COOKING PROPERTIES AND SENSORY QUALITY OF GLUTEN-FREE ADLAI (*Coix lacryma – jobi L.*) PASTA

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ABSTRACT

Adlai is an underutilized cereal for human food production despite its flour being a potential gluten-free (GF) source in the development of several foods. Thus, the aim of this research was to develop a good quality GF pasta from Adlai flour and to evaluate the cooking properties, sensory attributes, and proximate composition of the different gluten-free Adlai pasta formulations in comparison to the commercial ones. Adlai flour (AF) was mixed with pre-gelatinize cassava starch (PGCS) [AF: PGCS] to produce three (3) treatments, namely: Treatment 1 (100: 0); Treatment 2 (95:5) and Treatment 3 (90:10)]. Xanthan gum (XG: 5 % w/w) and egg white powder (EWP: 10% w/w) were added using full factorial complete randomized design to produce GF pasta. The developed pasta and the control treatment (Treatment 4) were subjected to cooking properties such as cooking time, cooking loss, and water absorption. Sensory analysis was done using 9-point hedonic scale (n=50) for the three (3) GF pasta formulation including the control (commercially available GF pasta). The results showed that the use of Adlai flour with PGCS, EWP, and XG to produce a gluten-free pasta significantly affected its cooking properties, sensory attributes, and proximate composition. Sensory evaluation indicated that Treatment 4 (brown rice pasta; control) gained the highest acceptability for all sensory attributes (like moderately) and is comparable to Treatment 3 (90:10) in terms of texture. However, scores regarding aroma have no significant difference among the different samples. In terms of the cooking properties, results showed that as the level of PGCS increased, water absorption tends to increase, whereas, cooking time and cooking loss were likely decreased. The developed GF Adlai pasta showed a great number of total energy (kcal), protein, and dietary fiber which are higher than both the commercial (non-gluten-free) pasta product and GF pasta. Moreover, compared to the commercially available GF pasta, the Adlai pasta is cost-efficient.

Keywords: Gluten-free pasta, Adlai (Coix lacryma – jobi L.), Cooking properties, Sensory evaluation

INTRODUCTION

Pasta is a popular food consumed in different countries. With its simple ingredient list, it can ease the preparation time and make it a quick food option for people around the globe (Slinkard et al., 2014). As a wheat-derived staple food with a very long shelf life, it ranked second to the bread in world consumption (Mariani-Constantini, 1988 & Madhumitha, 2011). Thus, it is a product massively consumed by the general population and at the same time, pleases even the pickiest of young eaters. It is typically made from an unleavened dough of wheat flour mixed with water or eggs, and formed into sheets or other shapes, then cooked by boiling or baking (Serventi et al., 2002). The most preferred raw material to produce pasta is durum wheat semolina. It contains gluten protein that enables proper dough formation via efficient networking of the matrix due to essential viscoelastic behaviour exhibited upon mixing with water and in further extrusion process that is also vital for the desired

quality attributes of cooked pasta. Semolina flour, however, has a limited nutritional profile and lacks the amino acids lysine and threonine (Kies and Fox,1970; Abdel-Aal and Hucl, 2002; Zhao et al., 2005). In addition, with gluten as one of its components, it possesses harmful effects for the sensitive consumers with gluten intolerance and celiac disease (Wieser and Koelher, 2007).

Since the discovery of Dicke (1950) that the ingestion of wheat was responsible for the symptoms of celiac disease and people with gluten-intolerance, numerous reviews appeared in order to meet the demand for gluten-free products such as pasta. In order to meet market demand for better gluten free products, development of gluten-free foods and beverages has acquired great importance in recent years (Sharma et al., 2015).

Pasta is known as one of the most popular carbohydrate-based food products. It is also a key element in the basic diet of most cultures and is consequently one of the most consumed foods in the world. It has a high acceptability due to its great convenience, fast preparation, as well as the satiety it provides (Charoenthaikij, 2018). However, it is traditionally made from durum wheat flour which contains gluten. This cannot be consumed by the entire population due to the fact that some individuals have a gluten-intolerance.

Gluten intolerance can cause digestive problems such as gassiness, abdominal pain, or diarrhea due to the consumption of gluten. This also involves individuals who have celiac disease which remains obscure from public concern because the symptoms are not uniquely alarming compared to other chronic diseases. These symptoms are diarrhea, weight loss, and deficiency in iron, folate, vitamin B12 and D (Woodward, 2007). Individuals with gluten-intolerance like those with celiac disease can only be treated by a complete avoidance of wheat, rye, barley, and their derivatives in the diet (Palavecino et al., 2017). There has been a rising demand for gluten-free (GF) products due to the growing number of individuals who have gluten intolerance (Bustos et al, 2015) and a growing segment of the population choosing to follow gluten-free diet for nonmedical reasons (Hager et al., 2012). However, it is difficult to produce good quality gluten-free (GF) foods such as pasta, without the technological properties provided by gluten (Green and Cellier, 2007; Sciarini et al, 2012).

Development of gluten-free pasta is a big challenge for food research and development. The network forming ability of gluten needs to be substituted by other means, in order to achieve products with satisfying quality (Schoenlechner et al., 2010). Consumer acceptance of cooked pasta is based primarily on textural properties, but unfortunately, GF pasta tends to be sticky, produces a lot of cooking residue, and has an unpleasant texture (Marti and Pagani, 2014). Thus, in order to improve these properties, ingredients from several sources are currently being investigated, such as native and modified starches, GF flours, gums, whey, and egg proteins (Kahlon et al., 2013).

