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# Rice-Like Grains from Broken Rice (*Oryza sativa L.*) and Adlai (*Coix lacryma-jobi L.)*

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**ABSTRACT—** ***Process optimization for rice-like grains preparation through cooking the fusion of adlai and broken rice together with water to produce a partially gelatinized mixture then extruded to form a rice-shaped kernel and finally dried, cooled and packed. Specifically, determine the operating parameters that can be controlled and modeled, addressing the concepts of control stability for preparing rice-like grains. Three rice varieties with high, intermediate and low amylose content; rice-adlai mixture (1:0, 1:1, 1:2); mixture moisture content (25%, 30%, 35%); and gelatinization temperature (80, 90, 100) were set and controlled for this study. The optimum combination established were intermediate amylose content for rice variety, 1: 0.9 rice-adlai mixture, 30% moisture content of the mixture and 91$^{o}$C gelatinization temperature. Verification test showed that predicted, experimental and actual values were reasonably close. Thus, the percentage difference for all the responses for compression test could be attributed for extrusion test such as processing time 8%, compression force 20% and moisture content 0.6%. Physicochemical and cooking characteristics of these rice-like grains can be modified by alteration of the different reconstitution parameters for specific quality requirement.***

**Keywords—** adlai, broken rice, extrusion and rice-like grains

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## 1. INTRODUCTION

Rice is the staple foods in the large part of the world including the Philippines. *Palay* production in the Philippines is about 17.1 million metric tons, most of which is grown domestically and produces only about 10.8 million metric tons of milled rice (GAIN Report, 2013). Philippines consume about 12.8 million metric tons of rice annually. Frequent deficit created due to declining domestic production caused by unpredictable calamities, increasing population and corruption in the rice supply chain, making Philippines one of the largest world rice importers. And the challenges today that most of the Filipinos encounter is the price hike of this staple food. Perhaps, corn can be adapted, but most of it is being process into other things like animal feed and now, bio-ethanol for fuel. Therefore, an alternative for rice and corn crops was needed also find ways to meet the national cereal requirement. *Adlai* comes from the family Poaceae or the grasses, the same family where rice, corn, and wheat belong. *Adlai* may be an indigenous and unfamiliar cereal grains grown in the Philippines but this plant could address the food requirement of Filipinos especially, during calamities. It is potentially suitable for use hence this crop resembles and tastes like rice and abundant in the country. *Adlai* contains higher food energy, carbohydrates, protein, fat and dietary fiber directly compared to rice and corn. *Adlai* is packed with other minerals also, such as: calcium, phosphorus, iron, niacin, thiamine, and riboflavin. However it has not yet been well documented and given priority. Another problems concern is the breakage of rice kernels during milling processes, 67% milled rice was obtained after milling rough rice. It contained 52% head rice and 15% broken rice. And these broken kernels are not generally accepted by consumers and sell at low price. In the past few decades several studies have been conducted and revealed that broken milled rice can be mixed with some desired additives to improve their quality and extruded to form rice-like grains.

These are the main reasons why this study, intends to develop a rice-like grains by reconstituting the broken milled rice and mixed with *adlai,* to promote the utilization of broken rice and exploring the potential of *adlai,* as an alternative source of food to at least alleviate the deficit in rice production. Most importantly, the process intends to upgrade the value and quality of the rice to be produced leading to innovation of the technology. At the same time provide basic information for determining the operating parameters that can be controlled and modeled, addressing the concepts of control stability for preparing rice-like grains, also established the optimum combination of the different reconstitution and extrusion parameters for preparing rice-like grains.

## 2. MATERIALS AND METHODS

### *2.1. Materials*

Samples prepared for this study are *adlai* and three rice varieties with high (RC-10), intermediate (RC-18) and low (RC-160) amylose content.

