC CFU/g (m=10^4)	YM CFU/g (m=<10)	COLIFORM CFU/g (m=<10)	*E. coli (IF + FOR COLIFORM, SHOULD BE -)*	*S. aureus*	*SALMONELLA (ABSENCE NOT DETECTED AT 25 g)*
T_0- 0% *Adlai* flour (Control)	1	<100	<100	<100	Negative	Negative	Negative
	5	<100	<100	<100	Negative	Negative	Negative
T_1- 25% *Adlai* flour	1	<100	<100	<100	Negative	Negative	Negative
	5	<100	<100	<100	Negative	Negative	Negative

Note: Triplicate samples
CFU/g = Colony Forming Unit per gram
m= minimum level accepted and values above m are marginally acceptable
M= maximum level tolerated and values above M are unacceptable
Figures in parentheses are based on FDA Circular No. 2022-012 Revised Guidelines for the Assessment of Microbiological Quality of Processed Foods

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Product Costing

All the expenses in the production of muffins made from *Adlai* flour are presented in the Appendix table. Different table was presented for each treatment and it showed that each treatment varies in its price as some of the materials have lesser use. The said table indicated the summary of cost production in formulated muffins from different percentages of *Adlai* flour per piece.

It appears that muffin with T_1- 25% *Adlai* flour ₱28.31 – ₱29.80, appears to be more expensive compared to muffin with T_0- 0% *Adlai* flour (Control), ₱27.60 – ₱29.06, which served as the standard for commercial muffin. Followed by muffin with T_2- 50% *Adlai* flour amounting ₱29.01 – ₱30.54. Third with muffin with T_3- 75% *Adlai* flour amounting ₱29.71 – ₱31.28. Lastly, muffin with T_4– 100% *Adlai* flour which cost ₱30.40 – ₱32.00.

Muffin with T_1- 25% *Adlai* flour is evaluated to be the most acceptable. Despite the higher cost of the best treatment compared to the control, incorporating *Adlai* flour to the formulation of muffin is beneficial due to its nutritional value once consumed as reported in different literatures.

Summary

Generally, the study was conducted to utilize and introduce the indigenous crop, *Adlai* flour (var. Tapul) as a substitute to all-purpose wheat flour. This study was composed of five (5) treatments including the control. Specifically, it aimed to produce formulation and procedure for muffins made from *Adlai* flour as primary ingredient; to evaluate the physico-chemical properties of muffins made from *Adlai* flour in terms of pH, water activity and moisture content; to evaluate the physical properties specifically the weight, height and top-diameter; to assess the sensorial characteristics of muffins made from *Adlai* flour in terms of color, aroma, flavor, mouthfeel and to determine the consumer acceptability of the most acceptable formulation of muffins; to determine the shelf-life of the most acceptable formulation of muffin monitoring it's physico-chemical and microbiological parameters and lastly to determine the production cost of muffins made from *Adlai* flour. This was conducted at the processing laboratory and physicochemical laboratory at Cavite State University- Main Campus from October 2022 to December 2022 while for the shelf-life study, this was being analyzed at PHILEXPORT Testing Laboratory at Farmtec Foods Inc., Silang, Cavite.

A total of five (5) treatments including control were used in this study. Muffins with different ratios of *Adlai* flour incorporation (25 – 100%) have an effect in pH, water activity and moisture content. The pH values of the samples T_1 to T_4 ranges from 7.03 to 7.46; 0.78 to 0.83 Aw and 10.56 to 12.84 %moisture content. Also, it had an effect in terms of height and top-diameter. Height ranges from 31.73 to 41.11 cm, while top-diameter is from 53.10 to 53.79 cm.

Sensory evaluation is carried out using 20 semi-trained panelists while consumer acceptance test was carried out by a total of 100 individuals that are student from Cavite State University- Main Campus. The sensory result was subjected to Friedman Test to determine which among the treatment is the most acceptable. Upon doing the statistical analysis, it is determined that the sample with 25% *Adlai* flour was the most acceptable thus subjecting to consumer analysis test. Out of 100 consumers of muffins in CvSU, 100% rated the sample on Wilcoxon-signed rank statistics as acceptable and comparable to the standard or commercial muffin (control). And 98% of the said consumers were willing to buy the said product once marketable. The shelf-life of the muffin can last until Day 5. For the cost, it is revealed that the price range for per 42 grams/ piece of muffin is ₱28.31 – ₱29.80. It might be higher to the control, but given the health benefits from said product, it gives an advantage as reported in different literatures cited.

Conclusion

Producing a muffin made from *Adlai* flour is feasible using the standard procedure and formulation done by the researcher. There were five (5) treatments and only *Adlai* flour was the variable being studied.

Muffins were characterized in terms of its physico-chemical properties, physical and sensorial properties. For physico-chemical properties, different *Adlai* flour ratios (25 – 100%) has an effect in pH, water activity and moisture content. The sample, specifically the muffin with T_1- 25% *Adlai* flour has the lowest pH value and considered as neutral (7.03), has the lowest water activity (0.78) and the highest moisture content (12.84%) among treatments. It falls under the category of intermediate moisture foods (IMFs). While for the physical properties, it has an implication as well in top-diameter and height. It was the highest value in top-diameter (53.79 cm) and height (41.11 cm). And lastly, for the sensory evaluation, it showed that muffin with T_1- 25% *Adlai* flour is comparable and relatively similar with the muffin with T_0- no *Adlai* flour (control) across all sensory attributes. Overall, the muffin with T_1- 25% *Adlai* flour rated as the highest with a ranking of 7.90 that fall under the "Like Very Much".

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Consumer acceptability was determine resulted that among 100 consumers of muffins in CvSU, 100% rated the sample as acceptable and comparable to the standard or commercial muffin (control). And 98% of the said consumers were willing to buy the said product once marketable.

Based on real time shelf-life study the best treatment determined that can last until 5 days in ambient condition. And in terms of microbial analyses, it conforms on the standard for microbiological requirements and assessment of certain prepackaged processed food products by the Philippine Food and Drug Administration (FDA).

For the cost, it is revealed that the muffin with T_1- 25% *Adlai* flour would cost ranging ₱28.31 – ₱29.80 per piece, given the health benefits from said product, it gives an advantage as reported in different literatures cited. Moreover, given the rising economic global crisis in wheat flour supply, this will help food manufacturers and consumers to shift and look for wheat flour alternatives.

Recommendations

The following recommendations and suggestions of the researcher are for the betterment of the study as well as the studies that will follow:

Advance study in terms of processing technologies and equipment to improve the quality attributes of the muffin with T_1- 25% *Adlai* flour is highly recommended by the researcher to address the gritty and starchy end note mouthfeel perceived during the sensory evaluation. Milling equipment in flour as pulverizer and automated sieving machine can be used as an examples of processing technologies. Moreover, the researcher also recommends exploring other cheaper ingredients to cost optimized the formula of said product so that it can be cost competitive with the market. Thus, it will be able to produce into micro-scale production and can be explore with other product application.

As the study is only limited on determining these physico-chemical parameters such as pH, water activity and moisture content, further studies on proximate analysis (crude fiber, protein, fat, fiber and carbohydrates), nutrient content composition and additional study Glycemic Index (GI) evaluation. It is also recommended that other age group should evaluate the product.

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