Protein is one of the most important factors affecting pasta properties. It is used for building structure in solid and semi-solid foods to provide the mechanical strength and textural properties of pasta (Bruneel et al., 2010). Egg protein has multifunctional properties such as gelling, foaming and emulsifying characteristics, in addition to its high nutritional quality. It is known to improve firmness and elasticity as well as the protein content of the developed pasta (Kiosseoglou, 2003). In addition, hydrocolloids such as pre-gelatinized starch and xanthan gum can be added to improve the quality of GF pasta due to their ability to bind water. Xanthan gum has the ability to stabilize temperature, has shear thinning rheological properties, and improves firmness and mouthfeel (Sozer, 2009). Although most of the cereal flour used in the production of GF pasta are made of rice and corn with the addition of proteins, gums, and emulsifiers, there are more nutritionally valuable cereal with good textural qualities and readily available alternative crops that could contribute towards the much-needed steadiness of food supply and other resources to sustain the life of people while at the same time maintaining ecological balance. One such bio resource that has a big potential in meeting this challenge is Job's-tears (Coix lacryma-jobi-L) (Lirio et al., 2013).

Job's tear (Coix Lacryma-jobi L.), also known as Adlay/Adlai in the Philippines, is a tall grass Gluten-Free grain-bearing tropical plant of the family Poaceae. Depending on the variety, the seeds are yellow, purple, or brown and are often tear-shaped, hence, the name "Job's tears". It has been widely studied across the globe and predominantly contains carbohydrate (73.9 g), protein (12.8 g), and fat (1.0 g) with trace minerals and vitamins such as calcium (25 mg), phosphorus (43.5 mg), iron (5 mg), niacin (4.3 mg), thiamine (0.28 mg), and riboflavin (0.19 mg).; and food energy (360-380 cal/100 g). (Mulyon et al., 2019). These macronutrients (carbohydrates, protein, fat), minerals (Calcium, Phosphorus, Iron), B- vitamins (Niacin, thiamin and Riboflavin) and dietary fiber are on a higher level over rice and wheat. The major protein is coixin which is rich in proline and leucine

but is insufficient in lysine (Gupta, R., 2015). The preliminary field investigation showed that Adlai is a promising supplement to rice as staple food. It grows naturally on marginal uplands without requiring the traditional land cultivation, irrigation, fertilizer, and pest control demands of rice. The harvesting, threshing, and milling are done manually. Adlai has a low glycemic index rating of 35. Glycemic index (GI), among other indicators, measures the increase of blood sugar caused by the intake of carbohydrates. In the case of rice, both amylose and dietary fiber content were found to be inversely proportional to the GI. That means that when compared to white or brown rice, Adlai can be a great source of carbohydrates for people at risk of diabetes, obesity, and colon disorders (Trinidad & Mallilin, 2011).

Meanwhile, studies indicate that Adlai has anti-allergic, anti-mutagenic, hypolipemic, and anti-diabetic effects. It also exhibits anti-cancer activity. In a study by Hung et al. (2003), Adlai seeds were found to exert an anti-proliferative effect on human lung cancer cells in vitro and in vivo and prevent the development of tobacco carcinogen-induced tumors. The anti-cancer activity of Adlai was further proven by the study of Lee et al. (2008), who isolated five active compounds from Adlai bran that inhibit cancer cells. In traditional Chinese medicine, Adlai hull extract is used to treat dysmenorrhea and was proven in a recent study that, indeed, it is a feasible alternative therapeutic agent. Wet-milling process of Adlai flour is known to have a high viscosity, swelling and gelatinization enthalpy (Mulyono et al., 2019). Thus, Adlai flour can be a great alternative ingredient in the production of gluten-free pasta. Furthermore, this grain has nutritional, bioactive compounds, and cooking properties suitable for functional foods (Andoy et al, 2019).

This study aims to develop a good quality gluten-free pasta from Adlai flour by determining the cooking properties such as cooking time, cooking loss, and water absorption of the most acceptable treatment of the GF Adlai pasta, identifying the most acceptable treatment of GF Adlai by sensory evaluation and determining the proximate analysis (% moisture content, ash, carbohydrates, protein, fat, sugar as invert, and total dietary fiber) of the most acceptable treatment of the GF Adlai pasta.

This study will benefit the consumers, particularly individuals who have a gluten-intolerance like celiac patients as well as the growing segment of the population choosing to follow a gluten-free diet. The gluten-free Adlai pasta can also be a great source of carbohydrates for people at risk of diabetes, obesity, and colon disorders (Trinidad & Mallilin, 2011) due to its low glycemic index rating of 35. This study will also help in promoting the use of Adlai in the field of research and development and increase its demand in the market. Furthermore, the use of Adlai flour in gluten-free pasta production will be a good alternative for it is readily available and can contribute towards the much-needed steadiness of food supply and other resources to sustain the life of people while at the same time maintaining ecological balance. In addition, it has nutritional and cooking properties, and sensory qualities which are considered as functional attributes necessary for gluten-free pasta production. Thus, Adlai pasta is a potential supplement to staple food and can improve the overall diet quality of an individual.