### *2.2. Methods of Reconstituting Rice and Adlai*

#### *2.2.1. Compression Test (Laboratory Process)*

The grind *adlai* and broken milled rice together with water was put inside the tube then cooked in an oven for a certain period of time to gelatinize the mixture. The processing time was measure using stop watch. It was switched on from the start the sample was put inside the oven at a certain temperature and switch off when the sample was partially gelatinized. Then, using the round bars to compress the gelatinized samples inside the tube to form new rice-like grains shape. These improvised pelletizing instrument which is attach to universal testing machine was utilize to reconstitute the broken rice and *adlai* and also determine the applied compression force. Products obtained from the experiment were dried and allowed to cool at room temperature and immediately packed airtight in plastic bags. Later, samples are subjected for analysis of their physicochemical characteristics, cooking properties and quality.

The moisture content of the extruded product was determined using moisture analyzer. Bulk density of rice-like grains was measured as the weight per volume (g/ml), through a measuring cup. Whiteness index of the rice-like grains was determined by a whiteness meter (Kett Whiteness Meter C-3).

Evaluating the quality of the cooked rice-like grains, automatic rice cooker was used for better control and uniformity of the cooking conditions. Cooking time was measured by a stop watch from the time the rice cooker is switch on and stopped when the rice cooker automatically switch-off. Water absorption was measured as the increase in weight of the cooked rice grains, while volume expansion was quantify as the increase in height of the cooked grains inside a cooker container of known dimensions. Sensory evaluation for cooked rice-like grains, ten trained panelists were asked to score samples in terms of flavor (aroma and taste), texture (cohesiveness and tenderness) and general acceptability using a hedonic scale. They were screened and trained to evaluate the cooked extruded samples. Final evaluation was also conducted for the selected optimum results.

#### *2.2.2. Extrusion Process (Machine)*

Samples was sorted to remove the impurities and mixed at the corresponding ratio of the rice and *adlai.* Next, sample was grind into flour then rewetting to allow exposure to moisture, afterwards the mixture was gelatinized. Lastly, extrusion process covers the entire processing operation. The gelatinized mixture of raw materials was fed into the extruder screw feeder which has maintained the rate of feeding. It was extruded at different extrusion variables, through a rice-grains-shaped die then cut by a rotary knife to form the rice-like grains. Extruded products were further dried until the moisture content is about safe for storage and allowed to cool then immediately packed in airtight plastic bags. Samples were subjected for analysis and evaluated to select the best combination for preparing rice-like grains. Optimum value obtained from compression test was utilizes as experimental design for extrusion test to validate the acceptability of the result gathered from the laboratory analysis.

#### *2.2.3. Optimization of the Extrusion Process*

Reconstituting of broken rice and *adlai* was optimized using Response Surface Methodology. The analysis of the study, a three-level-four-parameters incomplete factorial experiment was utilized to establish the optimum operating condition. Independent variables include amylose content, $(X_1)$; rice-*adlai* mixture, $(X_2)$; moisture content, $(X_3)$ and gelatinization temperature, $(X_4)$. While the dependent variables are gelatinization time, compression force, extrudates moisture content, physicochemical and cooking properties of the uncooked rice-like grains and quality of the cooked rice-like grains. Through response surface regression procedure, parameters of complete quadratic response surface was fitted and critical values was determined, such that response optimization with respect to the factors was effective. Data analysis was done using Statistical Analysis System for Windows and Design Expert software for establishing the optimum points. Then, verification of the response models was made by making several separate experimental test runs using optimum conditions.

