DEVELOPMENT AND EVALUATION OF RICE – BASED CHIPS USING LOCALLY AVAILABLE LEGUMES

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Abstract — The effect of the different locally sourced legumes as protein source in rice-based chips was investigated in this study. Extruded snacks was produced from rice and locally sourced legumes namely mung bean (*Vigna radiata L.*), pigeon pea (*Cajanus cajan)* and chickpea (*Cicer arietinum*) in 70:30 (rice:legume) ratio. The physicochemical properties were evaluated and results revealed that the three treatments had expansion ratios of 2.35 to 2.61, moisture content ranged from 3.38 to 5.08%, and water activity of 0.43 to 0.57. The protein content of the three treatments contained 10.02, 10.33 and 11.66 of protein for rice-based chips, respectively. Based on the sensory evaluation and texture profile analysis, the use of chickpea for rice-based chips showed significant difference among the other legumes and was the most acceptable treatment in terms of color and general acceptability. The microbial load of the three treatments had a colony count of 2.9-4.21 CFU/g aerobic plate count and have no growth for yeast and molds. The results of the nutritional facts computation for 100g dried chips based on the Food Standards Australia New Zealand (FSANZ) for the Treatments 1, 2, and 3 were the following: energy kcal of 1650, 1580, and 2050, carbohydrate of 84.2, 80.0, and 104.0, protein content of 9.4, 11.9, and 11.0, a total fat of 0.7, 0.7, and 1.7, and a saturated fat of 0.1, 0.1, and 0.2, respectively.

Keywords **— Extruded snacks, local legumes, natural rice-based chips, Philippines**

INTRODUCTION

Rice *(Oryza sativa)* is a staple food crop and one of the most important foods in the Philippines. It is also consumed in the form of noodles, puffed rice, fermented sweet rice, and snack foods made by extrusion cooking. However, rice protein, like other cereal proteins, is not an ideally balanced protein (Patrick, 1971). Combination of rice and legumes or pulses such as “rice and bean” are eaten by many people. This is a favorable dietary trend because the legumes are relatively rich in protein which in turn is relatively rich in lysine. Legumes are low-cost and high-quality protein that can supplement or substitute the daily protein requirement, which is usually obtained from expensive animal and marine sources.

The Food and Nutrition Research Institute (FNRI) has developed Rice-Mongo crunchies as one of the protein-rich food products that could address the nutritional problems of the country. The development of this nutrient-rich foods particularly snack foods that resemble the chips and crunchies sold at commercial outlets is also prepared at the Complementary Food Processing Facility located at the Central Bicol State University of Agriculture (CBSUA), Philippines.

The desire for sustainable protein sources has brought a new focus on legumes. Legumes are food resources that is a good source of complex carbohydrates, proteins, and dietary fiber. The protein content of legume grains range from 17 g/100 g to 40 g/100 g and approximately equal to the protein content of meat which is 18 to 25 g/100 g (de Almeida Costa et al., 2006).

The pigeon pea (*Cajanus cajan*) and chickpea (*Cicer arietinum*) are also common legumes that is grown in the Philippines. These locally grown legumes constitute as an important source of dietary proteins and many other nutritional values (Martin, 2018). The protein content of pigeon pea varieties ranged from 23 to 26% (Fasoyiro et. al, 2010), and chickpea varieties contained 22 to 24% of protein (Rachwa-Rosiak et al, 2015). The protein content of both the pigeon pea and chickpea are comparable with those of the other legumes such as the mung bean. However, the utilization of these legumes as an alternative source of protein has not been undertaken for producing rice based-chips.

Therefore, this study was conducted to develop and evaluate the properties of rice-based chips using different kinds of local legumes.

MATERIALS AND METHODS

Materials

Rice, mungbean and chickpea were purchased at Naga City Peoples Mall in Naga City, Camarines Sur. Brown colored pigeon pea seeds was purchased from Mariano Marcos Memorial State University, Ilocos Norte. All the raw materials were processed at the Complementary Food Processing Facility, CBSUA, San Jose, Pili, Camarines Sur. The legumes were ground separately to produce flour using an industrial grinder and then sieved to remove dirt and its outer layer.