This study focused mainly on the cooking properties, proximate composition, sensory quality, and consumer acceptability of the gluten-free Adlai pasta formulations. Further, this study will focus on the total carbohydrates, ash, moisture, protein, sugar as invert and total dietary fiber content of the most acceptable GF Adlai pasta formulation. In terms of the cooking properties, only the cooking time, water absorption, and cooking loss was undertaken. In addition, this study is limited to using only the Adlai grits and the Ginampay variety. Texture analysis will be excluded due to the unavailability of the equipment to be used for the pasta samples.

Review of Related Literature

Pasta is a cereal-based staple food, known as one of the most popular carbohydrate-based products that is consumed worldwide. It has a high acceptability, due to its great convenience, fast preparation, as well as the satiety it provides (Meena, 2019). Having originated in Asia and the Mediterranean, Italy is still most well-known for its pasta making and leads in national consumer consumption per capita (International Pasta Organization, 2011). As a wheat-derived staple food with a very long shelf life, it is second only to bread in world consumption (Mariani-Constantini, 1988; Madhumitha, 2011). The highest quality pasta is made solely from durum wheat semolina flour. This creates a product that has great rheological properties, cooking quality, and high consumer acceptance (Dexter et al., 1979).

The versatility of pasta allows it to be formed into almost any shape and size. It comes in varieties such as spaghetti,

fettuccine, macaroni, rotini, and farfalle. Pasta can be made either fresh or dried. Fresh pasta skips the drying step and allows for a much quicker process. Dried pasta, on the other hand, has a longer shelf-life than the freshly made pasta (Slinkard et al., 2014).

According to Kill (2001a), a good quality pasta is based on three crucial factors: raw material, mixing and production, and drying. Since basic pasta is made using flour and water, the use of quality flour is essential, hence, the strong preference to durum wheat. Protein is also one of the most important factors affecting pasta properties. It is used for building structure in solid and semi-solid foods to provide the mechanical strength and textural properties of pasta. Egg white protein in particular, has a multifunctional property such as gelling, foaming and emulsifying characteristics, in addition to its high nutritional quality. It is known to improve firmness and elasticity as well as the protein content of a pasta (Kiosseoglou, 2003). In addition, hydrocolloids such as pre-gelatinized starch and xanthan gum can be added to improve the quality of GF pasta due to their ability to bind water. Xanthan gum in particular has the ability to stabilize temperature, has shear thinning rheological properties and improvement of firmness and mouthfeel (Padalino et al, 2016).

The change in lifestyle, income, food preferences and consciousness of consumers towards safe, nutrient-rich healthy foods has increased the demand of pasta enriched with nutrients and functional attributes and has driven researchers to develop its variants containing natural compounds like cereals (rice, corn and sorghum), minor cereals (fonio, teff, millet and job's tears) or pseudo-cereals (amaranth, buckwheat, quinoa) as reported by (Moreno, 2014). Moreover, consumption of gluten containing foods made from wheat, rye or barley is a severe problem for the persons suffering with celiac disease and gluten intolerance. Gluten intolerance can cause digestive problems such as gassiness, abdominal pain or diarrhea due to the consumption of gluten. This also involves individuals who have celiac disease which is defined as an autoimmune disease that can potentially affect any organ, not merely the gastrointestinal tract, as previously assumed. The only satisfactory treatment for celiac disease is a gluten-free diet which involves complete avoidance of wheat, rye, barley, oatmeal and their derivatives in the diet (Palavecino et al., 2017). Unfortunately, most common foods and beverages, such as bread, biscuits, pizza and pasta, are made from cereals containing gluten such as wheat. Wheat contains two proteins, glutenin and gliadin, which during mixing and kneading develop into gluten. Gluten is responsible for the protein-starch interaction that provides specific viscoelastic properties in products (Bustos et al., 2015). For such patients, gluten free products are being manufactured from.

With pasta as a key element in the basic diet of most cultures; and is consequently one of the most consumed foods in the world, with the market presence of gluten-free pasta being important for coeliac health. Development of gluten-free pasta is a big challenge for food research and development, the network forming ability of gluten needs to be substituted by other means, in order to achieve products with satisfying quality (Schoenlechner et al., 2010). Consumer acceptance of cooked pasta is based primarily on textural properties, but unfortunately, GF pasta tends to be sticky, produces a lot of cooking residue and has an unpleasant texture (Marti and Pagani 2013). Although most of the cereal flour used in the production of GF pasta are made of rice and corn with the addition of proteins, gums, and emulsifiers (Palavecino, 2017), there are more nutritionally valuable cereal with good textural qualities and readily available alternative crops that could contribute towards the much-needed steadiness of food supply and other resources to sustain the life of people while at the same time maintaining ecological balance. One such bio resource that has a big potential in meeting this challenge is Job's-tears (Coix lacryma-jobi-L) (Lirio et al., 2013).

Job's tear (Coix Lacryma-jobi L.), also known as Adlay/Adlai in the Philippines, is a tall grass, a grain-bearing tropical plant of the family Poaceae. Depending on the variety, the seeds are yellow, purple or brown and are often tearshaped; hence, the name "Job's tears". It has been widely studied across the globe and predominantly contains carbohydrate (65%), protein (15%), moisture (11%), fat (6%) with trace minerals and vitamins such as calcium, phosphorus, niacin, thiamine, and riboflavin; and food energy (360-380 kcal/100 g) (Mulyono et al., 2019). These macronutrients (carbohydrates, protein, fat), minerals (Calcium, Phosphorus, Iron), B- vitamins (Niacin, thiamin and Riboflavin) and dietary fiber are higher level over corn, rice and wheat. Job's tears flour contained 2.25% amylase. The major protein is coixin which is rich in proline and leucine but is insufficient in lysine (Gupta, 2015).