## 3. RESULT AND DISCUSSION

### *3.1. Reconstitution of Broken Rice and Adlai*

Reconstitution of broken rice and *adlai* starts the process from mixing the grind rice and *adlai* at a desired ratio and by adding appropriate amount of water to the mixture. Then, the mixture was heated and the granules melt and become soft or gelatinized. The structure of the rice-like grains is created by forming through compression of the gelatinized mixture of rice and *adlai*. During gelatinization process, the melted mixture and expanding bubbles of water vapor in the mixture transform into foam. The layer of gelatinized mixture flows easily in the bubble walls that allows the bubbles to expand as the superheated water is released very quickly at atmospheric pressure. Melted fluids of the gelatinized mixture hold and expand due to bubbling of water vapor during extrudates expansion until it reached the rupture point. After expansion, rapid fall in the temperature caused by evaporation and the rise in viscosity due to moisture loss, the cellular structure shrink back and solidify as they cool to stabilize the structure of the rice analog. Accompanied by the rapid increase in viscosity is the formation of a glassy state as the moisture is removed to form a hard brittle texture. Thus, the essential features of the process are the melting of the crystalline regions of granules and degradation of starch polymers, [10]. Forming the structure of gelatinized mixture, must have minimum molecular weight adequate to give enough fluid viscosity to prevent or manage the shrinkage of reconstituted rice kernel or extrudates. Once an extrudates was too viscous, there will also rapid shrinkage or collapse after expansion due to low internal pressure in the unbroken bubbles or low viscosity that gives little apparent expansion on cooling. “Globular proteins even if smaller than starch polymers in a melted fluid they linked together to form larger structures as they flow through a die channel. They aggregate and form higher viscosity complexes, which serve to form crude films and retain some of the expanding water vapor. Their viscosity on cooling is sufficient to prevent shrinkage. Thus, it may also use to form structures of extrudates at high concentrations”, [10].

### *3.2. Effect of Independent Variables on Reconstituting Rice and Adlai*

#### *3.2.1. Gelatinization Time*

The combination of rice variety with intermediate amylose content, without mixture of *adlai*, 25% mixture moisture content and 90°C gelatinization temperature has the lowest value of 33 minutes. While the combination of rice variety with intermediate amylose content, 1: 2 rice-*adlai* mixture, mixture moisture content of 30% and 80°C gelatinization temperature gives the highest value of 44 minutes gelatinization time. The gelatinization time increases as the rice-*adlai* mixture and mixture moisture content increases also by decreasing the gelatinization temperature shown in Figure 1.

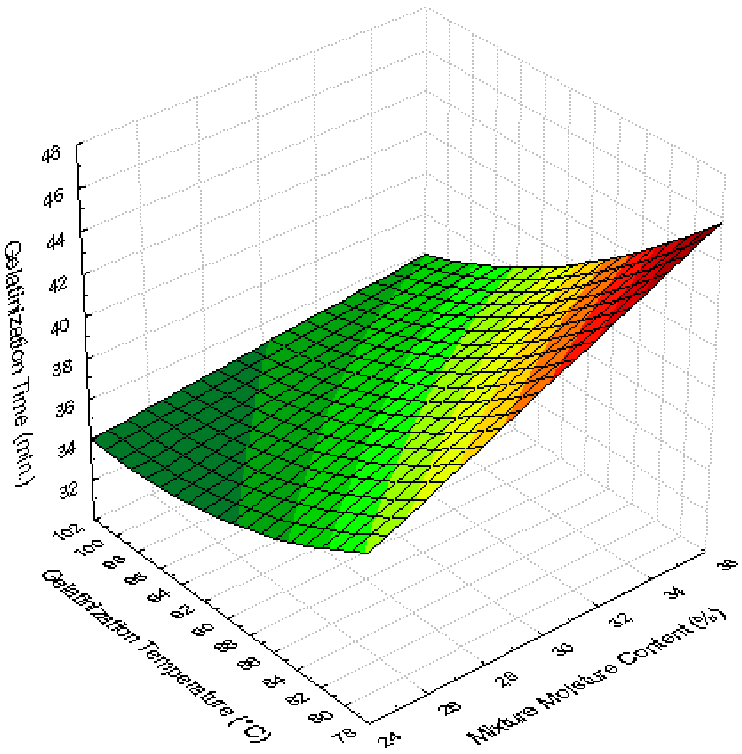


**Figure 1.** The interaction effect of gelatinization temperature and mixture moisture content on gelatinization time.

Analysis reveals that amylose content, rice-*adlai* mixture, moisture content and gelatinization temperature mainly affects the gelatinization time. Gelatinizing the mixture of rice and *adlai* granules takes more time for the reason that *adlai* contains enough proteins, and this protein plays a role in gelatinization of starch granule, which the main component are amylose and amylopectin, it must be heated to a desire temperature to absorb water in order to gelatinized. Water absorption causes the proteins to make new bonds and this will affects the gelatinization time. Also, the gelatinization temperature and moisture content are liable for starch granule to starts swell in hot water, accompanied by the loss of crystalline structure.