Processing of Rice-Based Chips

The formulation for the different treatments of rice-based chips was patterned from the FNRI wherein the rice-legume ratio is 70:30 which means that for every seven cups of rice flour, three cups of the legume flour is added. Three legumes were used as treatments for the development of rice-based chips: T1 (rice-mung bean), T2 (rice-pigeon pea) and T3 (rice-chickpea) combinations. Rice-based chips was prepared by mixing rice flour and legume flour following the 70:30 ratio. Water was then added and the mixture were mixed for 10 minutes using a mechanical mixer. The mixture was placed on a tray evenly flattened with a 5cm thickness and then steamed for 30 minutes at 100°C. The product was cooled down and then extruded. The extruded mixture was pre-dried in a mechanical drier for 30 minutes at 65°C. The pre-dried product was cut into small pieces approximately 8-10 cm long and dried again in the mechanical drier for 2 hours at 65°C. The dried product was deep-fried in oil for 2-3 seconds at 280°C and then cooled down for packing.

Examination of Physicochemical Properties

The expansion ratio (ER) of extruded samples were examined by using a micrometer to measure the diameter of a cylindrical sample. Ten measurements were taken and then averaged. The Moisture Analyzer (Model No. LSC-60) was used to test the moisture present in the sample. Five (5) grams of the sample was dried at 1050C and weighed until the weight is constant and results for % moisture content is recorded. The water activity (aw) of the sample was measured using the ROTRONIC aw which includes the bench-top unit HygroLab C1, the handheld device HP23-AW-A and the software HW4-P-QUICK-Vx for its quick capability.

Fat extraction method was conducted to measure the percentage of lipid in the initial sample can then be calculated. In this method, the sample was pulverized into small particles and placed in a porous cellulose thimble. The thimble was placed in an extraction chamber, which is suspended above a flask containing the solvent and below a condenser. The flask is heated and the solvent evaporates and moves up into the condenser where it is converted into a liquid that trickles into the extraction chamber containing the sample. At the end of the extraction process, which lasted for 16 hours, the flask containing the solvent and lipid was removed. The solvent in the flask is then evaporated by boiling. Once the boiling point of the solvent is reached, the solvent evaporates and the mass of the remaining lipid is measured. The percentage of lipid in the initial sample is calculated. Whereas the Protein analysis of each treatment was tested in the Department of Science and Technology-Regional Standards and Testing Laboratory. The crude protein content was determined using the methods described in Association of Official Analytical Chemists (AOAC, 2006) TM-Ch-004 with reference to AOAC 978.04A, 19th Ed.

Sensory Evaluation

Rice-based chips was evaluated by ten (10) trained panelists using the sensorial attributes such as color, aroma, flavor, crunchiness, hardness and general acceptability of the product using the descriptive score sheet. The general acceptability was evaluated to determine the most acceptable among the three (3) treatments. Each panelist was provided with three (3) different samples randomly together with the score sheet.

Coded sample was presented to each of the panelists using ranking test. The gathered results were decoded and analyzed through the analysis of variance test (ANOVA) to determine the acceptability of the product.

Textural Profile Analysis

The different treatments were evaluated by fifteen (15) untrained panelists according to each Textural attributes such as Crispiness, Hardness, Brittleness and Fracturability. Each panelists was provided with three (3) different samples randomly arranged together with the score sheet. The panelists underwent a brief orientation for the evaluation of the texture of the product through mastication. The panelists draw line across the 7cm line scale with the code number of the sample which corresponds to the scale of evaluation. The sample score card was shown in appendices.

Statistical Analyses

All measurements were done in triplicate. Analysis of variance (ANOVA) and least significant difference were done using the Statistical Analysis System (SAS Institute, Carry, NC) while differences between treatments were determined using Duncan's multiple range test.

Microbial Analysis

The aerobic plate count was carried out using Standard Plate Count Agar AOAC (1996). Initial product sample homogenates were prepared in sterile diluents in ratios of 1:10. One ml from the sample was aseptically diluted in series up to a dilution of 10-3 using sterilized pipette. The diluents were pour plated in triplicates then the liquefied media around 35ºC was poured and mixed thoroughly with the sample by mixing the contents by moving the plates gently in clockwise and counter clockwise direction for three times. When the agar solidified the plates were inverted and wrapped using cleaned surface of bond paper. Incubation was done at 25ºC for 48 h. After the incubation period, the number of visible colonies grown on each dilution plates were counted and recorded. The corresponding average CFU/g of the sample was computed using the formula below:

$$N = \frac{\Sigma C}{[(1\ x\ n_1) + (0.1\ x\ n_2)\ x\ (d)]}$$

Where:
N = Number colonies per gram of product
ΣC = Sum of all colonies in all plates counted
n_1 = Number of plates in first dilution counted
n_2 = Number of plates in second dilution counted
d = Dilution from which the first counts were obtained

were determined. The procedure on homogenization of the samples was the same as with the procedure of aerobic plate count analysis except that the 3M Petrifilm was used for the enumeration of yeast and mold (AOAC Official Method 2014.05) and the incubation period was 5 days.

Nutritional Fact Computation

Nutritional Facts could help consumers to follow a healthy diet and make healthy food choices. The Nutrition Facts of the samples were computed including the serving size, number of serving and the amount of various nutrients contained in the product. It was calculated using the Nutritional Panel Calculator (NPC) under the Food Standards Australia New Zealand (FSANZ). It is a governmental body responsible for developing standards for food available in Australia and New Zealand. The NPC assist in obtaining average nutrient quantities for nutrition labelling (FSANZ Explanatory Note, 2011).

RESULTS AND DISCUSSION

Moisture Content Determination

Results show that the moisture content of the three treatments ranged from 10.33 to 12.02% dry basis. Among the different composite flours, the highest moisture content was observed in mung bean flour whereas pigeon pea flour has the lowest moisture content. However, after the drying and frying process results revealed that the rice-based chips containing the highest moisture content was with the chick pea flour having a moisture content of 5.08 and 4.62 for dried chips and fried chips, respectively. Moisture content of the composite flours has higher moisture content than on the dried chips and fried chips. The drying and frying processes using high temperatures will cause lower water content of rice-based chips due to the evaporation of water (Setyaningsih, 2019). These also provides the desired crispiness of the chips.

Table 1. Moisture Content of flours, dried chips and fried chips.

Treatment	Moisture Content (%)		
	Flour	Dried Chips	Fried Chips
Rice	12.2	-	-
T1 (Mung bean)	11.05	4.62	3.48
T2 (Pigeon pea)	10.33	4.25	3.38
T3 (Chickpea)	10.52	5.08	4.62

Water Activity

The analysis for the determination of water activity content for rice-based chips showed that the rice-mung bean combination has the highest water activity having the amount of 0.57, whereas rice-pigeon pea and rice-chickpea combination has a water activity of 0.43 and 0.48, respectively. More recently, it has been shown that water content has an effect on the crispness of the product. The lower water content, the crunchier the product will be. A study conducted showed that the water activity of rice crispies is 0.56, whereas extruded cereals range from 0.64 to 0.68, and extruded snacks ranges from 0.708 to 0.762, (Sauvageot and Blond, 2007).

Expansion Ratio

The expansion process of the pellets by frying can be divided into three phases. In the first phase, moisture loss occurs at the periphery of pellets into the oil, and the pellet becomes plastic in texture. In the next phase, moisture inside the pellets turns to steam by the heat. And finally, as the vapor quickly evaporates, the pellets expand for the expansion, the product should be thoroughly cooked and be elastic enough to have gas-retaining ability for air cells. The results for the expansion ratio of the rice-based chips revealed that the rice-pigeon pea has the highest expansion ratio of 2.61 mm, whereas the rice-chickpea has 2.49 mm expansion ration and the rice-mung bean combination had the lowest expansion ration of 2.35 mm. The lower particle size of the different legume flour likely attributed the expansion ratios of the product. It is said that a lower particle size can result in more gelatinization and increased cooking of the starch due to the increased surface area to volume ratio of the particles (Martin, 2020).

Chemical Composition of the Natural Rice-Based Chips

The result shown in Table 2 revealed that the extracted fat in the different treatment of rice-based chips ranged from 17.3 to 20%. Rice-pigeon pea combination has the highest fat extracted among the treatments. Extruded snack foods such as chips are fried after extrusion. The oil content of this extruded snack ranged from 20 to 35% as compared to a commercial product that has only 21% oil.