The preliminary field investigation showed that Adlai is a promising supplement to rice as staple food. It grows naturally on marginal uplands without requiring the

traditional land cultivation, irrigation, fertilizer, and pest control demands of rice. The harvesting, threshing, and milling are done manually. Adlai has a low glycemic index rating of 35. Glycemic index (GI), among other indicators, measures the increase of blood sugar caused by the intake of carbohydrates. In the case of rice, both amylose and dietary fiber content were found to be inversely proportional to the GI. That means that when compared to white or brown rice, Adlai can be a great source of carbohydrates for people at risk of diabetes, obesity, and colon disorders (Trinidad & Mallilin, 2011). Meanwhile, studies indicate that Adlai has anti-allergic, anti-mutagenic, hypolipemic, and anti-diabetic effects. It also exhibits anti-cancer activity. In a study by Hung et al. (2003), Adlai seeds were found to exert an anti-proliferative effect on human lung cancer cells in vitro and in vivo and prevent the development of tobacco carcinogen-induced tumors. The anti-cancer activity of Adlai was further proven by the study of Lee et al. (2008), who isolated five active compounds from Adlai bran that inhibit cancer cells. In traditional Chinese medicine, Adlai hull extract is used to treat dysmenorrhea and was proven in a recent study that, indeed, it is a feasible alternative therapeutic agent.

In addition, a study conducted in the School of Food Science and Engineering, Nanjing University of Finance and Economics in China, the phytochemicals profiles of three Adlai varieties, including both free and bound of total phenolic and total flavonoids, and total antioxidant activity of Adlai was determined. On average, the bound phenolic contributed 45.3% of total phenolic content of the Adlai varieties analyzed and the average values of bound flavonoids contributed 71.1% of total flavonoids of the Adlai varieties analyzed. The Adlai sample itself has no cytotoxicity (Wang et al., 2013).

Adlai (Coix Lacryma-jobi L.) originated from India and now are native to the East and Southeast Asian region in China, Japan, Myanmar, the Philippines, and Thailand. Their seeds have been used to produce food products as well as ornamental products such as rosaries and necklaces. De-hulled mature seeds can be cooked and consumed together with cooked rice. The polished and milled flour can be sometimes mixed with water and consumed as a cooling drink like barley or flour water. The pounded grain of Job's tears can also be used for brewing of beer in the Garo, Karbi and Naga tribes (Burkill, 1935). In China, they are used as traditional medicine and supplementary medicinal foods. The beneficial health effects of Adlai are: (i) reducing liver fat accumulation, (ii) protecting from tumor stimulating compounds, (iii) protecting against viral infection, (iv) reducing allergic reaction, (v) reducing coronary artery disease and arthrosclerosis, and (vi) reducing osteoporosis (Chang et al., 2003; Hung and Chang, 2003; Shih et al., 2004; Yu et al., 2011). In Thailand, after the seed coats are removed, the seeds are cooked, dried, deep fried or baked and then consumed as a snack with different flavors. The seeds are also boiled with water to produce Adlai beverage, which is available in the market as an alternative healthy cereal drink.

In the Philippines, the Department of Agriculture – Bureau of Agricultural Research (DA – BAR) is promoting the use of Adlai in the field of research and development due to its versatility and nutritional value. Adlai is known in Mindanao for it is the top grower of this crop. This crop has the ability to survive from drought and flood and can grow robustly even in the most demoted area. DA has seen the potential of this grain as a staple crop to help solve the problem of the country's chronic insufficiency as far as rice crop is concerned.

Another important characteristic of the plant is its resilient adaptability to marginal or poor soil conditions. Bansen et al. (2010) reported that "katjan" (the plant's common name) was found to tolerate and grow in a wide range of temperature, elevation, pH, organic matter and soil nutrient contents. In contrast to rice, Job's tears can grow well in upland areas with very low soil fertility and poor irrigation. Job's tears, to grow well, does not require too much attention. It needs a little care after planting and weeding may only be once or twice, therefore the expenditure for its cultivation is much more affordable to local farmers. Rice production is more dependent on cash inputs; it intensively uses labor, chemical inputs such as manufactured fertilizers and pesticides (Douangsavanh & Buoahom, 2006).

Addition of Adlai flour to substitute the wheat flour in bakery products is also of interest. A recent study in the Philippines was conducted on the utilization of Adlai flour as a composite for all-purpose flour in Saltine Crackers (Andoy et al., 2019). Recorded studies which use minimally processed Adlai in single form or combination with other grains are already performed in butter cakes and formulated rice like grains. Adlai flour was obtained after polishing and milling and can be used as a food ingredient such as pasta.

Adlai (Coix Lacryma-jobi L.) is a gluten-free grain that contains various nutrients, vitamins, and minerals, with a level higher than wheat and rice. A study conducted in Indonesia was done to determine the physical and chemical

properties of Adlai flour and was subjected to wet milling and dry milling techniques. The result showed that wet-milling process increased viscosity, swelling and gelatinization enthalpy, therefore, is recommended for producing Adlai flour (Mulyono et al., 2019). Thus, Adlai can be a great alternative ingredient in the production of gluten-free pasta. Furthermore, this grain has nutrition, antioxidants, and textural qualities suitable for functional foods (Andoyet al., 2019).