Response surface regression yielded the following equation for gelatinization time:

$$Gelatinization\ Time = 9.145\ X_2 + 3.347\ X_3 + 0.861\ X_2^{\ 2} + 0.0179\ X_4\ X_1 - 0.025\ X_4\ X_3$$

The model indicates that interaction among the independent variables influences the processing time significantly. The positive slope indicates that the gelatinization time increases with increases on the rice-*adlai* mixture and moisture content also by decreasing the gelatinization temperature. The higher a moisture content and having a lower temperature for processing makes a higher time for gelatinizing the mixture, thus makes the difference in gelatinization time.

### *3.2.2. Compression Force*

The interaction effect among the independent variables on compression force is shown in Figure 2. In which the combination of rice variety with low amylose content, 1: 2 rice-*adlai* mixture, moisture content of 30 % and gelatinization temperature of 90°C gives the highest value of 345 Newton. While the combination of rice variety with high amylose content, without mixture of *adlai*, moisture content of 30 % and gelatinization temperature of 90°C gives the lowest compression force of 226 Newton.

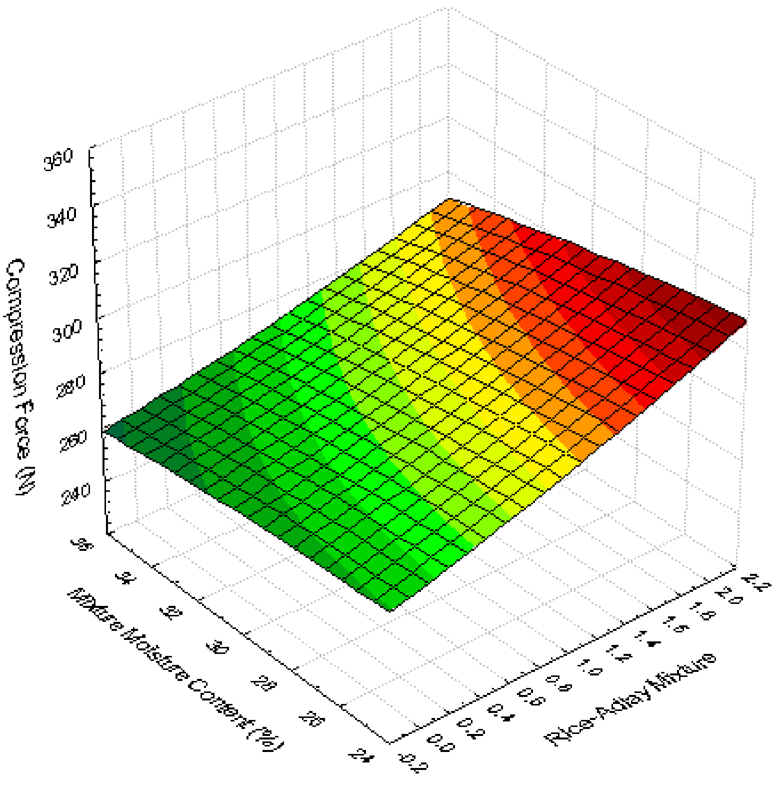


**Figure 2.** The interaction effect of mixture moisture content and rice-*adlai* mixture on compression force.

The amylose content, rice-*adlai* mixture and moisture content entails to the increase the compression force. Viscosity is the property of fluid which contributes more to affect this force. Since, these variables were directly related to gelatinize mixtures and these mixtures have no internal friction and they are able to withstand pressure. Thus, when external forces are applied they will easily flow. However this gelatinized mixture tends to develop internal pressure that resists flow. Therefore, it is because of the viscosity of the gelatinize mixture of rice and *adlai*, that is characterized by the starch composition, which influence the compression force.