The protein content of the rice-based chips ranged from 10.02 to 11.66%. Rice-mung bean has the highest protein content among the treatments. The amount of the legume flour influences the protein content of the rice-based chips because the legumes have a high protein level (Sumardiono et. al, 2022). Extrusion process improves protein digestibility via denaturation, which exposes enzyme-access sites. Denatured proteins, incorporated in a snack food formula, are considered to be less functional and contribute little or nothing to the expansion process that occurs during extrusion. The variation in the fat and protein content of the rice-based product can be attributed to the differences in the genetics, varieties, and growth environments of the legumes used (Du et al., 2014)

Table 2. Fat and protein content of rice-based chips.

	T1 (Mungbean)	T2 (Pigeon Pea)	T3 (Chickpea)
Fat (%)	18.39	18.65	18.17
Protein (%)	11.66	10.02	10.33

Sensory Evaluation

The results for sensory evaluation were summarized in Table 3. Three Treatments were subjected to sensory evaluation to determine the specific characteristic of the rice-based chips through attribute test by ten (15) selected trained panelist who assessed the different sensory attributes in terms of Color, Aroma, Texture (crunchiness), Texture (hardness) and the General acceptability.

Table 3. Mean scores of the different attributes of Rice-based Chips.

Attributes	T1 (Mungbean)	T2 (Pigeon Pea)	T3 (Chickpea)
Color	2.8[a] Brown	4.07[c] Dark Brown	3.0[b] Cream
Aroma	3.07 Moderately Pronounced	3.33 Moderately Pronounced	3.1 Moderately Pronounced
Flavor	3.47 Moderately Perceptible	3.80 Moderately Perceptible	3.5 Moderately Perceptible
Texture (Crunchiness)	4.27 Crunchy	3.87 Crunchy	4.1 Crunchy
Texture (Hardness)	3.40 Hard	3.07 Hard	3.5 Hard
General Acceptability	7.27[b] Like Very Much	6.53[a] Like Moderately	7.6[b] Like Very Much

Mean scores with different letters are significantly different at 5% level of significance under Table 3.

The result shows that the color of the treatments is significantly different from each other. This is because of the different colors of legumes seed coat used and the effect of color during the frying process that darken the color due to high temperature of frying oil. The aroma of the different treatments showed no significant difference. The aroma of the legumes on the different treatments did not affect the aroma of the rice-based chips. This is because the chips undergo frying process in which this process lessens the aroma of legumes after frying. The flavor of the legumes used for rice-based chips were rated as moderately perceptible and shows no significant difference among treatments due to the weak flavor of legumes which is based from the total legume content of 18.75% of its total formulation on the rice-based chips. Crunchiness of the rice-based chips was also evaluated and results revealed that all the treatments were rated as crunchy which showed no significant difference among treatments. The texture of the rice-based chips in terms of hardness showed that all treatment was not significantly different and rated as hard. It was related to the texture profile that are near ranged and through its low moisture content that harden the rice-based chips.

The general acceptability of the rice-based chips has a mean score ranging from 6.54 to 7.6 among treatments and showed significant difference. The rice-chickpea combination for rice-based chips has the highest mean value of 7.6 characterized as like very much, whereas rice-pigeon pea has the lowest mean score of 6.53 characterized as like moderately. Although the rice-chickpea combination was not always rated as the most preferred treatment in terms of sensory attributes, however the general acceptability revealed that rice-chickpea was the most acceptable treatment.

Texture Profile Analysis

Mean score results for the texture profile analysis of the rice-based chips as shown in Table 4. Results revealed that rice-chickpea has the highest mean score in terms of hardness, crispiness, and brittleness, while rice-mung bean has the highest mean score in terms of fracturability.

From a sensory perspective, Figure 1 shows the relationship among the textural attributes of each treatment. It is well documented that water affects the crispness of the rice-based chips. Water is essential since it gives an effect to the appearance, texture and taste of the food. The crispiness of the rice-based chips was supported by the low water content and the drying and frying process (Setyaningsih et. al, 2019).

Table 4. Mean score of texture profile analysis.