Optimization of ingredient proportion is needed to be studied as well as the knowledge of the precise influence of ingredients/additives on the cooking and textural properties of Adlai flour as an alternative base for a good quality pasta. This study aims to develop a gluten-free pasta from Adlai flour, evaluate the cooking properties, proximate composition and compare the sensory characteristics of the developed sample with the similar product available in the market through sensory evaluation, using the different pasta formulations.

The development of gluten-free Adlai pasta and the desired outcomes through the evaluation of cooking properties, proximate composition and sensory quality will be done to determine its feasibility and consumer acceptability in comparison to the ones available on the market as shown in Figure 1.

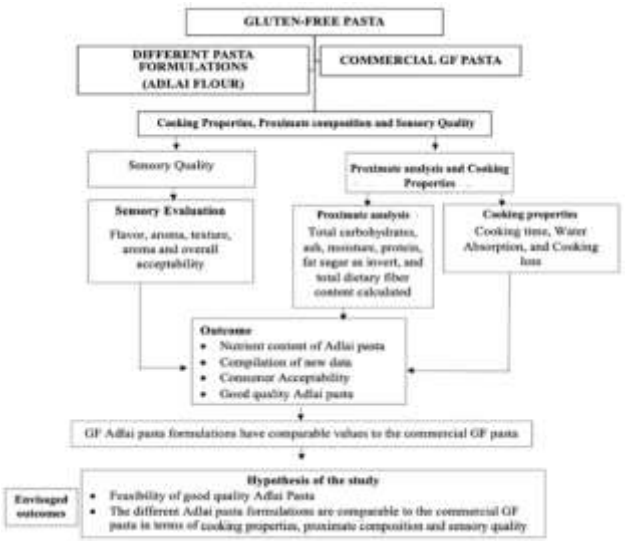

Figure 1. Conceptual Framework

METHODOLOGY

Raw Materials

The Adlai grits (Ginampay Variety) was procured at Department of Agriculture-Cagayan Valley Research Center (DA-CVRC), San Felipe, Ilagan City, Isabela. Other ingredients such as salt and oil were purchased from the local market. The following food grade ingredients were purchased from a local supplier: Xanthan Gum (XG) (Kemrad Incorporation, Quezon City, Metro Manila) Pre – Gelatinize Cassava Starch (PGCS), Egg White Powder (EWP) (Dalkem Corporation, Quezon City, Metro Manila), Brown Rice Pasta (BRP) (Healthy Options).

Processing of Adlai flour

Processing of Adlai flour was done according to the procedure of (Mulyono et al., 2019) by using the wet milling process as shown in Figure 3.1. The wet-milled Adlai flour was produced as follows: the grains were cleaned and soaked in water overnight at room temperature, with ratio grain to water (3:1 w/w), followed by milling using an Adlai hammer mill with addition of water. The wet flour was placed in the container and dried in a tray dryer at 60°C for 1 hour. The flour was then sifted twice using 100 mesh sieve and was stored in sealed-plastic bag at 4°C.

Figure 2. Production of Adlai flour from wet-milling process

Pasta Formulation and Processing

A full factorial complete randomized was used as an experimental design for the levels of the selected variables. The formulation and processing were based on the procedure of Charoenthaikij (2018) with some modifications. With a 100 g flour basis, consisting of Adlai flour (AF) mixed with pre – gelatinize cassava starch (PGCS) (AF: PGCS at 100:0 ;

95 : 5 and 90 : 10), xanthan gum (XG : 5% w/w), egg white powder (EWP : 10% w/w) and the following ingredients: salt (2%), rice bran oil (19%) and water (70-90%). The limits established by Codex Alimentarius regulation for the xanthan gum (XG) content was considered. The pasta formulations are shown in Table 1.

The raw ingredients and water were then mixed by hand to form a rough dough. Rice bran oil was added for kneading to form a smooth dough. The dough was rested and covered with a plastic wrap for 30 minutes at room temperature (28 ±2°C). After that, the dough was sheeted and cut into a length of 40 mm with a 1.5 mm thickness (fettuccini shape) using a pasta maker. The pasta was then steam-cooked using a steamer for 10 minutes and dried in a tray dryer at 60 ±5°C for 3 hours to obtain less than 10% moisture content.

Table 1. Pasta Formulation

Formula	T1	T2	T3
AF: PGCS	100:0	95:5	90:10
EWP (%)	10% w/w	10% w/w	10% w/w
XG (%)	5% w/w	5% w/w	5% w/w

Cooking Properties of Pasta

Optimal cooking time

The optimal cooking time (OCT) was determined according to AACC method no. 66-50. Ten grams of pasta were placed into a pot containing 1,000 mL of boiling water while stirring and partially covering the pot to help reduce evaporation and maintain consistent temperature. The OCT was determined by compressing a pasta sample between 2 glass slides and observing the line disappearance by taking samples at intervals of 1 min. Once the center core of pasta disappears, the cooking time is recorded.

Cooking loss

The cooking loss of pasta was determined according to the AACC2000 method no. 66-50. Five-gram pasta were cooked in 50 mL of boiling water (the ratio of pasta: water = 1: 10). Pasta samples were then cooked using optimal cooking time. Cooking loss (CL) can be determined by evaporation of the cooking water contained in a pre-weighed beaker, to constant weight at 105 °C, the residue was expressed as g of solids/100 g of raw pasta. The reported values were the average of at least two replicates for each sample.