Response surface regression yielded the following equation for compression force:

$$Compression\ Force = 1.1356 - 0.0336X_1 + 0.0002X_1^{\ 2} + 0.0002X_3X_1 + 0.0001X_4X_1$$

The model indicates that decreasing amylose content and rice-*adlai* mixture but increasing the mixture moisture content will increased the compression force.

### 3.3. Physicochemical Properties of the Rice-like Grain

#### 3.3.1. Moisture Content of the Extruded Rice-like Grains

Moisture content of the extruded rice-like grains is a physical property that has a direct implication for microbiological safety of food. It influences the storage stability of foods as some deteriorative processes in foods are mediated by water activity. Several factors that control water activity in a system was colligative effects of dissolved species like salt or sugar interact with water through dipole-dipole, ionic, and hydrogen bonds. Capillary effect because of changes in the hydrogen bonding between water molecules, where the vapor pressure of water above the curved liquid meniscus is less than that of pure water. Surface interaction in which water interacts directly with chemical groups on undissolved ingredients such as starches and proteins through dipole-dipole forces, ionic bonds, hydrophobic bonds, and hydrogen bonds. Combination of these three factors in a food product reduces the energy of the water.

As well as the gelatinization temperature changes moisture content during processing due to changes in water binding, dissociation of water, solubility of solutes in water, or the condition where glassy or rubbery state. Although solubility of solutes can be a controlling factor, usually from the conditions where glassy or rubbery state.

Analysis revealed that high moisture content of the mixture during processing will gives a higher moisture content of the rice-like grain. Combination of rice variety with low amylose content, rice-*adlai* ratio of 1: 1, moisture content of 35% and gelatinization temperature of 90°C gives the highest value of 19.79% of moisture content. While the combination of rice variety with intermediate amylose content, 1:1 rice-*adlai* mixture, 25% moisture content and 80 °C of gelatinization temperature gives the lowest moisture content of 17.32%.

#### 3.3.2. Whiteness Index

Whiteness is a concern for the appearance of the reconstituted rice-like grains also a basis as an indicator for rice quality. Rice that is not attractive to the consumer will have a lower value in the market place. Thus, rice grains value increases by improving their whiteness index. The combination of low amylose content, without mixture of *adlai*, 30% mixture moisture content and gelatinization temperature of 90°C gives the highest value of 31 for whiteness index of the rice-like grains. Increasing the processing temperature causes overheating in material which induce changes on the color development due to the effects of the non-enzymatic browning by Maillard reactions. Sugar released during the boiling process that reacts with the amino acids of the grain, causing discoloration of rice-like grains. The *adlai* bran and husk pigments might also contribute to discoloration of rice-like grains, thus increasing the mixture of rice and *adlai* increases the discoloration of the rice-like grains. Also, moisture have a direct influence on the change of color during cooking but the most likely explanation is that the moisture affects the dissipation of heat. Water acts as a plasticizer on the starch-based material and reduces the viscosity of the melted fluid so that less heat is dissipated in the material. It influences the temperature profile of the material in the cooking zone, and thus some degree of change in the color.

#### 3.3.3. Bulk Density

It provides gross measure of particle size and dispersion which can affect material flow consistency and reflect packaging quantity. The bulk density of rice-like grains from different combination studied ranging from 0.57- 0.61 g-ml$^{-1}$. It was primarily influence by amylose content in the rice variety, and moisture content possibly due to the intrinsic characteristics of every variety. This finding is in line with the results presented for rough rice, [5]. Depending on the moisture content, the amount of impurities, and the degree of filling the bulk density can be changed. The higher the sphericity of the rice-like grains, the better was the arrangement of them together. Consequently, there would be smaller space between the rice-like grains which in turn results in a higher bulk density. Also densities are dependent on the amount of moisture they contains. Hence, rice-like grains contains rigid cell wall that allows a certain degree of porosity that confine moisture. This was attributed to an increase in mass due to moisture gain in the material was lower than the associated volumetric expansion of the bulk.