Treatments	Hardness	Crispiness	Brittleness	Fracturability
T1 (Mungbean)	2.73	3.53	2.13	2.93
T2 (Pigeon pea)	2.40	4	2.33	2.80
T3 (Chickpea)	3.0	4.2	3.2	2.5

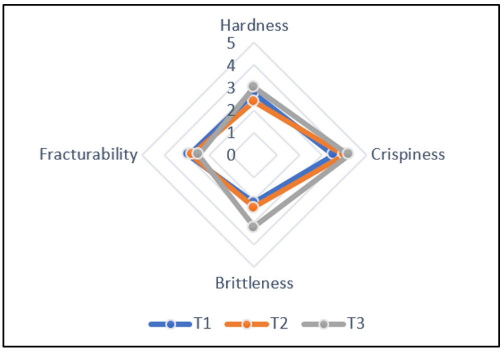

Fig. 1. Texture Profile Analysis of Rice-based chips.

Microbial Analysis

The results for the microbial analysis of rice-based chips in terms of Aerobic Plate Count and Yeast and Molds Count showed that all treatment confirms to the microbial standards for Rice-based Chips.

The aerobic plate count of all treatments reported to have 2.9 to 4.21 CFU/g. Based from the results, it was observed that there was a minimal microbial growth in the product this is because the rice-based chips undergo high temperature processing such as drying and frying. Results passed the FDA Revised Guidelines for The Assessment of Microbiological Quality of Processed Foods with the standard of 103. On the other hand, the result for the yeast and molds count was reported to be <1. This is in conformity for the microbiological quality standards set for snack foods as stipulated under FDA Circular 2013-010 otherwise known as the Revised Guidelines for the Assessment of Microbiological Quality of Processed Foods where yeast and mold count should not exceed at 10. The same was observed by Uzoaga and Kanu (2020) on the yeast and mold count of extruded and baked samples made from sweet potato, cassava, and plantain fortified with Moringa oleifera powder. Yeast and molds are generally more resistant to dry conditions (e.g., low water activity) than other microorganisms. However, the high temperature used for drying and frying as well as the extrusion processes and the conduct of microbial analysis immediately after processing resulted in the very low microbial count of the product.

Nutrition Facts Computation

Nutritional facts were also calculated per 30g serving of the most preferred formulation using the Nutritional Panel Calculator. Based on the result shown in Table 5, computed results were comparable to the energy recommendations which was based on the Recommended Energy and Nutrient Intake (2003). The formulated product was a good source of energy and can supply the nutrient requirements needed for the diet.

Table 5. Computed Nutritional Composition of Rice-Based Chips.

Nutrition Information	T1 (Mungbean)	T2 (Pigeon pea)	T3 (Chickpea)
Serving size (g)	100	100	100
Energy (kcal)	1650	1580	2050
Protein (g)	9.4	11.9	11.0
Fat, total - saturated	0.7 0.1	0.7 0.1	1.7 0.2
Carbohydrate -sugars	84.2 0.4	80.0 0.2	104.0 0.6
Sodium	6	9	137

In terms of protein and fat, the rice-based chips have higher value present since legumes used are good sources of protein and may contain more lipids and essential fatty acid.

CONCLUSION

The results of the study lead to the following conclusion that rice-based chips were processed in combination with different legumes such as mung bean, pigeon pea and chickpea using the formulation 70% rice flour and 30% legume flour. The physico-chemical properties such as moisture, water activity, expansion ratio, fat and protein of the rice-based chips with different legumes were determined and it was found that rice with mung bean, pigeon pea and chickpea combination had a moisture content of 3.48, 3.38 and 4.62; a_w of 0.43, 0.48 and 0.57; expansion ratio of 2.35, 2.61 and 2.49; fat of 18.39, 18.65 and 18.17; protein of 11.66, 10.02 and 10.33, respectively.

It can be concluded that the most acceptable rice-based chips in terms of the sensory analysis using descriptive test is the use of chickpea on the development of rice-based chips which gained the highest mean value of 7.6 characterized as like very much. Microbial analysis for the three treatments were conducted and it was found out that treatments had colony count of 2.9 to 4.21 CFU/g aerobic plate count and have no growth for yeast and molds.

The computed nutritional content of the rice-based chips using different legumes was computed FSANZ Nutrition Facts Calculator. The samples had the following computed nutrition facts: energy kcal of 1650, 1580, and 2050, carbohydrate of 84.2, 80.0, and 104.0, protein of 9.4, 11.9, and 11.0 total fat of 0.7, 0.7, and 1.7, saturated fat of 0.1, 0.1, and 0.2 for Mung bean (T1), Pigeon pea (T2), and Chickpea (T3), respectively.

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