Water absorption

The cooked product was drained for 3 minutes and weighed to determine water absorption using the following equation:

Water absorption = [(weight of cooked pasta) – (weight of raw pasta)] / (weight of raw pasta)

Sensory evaluation

The different formulations of Adlai pasta, along with the commercial brown rice pasta were carried out by 50 untrained panelists (20-50 years of age; equally divided among men and women) who have no allergies to gluten and all ingredients used in the pasta formulations. Portions of 100g of pasta were cooked in water at the time point defined previously by the cooking test. Cooked samples (5g) were provided to the testers in encoded disposable cups at a random order. The sensory attributes of the cooked gluten-free Adlai pasta were evaluated 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). Panelists were asked to evaluate sensory attributes including taste, color, texture, aroma, and general acceptability.

Proximate Analyses

The gluten free Adlai pasta that obtained the highest score in the Sensory Evaluation was sent to SGS Philippines, Inc. in Marikina City for proximate analyses. The samples were determined by the following parameters: total carbohydrates, ash, moisture, protein, sugar as invert and total dietary fiber. The Analytical Methods were based on the AOAC official.

Gluten Testing

The gluten free Adlai pasta that obtained the highest score in the Sensory Evaluation was sent to SGS Philippines, Inc. in Marikina City and was forwarded to SGS Vietnam Ltd. in Ho Chi Minh City, Vietnam for gluten testing. The 220 g Adlai pasta sample has undergone comprehensive testing for the detection of gluten Enzyme-Linked Immunosorbent Assay (ELISA) testing methodologies to determine the presence of gluten at low levels. Specifically, the AOAC

2012.01 (21st Ed., 2019) R5 sandwich ELISA method (A) was used in this study.

Statistical Analysis

The results for the Sensory Evaluation were subjected to the Analysis of Variance (ANOVA, (Kruskal-Wallis Test), while the cooking properties and the proximate composition were subjected to a one-way ANOVA. The Tukey's range test was performed for post-hoc multiple comparison. Statistically significant difference was established at $P < 0.05$.

RESULTS AND DISCUSSION

Cooking properties of GF Adlai pasta

The pasta cooking process involves a complex molecular transformation: starch swells because of contact with hot water, some granules gelatinize into the pasta structure, but others are leached to the medium along with amylose chains, causing an undesirable sticky pasta surface and turbid cooking water (Beta and Corke, 2001; Heo et al., 2014; Larrosa et al., 2016). The three-dimensional network that retains the granules in GF pasta is usually made up of proteins, pregelatinized starch and hydrocolloids (Marti and Pagani, 2013).

Table 1: Water Absorption and Cooking Loss

Treatment	Optimal Cooking Time (minutes)	Water Absorption (%)	Cooking Loss (%)
1 (100:0)	3^{b}	$115 \pm 2.83_{b}$	1^{bc}
2 (95:5)	3^{b}	75 ± 12.73^{d}	1.85^{b}
3 (90:10)	3^{b}	159 ± 9.19^{a}	1.15 ± 0.04^{bc}
4 (Control)	10^{a}	113.63 ± 8.41^{c}	8.56 ± 0.75^{a}

Optimal Cooking Time (OCT)

The optimal cooking time (OCT) of the pastas containing Adlai flour were similar (3 minutes), but they differed from the time determined for the control sample, which can be attributed to the increase in fiber content of the formulations containing Adlai flour (Gatta et al., 2017). The values reported in the present research were similar to the results observed by Gatta et al., 2017) (9min for spaghetti produced with semolina and 20% of wheat bran), but lower than those reported by Ferreira et al. (2016) (11 – 15min for gluten-free pasta developed with a mixture of sorghum–rice–corn flour and potato starch). Thus, the type of flours used for pasta production can influence its cooking time.

Water Absorption (WA)

Good cooking quality is associated with high values of water absorption (WA). WA for Adlai pasta were between 75% and 159 % (Table 2). The results showed that GF Adlai pasta samples had significant differences in WA. The WA value can be considered acceptable if it can absorb 150-200g of water/100g pasta, namely a water absorption between 150% and 200% (Bustos et al., 2015). Thus, Treatment 3 (90:10) and Treatment 1 (100:0) are considered acceptable. In particular, the addition of pregelatinized cassava starch (PGCS), egg white protein (EWP) and xanthan gum (XG) promoted high hydrophilic starchy structure and resulted in high water absorption. This indicates that as the PGCS and XG increases, the water absorption also tends to increase. However, an increase in water absorption of pasta depends on the size and shape of pasta (Martinez et al., 2016) as well as the drying and cooking process (Teba et al., 2009). Sozer, 2009 also reported that hydrocolloids can increase viscosity and improve the texture of pasta with higher water absorption values.