#### 3.3.4. Crude Protein

Milled rice protein content range from 6.3 - 7.1 % and the nutritional value of the grains will improve through increasing the protein content for about 2 percent, [9]. The crude protein present in the rice-like grains from different combination studied ranging from 6.46 – 9.74%. Combination of low amylose content, rice-*adlai* mixture of 1: 2, moisture content of 30% and gelatinization temperature of 90°C gives the highest value of 9.74 % of crude protein. While the combination of low amylose content of rice variety, rice-*adlai* mixture of 1: 0, moisture content of 30% and gelatinization temperature of 90°C gives the lowest value of 6.46 % of crude protein. The crude protein was affected mainly by amylose content of rice variety and gelatinization temperature. This is because of the differences in amino acid composition, particularly lysine, between proteins from various tissues of the different rice grain and *adlai* variety. The outer tissues of the rice grain are riches in albumin, in view of the fact that it is a water soluble protein, at high temperature it will coagulate and then broken down into a small fraction after processing therefore protein content of the rice-like grains was affected. Also, *adlai* was known with higher percentage of proteins fraction as a result the protein content in the rice-like grains will also be increased.

### *3.3.5. Gel Consistency*

Gel consistency measures the tendency of cooked rice. When gel consistency is hard the cooked rice tends to be less sticky and hard texture. The gel consistency of rice-like grains from different combination studied were from the span of 41 – 53 mm. The combination of low amylose content of rice variety, rice-*adlai* mixture of 1: 2, moisture content of 30% and gelatinization temperature of 90°C gives the highest value of 54 mm of gel consistency of the rice-like grains. While the combination of rice variety with high amylose content, rice-*adlai* mixture of 1: 0, moisture content of 30% and gelatinization temperature of 90°C gives the lowest value of 41 mm of gel consistency of the rice-like grains. Amylose content and rice-*adlai* mixture had larger influence on gel consistency of the rice-like grains, mainly because of starch composition of rice and *adlai*, particularly the amylose-amylopectin fraction that they contains, thus when the grains was cooked and after it gets cool, the cooked rice-like grains becomes hardened. It could relates that the higher value of amylose content improves the capacity of the starch granules to absorb water and expand in volume without collapsing, because of greater capacity of amylose to hydrogen-bond or to produce retrogradation. Granule with limited swelling would increase the rigidity of the amylose gel drastically, since the swollen granule was confined in the gel medium of the amylose that strengthened the gel structure.

### *3.3.6. Gel Viscosity*

The viscosity measurements of paste or gels made from milled rice starch have long been in use for evaluating cooked rice texture [13]. The combination of rice variety with low amylose content, rice-*adlai* mixture of 1: 2, moisture content of 30% and gelatinization temperature of 90°C gives the highest value of 1.32 Pa-s for gel viscosity of the rice-like grains. Next highest value of gel viscosity is 1.28 Pa-s, which are the combination of rice variety with intermediate amylose content, rice-*adlai* mixture of 1: 2, moisture content of 25 % and gelatinization temperature of 90°C. While the combination of rice variety with high amylose content, without mixture of *adlai*, 30 % moisture content and 90°C gelatinization temperature gives the lowest value of 0.7 Pa-s of gel viscosity of the rice-like grains. Rice-*adlai* mixture and amylose content are the main factor affecting the gel viscosity of the rice-like grains. It was also observed that the gel viscosity increases with increase in amylose content while decreasing rice-*adlai* mixture. This is mainly because of mixture composition, particularly the amylose-amylopectin fraction. The structure of amylose and amylopectin has been reported to play an important role in the pasting properties of starches, [13]. An increase in molecular weight of amylose and amylopectin has been reported to decrease the amount of long-branch chain length as well as branching degree of amylopectin, which resulted into an increase in viscosity.

Processing history also influence gel viscosity, as a material passes through an extruder. Thermal changed comprehend that interactions between the molecules which generally control the frequency of breaking and formation of hydrogen and other physicochemical bonds. Also, the shear effect determines whether the end of a bond that breaks meets a new end or will re-attached to its old counterpart.

## *3.4. Cooking Characteristics of the Rice-like Grains*

Cooking time for rice-like grains varied from 17.3 to 23.9 minutes. Amylose content and rice-*adlai* mixture has greatly influence the time of cooking for rice-like grains. Hence, amylose content determine the rice water ratio for cooking milled rice [13], in which amount of water determines the cooking time. The dissimilarity in the texture and area of rice analog cause by drying, in which rate of water diffusion through the cooked layer toward the boundary of the uncooked interior become limited, thus, affecting the cooking time. Also, because of protein hydrophobic nature, it directly affects by acting as a barrier to inward movement of water diffusion into the rice-like grains thus the addition of *adlai* contributes to the increase of protein content on the rice-like grains and increasing the cooking time.

Since amylose content determines the rice-water ratio for cooking milled rice [13]. Water absorption and volume expansion of the rice-like grains obviously will be affected by amylose content, rice-*adlai* mixture, and mixture moisture content. The difference in water absorption and volume expansion was attributed to the differences in viscosity pattern and weak internal organization within the starch granules.

## *3.5. Sensory Evaluation for the Cooked Rice-like Grains*

Actual sensory evaluation of the cooked rice-like grains by trained panelists was conducted to determine the quality characteristics of the product in terms of flavor (aroma and taste), texture (cohesiveness and tenderness) and general acceptability using a hedonic scale. Almost all of the scores in all quality attributes and acceptability of cooked rice-like grains was in a range of acceptable value.

The aroma and taste of the cooked rice-like grains increases as the rice-*adlai* mixture increase. Mainly because of the concentration at which larger ratio of *adlai* than rice, the aroma and taste of the cooked rice-like grains is dominated by *adlai*. This is due to the large amount of protein molecules present in *adlai* thus when distorted during processing they were more susceptible to oxidation breakdown and therefore, causing the changes in aroma and taste of the cooked rice-like grains. The cohesiveness of the cooked rice-like grains decreases as the amylose content and rice-*adlai* mixture decreased. Addition of *adlai* contributes to the decrease in amylose content and increase in amylopectin. While the tenderness of the cooked rice-like grains increases as the moisture content increased but decreases as amylose content and rice-*adlai* mixture decreased. Since cohesiveness and tenderness is determined by the rice-water ratio evidently, it will be directly affected by moisture content. Also, it was determined largely by its starch composition, which is the main component are amylose and amylopectin [13]. Thus, cohesiveness and tenderness of cooked rice-like grains has been attributed primarily to the presence of abundant long chains in the amylopectin leads to strong and resilient starch granules that resisted swelling and breakdown, whereas their absence lead to weak and fragile granules that broke down easily during cooking.

### *3.6. Optimization*

Optimization involved determining an optimum combination of rice variety in terms of amylose content, rice-*adlai* mixture, moisture content and gelatinization temperature that will give the best potential combination for reconstituting rice and *adlai*. The results derived from canonical analysis, stationary point were not all located inside the experimental value and some were saddle point. This indicates that it could not be applicable to determine the optimum combination for analytical technique. Therefore, available literatures, preliminary results, observation and engineering judgment served as the basis for setting of acceptable boundaries or target point for each response in the absence of standards for the selection of the acceptable optimum combination for reconstituting the rice and *adlai*.

Optimum points established 49 solutions, but only several points was chosen as optimum points, on condition that it satisfied the criteria mentioned. In addition, it would be more efficient to operate at this point considering that all these combination have almost the same mixture of rice and *adlai*. Then, the moisture content and gelatinization temperature was much reasonable and acceptable level wherein nutrients like the protein content, vitamins and mineral of the samples mixture will not be degraded during processing at this phase. It is necessary in order that it can be recommended for the future studies. The optimum values obtained were rice variety with intermediate amylose content, 1: 0.9 rice-*adlai* mixture, 30% mixture moisture content and gelatinization temperature of 91$^{o}$C.