Cooking Loss (CL)

Consumer's acceptance depends on the pasta quality, which is strongly related to low values of cooking loss (CL), consequently to pasta resistance and to disintegration and leaching (Heo et al., 2014; Loubes et al., 2016). The cooking loss values for Adlai pasta varied from 1.00% to 1.85% (Table 4.1), with the lowest CL values in the present study being lower than those of the GF noodles and pasta reported by other authors (Suhendro et al., 2000; Larrosa et al., 2016; Loubes et al., 2016; Wang, et al., 2016). The different Adlai pasta formulations have no significant difference. However, Treatment 4 (control) was significantly different from the Adlai pasta. Moreover, increasing the amount of pregelatinized cassava starch resulted in higher cooking losses. This may be due to the formation of a very sticky

structure of mixed flour as a result of the lack of a well-structured protein reticule, hindering the excessive swelling of the starch granules and the consequent dispersion of components in the cooking water (Marti and Pagani, 2013). However, the CL among GF Adlai pasta samples in the present study was in the range of 1.00% to 1.85% (Table 2) which was in accordance with the research of Doxastakis et al. (2007) who stated that the acceptable level of CL for the spaghetti made from semolina flour should not exceed to 7-8%. Therefore, all pastas in this study have acceptable CL levels.

Sensory Evaluation

Table 3. Results of Sensory Evaluation and ANOVA

Treatment	Appearance	Texture	Aroma	Flavor	Overall Acceptance
1 (100:0)	6.5 ± 1.4^{acd}	6 ± 1.7^{bc}	6.4 ± 1.6^{a}	6.2 ± 1.6^{cd}	6.5 ± 1.5^{cd}
2 (95:5)	6.7 ± 1.3^{ac}	6.4 ± 1.7^{ab}	6.7 ± 1.4^{a}	6.5 ± 1.6^{ac}	6.7 ± 1.3^{ac}
3 (90:10)	6.7 ± 1.8^{a}	6.9 ± 1.5^{a}	6.9 ± 1.5^{a}	6.6 ± 1.6^{a}	6.9 ± 1.6^{a}
4 (Control)	7.5 ± 1.5^{b}	7.4 ± 1.5^{a}	7.02 ± 1.4^{a}	7.2 ± 1.6^{b}	7.5 ± 1.5^{b}

$^{a-d}$Means±SD within the same column followed by the same letter is not significantly different ($p>0.05$)

The selected formulations were used for sensory evaluation and the average scores given by the panelists can be seen in Table 3. The results showed that the degree of liking scores among all pasta formulations were significantly different ($p < 0.05$). Treatment 4 (Control) revealed higher values than the Adlai pasta samples in terms of appearance, texture, flavor, and overall acceptability. Scores in terms of aroma were not significantly different. In addition, the values for texture did not differ ($p > 0.05$) between Treatment 3 (90:10) and Treatment 4 (Control). This indicates that the textural qualities of Treatment 3 (90:10) were comparable to the commercial ones available on the market. Marti & Pagani (2013) stated that consumer acceptance of cooked pasta is based primarily on textural properties. Such an effect might be due to the high protein content of Treatment 3 (90:10) through the addition of egg white protein as well as the addition of xanthan gum and pregelatinized cassava starch. Thus, the developed gluten-free Adlai pasta exhibits a good textural quality, this is due to its protein content of 13.61% which is higher than the control with a value of 8% (Table 4.3). Protein, as stated by Bruneel et al. (2010), is one of the most important factors affecting pasta properties. In addition, the scores of Treatment 2 (95:5) and Treatment 4 (Control) also have no significant difference in terms of aroma. The least favored pasta was Treatment 1 (100:0). This may be due to the lack of hydrocolloids (pregelatinized cassava starch) which can result to a poor binding capacity to water (Padalino et al, 2016) as well as the poor textural properties of the formula that determines a good quality pasta (Marti and Pagani, 2013). Of the Adlai pasta formulations, Treatment 4 (Control) was found to be the most favored, followed by Treatment 3 (90:10), Treatment 2 (95:5) and lastly, Treatment 1 (100:0). Overall, pasta made Adlai flour scored above neutral on acceptability, which implies a good consumer acceptability of the pasta. It is important to note that the pasta was evaluated without sauce which most consumers are not used to. This may explain why the control pasta received a score between slightly liked and moderately liked. The results indicated that the developed GF pasta obtained above neutral scores comparable to the commercial pasta.

Price Comparison of GF Adlai Pasta to Commercially Sold GF Pasta

Table 4. Comparison of Prices between Adlai Pasta (90:10), Brand X, and Brand Y

Products	Commercially Sold GF Pasta (125g)		Adlai Pasta (125g)
	Brand X	Brand Y	Php 25.00
Price	Php 51.00	Php 61.00	

As seen in Table 4, Adlai Pasta is cheaper than the two commercially sold GF pasta. Compared to Brand X and Brand Y, Adlai pasta is half the price of the two selected products. With regards to the packaging expense of the two

commercially sold products, Adlai pasta is still cheaper. The price of Brand X and Brand Y also includes the additives that were present in the production of Adlai pasta

Proximate Composition

Table 5. Proximate Analysis and Total Dietary Fiber of GF Adlai Pasta

Parameters	GF Adlai Pasta	Brown Rice Pasta
Total Calories, kcal/100g	425	365
Total Carbohydrates, g/100g	58.98	75
Ash, g/100g	2.70	n/a
Moisture, g/100g	9.60	n/a
Protein (N x 6.25), g/100g	13.61	8
Total Fat, g/100g	15.11	3
Total Sugars as Invert, g/100g	< 1.80	1

*%Carbohydrates = 100 – (%Moisture + %Ash + %Protein + %Fat)
* "<": less than means the test result is lower than the Minimum Detection Limit

The protein content of the selected GF Adlai pasta formulation was 13.61%, respectively. As seen in Table 5, Adlai flour with addition of egg white protein, xanthan gum and pregelatinized cassava starch resulted in an increased protein content than that of the control (8%). The carbohydrate content of the GF Adlai pasta resulted in 58.98%, respectively. These values are lower than the control (75%).

Ash content is a measure of the nutritive mineral elements in food. The ash content of the GF Adlai pasta reported a high ash content of 2.70%, in line with the study of Jomduang and Bunthawong (2018) which indicates that Black Job's tears grains contained 2.12-2.29% ash and white Job's tears grains contained 0.33-0.69% ash. This could be as a result high mineral content of Adlai flour such as magnesium, calcium, phosphorus, and traces of iron (Chhabra, 2015).

One of the most essential analyses performed on food is moisture assay since water is a major constituent of most food products. Stability and shelf life of food products is greatly affected by moisture (Nielsen, 2010). When foods have less moisture or are dehydrated, microorganisms cannot grow, and foods will not spoil (Gray, 2019). Table 5 shows that the GF Adlai pasta has a high moisture content of 9.60% which closely relates to the study of Chhabra and Gupta (2015) in which the moisture of adlay grains comprises 10.83%. This could be due to the Adlai's high protein content. Proteins found in adlay grains could enhance the molecular interactions between protein and protein, or protein and starch by heat. Hydration of water may be obstructed and could reduce the swelling volume of starch granules (Hamaker et al.,1993). High moisture content considerably affects the shelf life of the product and influences mainly the rheological properties of the final product (Chaisiricharoenkul et al., 2011; Manohar et al., 1999; Maache-Rezzoug et al., 1998).

The fat content of the GF Adlai pasta was relatively higher in comparison to the commercial ones. Nevertheless, this is not a fact of worry for fat accumulation and being overweight as its main source is rice bran oil. Rice bran oil is a good source of unsaturated fats, vitamin E, and other important nutrients. It may also reduce heart disease risk by improving cholesterol levels (Most et al, 2005). When it comes to energy yield, Adlai pasta has a higher calorie content compared to the commercially sold GF pasta.

The levels of fiber content in the GF Adlai pasta were higher compared to the commercial ones. According to Brasil (2012), for a food product to be considered a source of fiber it must have 2.5g of fibers per portion of food. As the GF Adlai pasta had 5.96 g of fiber per portion, it can be considered a source of fiber. Presence of fibers contributes to satiety after food consumption and it can help to lower the glycemic index (Costa et al., 2015; Oliveira, et al., 2016).

Gluten Test Result

Table 6: Gluten Allergen Detection Result

Testing Analysis	Method	Result	Unit
Gluten Allergen	AOAC 2012.01 (21st Ed., 2019) R5 sandwich ELISA method (A)	Not detected LOD = 1	mg/kg

*LOD = Limit of Detection
*The method(s) remarked with (A), (H) and (T) is (are) designated by the Ministry of Agriculture and Rural Development, the Ministry of Health, and the Ministry of Industry and Trade, respectively

The set limit values for gluten-free food were determined (<20 mg/kg gluten) and the R5 sandwich ELISA method was defined for the determination of gluten (Codex Stan, 1979). Gluten test results found in Table 4.4 shows a limit of detection of 1 which indicates that gluten was not detected on the Adlai pasta sample.

CONCLUSION

Based on the overall results, it is concluded that the addition of Adlai flour with PGCS, EWP, and XG to gluten-free pasta significantly affected its cooking properties, sensory attributes, and proximate composition. Sensory evaluation indicated that Treatment 4 (Control) gained the highest acceptability for all sensory attributes (like moderately) and is comparable to Treatment 3 (90:10) in terms of texture. However, scores regarding aroma have no significant difference among the different samples. Since all pasta formulations received scores above neutral, it was determined that GF Adlai pasta has a good acceptability. Regarding the cooking properties, as the levels of PGCS increased, water absorption tended to increase, whereas cooking time and cooking loss were likely decreased. The developed GF Adlai pasta shows a great number of total energy (kcal), protein and dietary fiber that are higher than both the commercial (non-gluten-free) pasta product and GF pasta. However, there was a decrease in the carbohydrate content and the fat content was relatively higher in comparison to the commercial ones. This could be the result of nutritional composition being lost in the milling process or flour storage. Moreover, compared to the commercially available GF pasta, the Adlai pasta is cost-efficient. Thus, results demonstrated that it is possible to develop a good quality gluten-free pasta from Adlai flour. In addition, Adlai flour can be used as an alternative ingredient in order to increase the nutritional value of gluten-free pasta and improve its cooking properties.

For future study, the researcher recommends that texture profile analysis, identifying the pH. and Hunter color values of the Adlai pasta must be done. This is to further understand the effect of the different variables on the textural properties, shelf life, and overall appearance of the product. Controlled working environment must also be observed. It is also recommended to include pasta sauce to mask the color difference among the Adlai pasta samples and the control treatment. Different Adlai varieties must be tested for the feasibility of the utilization of the GF Adlai pasta. Different methods for making Adlai pasta must be done for comparison. The different pasta formulations could also be improved to eliminate other allergens such as egg white powder. Furthermore, it is also suggested that a bigger number of panelists must be included in the sensory evaluation. Lastly, purchase intention, packaging and vitamin analysis must be included in the future study.

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