Verification test was performed employing the method used in experiment by compression test and also using an extruder machine to validate the adequacy generated from the optimum combinations. Table 1 presents the comparison of predicted and experimental values at optimum combination. Verification showed that about 3% difference of gelatinization time was observed for predicted and experimental values. Approximately 7% difference of gelatinization time for compression test could be minimized for extrusion process. While for compression force 19.6% difference at compression test could be attributed for extrusion process. However, verification showed that predicted, experimental and actual values were reasonably close for moisture content, cooking quality and physicochemical properties except for whiteness index that has 16% difference for compression test that could be attributed for extrusion process.

**Table 1**. Predicted and experimental value of the response variables at optimum combination: rice variety with intermediate amylose content, 1:0.9 rice-*adlai* mixture, 30% moisture content and 91$^{o}$C gelatinization temperature.

| RESPONSE VARIABLES | PREDICTED VALUE | EXPERIMENTAL VALUES | | % DIFFERENCE | | |
|---|---|---|---|---|---|---|
| | | Compression | Extrusion | Predicted and Compression | Predicted and Extrusion | Compression and Extrusion |
| Gelatinization Time, *min.* | 36.54 | 37.67 | 35.00 | 3.08 | 4.22 | 7.08 |
| Compression Force, *N* | 264.44 | 283.00 | 338.46 | 7.02 | 28.00 | 19.60 |
| Physicochemical Properties: | | | | | | |
| Moisture Content, *%* | 19.46 | 19.18 | 19.06 | 1.45 | 2.07 | 0.63 |
| Whiteness | 24.73 | 25.00 | 29.00 | 1.10 | 17.28 | 16.00 |
| Bulk Density, *g/ml* | 0.607 | 0.604 | 0.591 | 0.52 | 2.71 | 2.20 |
| Amylose Content, *%* | 11.84 | 10.57 | 10.95 | 10.72 | 7.52 | 3.58 |
| Crude Protein, *%* | 8.52 | 8.49 | 8.79 | 0.34 | 3.14 | 3.50 |
| Gel Consistency, *mm* | 48.44 | 49.00 | 50.15 | 1.15 | 3.52 | 2.35 |
| Gel Viscosity, *Pa-s* | 0.96 | 0.93 | 0.97 | 3.28 | 0.88 | 4.30 |
| Cooking Quality: | | | | | | |
| Cooking Time, *min.* | 19.57 | 20.36 | 19.92 | 4.05 | 1.80 | 2.16 |
| Water Absorption, *g* | 134.11 | 133.00 | 131.50 | 0.83 | 1.95 | 1.13 |
| Volume Expansion, *mm* | 9.40 | 9.25 | 9.00 | 1.58 | 4.24 | 2.70 |

## 4. CONCLUSION

The studies conducted develop a rice-like grains by reconstituting broken rice and *adlai*. Determine the optimum operating parameter that was controlled and modeled addressing the concepts of control stability and design choices for preparation of rice-like grains which are the rice variety in terms of amylose content, rice-*adlai* mixture, moisture content of the mixture and gelatinization temperature. Also, establish the optimum combination of the different reconstitution parameters. The optimum values obtained were rice variety with intermediate amylose content, rice-*adlai* mixture of 1: 0.9, mixture moisture content of 30 % and 91$^{o}$C gelatinization temperature. Verification test showed that predicted, experimental and actual values were reasonably close. Thus, the percentage difference on the responses for compression test could be attributed for extrusion test such as gelatinization time 7%, compression force 20%, and moisture content 0.6%. Physicochemical and cooking properties of these rice-like grains can also be modified by alteration of the different reconstitution parameters.

## 5. ACKNOWLEDGEMENT

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