Optimization of the sensory qualities of extruded crunchies using mixture design

E L Pinili, R J A Tabinas, J R Besas, L T Esprela*

Food Technology Department, Davao del Norte State College, Davao del Norte, Panabo City, Philippines 8105

*Corresponding author: leizelesprela@dnsc.edu.ph

Abstract. The study aimed to optimize the sensory qualities of extruded crunchies using banana flour, cassava starch, and all-purpose flour as the main raw materials. Mixture statistical design was used to determine the optimum formulation of crunchies. Sensory acceptability in terms of color, taste, crunchiness, and general acceptability were evaluated. Results showed that the sensory qualities of crunchies were significantly affected by the level of banana flour, cassava starch, and all-purpose flour. Among the treatments, formulation of crunchies with 100% all-purpose flour, formulation with 50% banana flour & 50% all-purpose flour, and the mixture with 66.67% all-purpose flour, 16.67% banana flour & 16.67% cassava starch were considered as the optimum mixtures. It is recommended to use considerable amount of all-purpose flour with banana flour and cassava starch in the production of extruded crunchies.

1. Introduction
Crunchies is a local term for an expanded third generation snack. These third-generation snacks are also called semi or half products since after extrusion cooking, they are dried to a stable moisture content and then expanded by frying in hot oil, puffing in hot air or microwaving and infrared heating [1]. These snacks are nutrient-rich with long shelf life and high bulk density and can be transported long distances more cost-effectively [2]. Extruded snack manufacturers usually utilized tapioca, potato, mixed grains, and corn in the production of this third-generation snack [3].

In this research, one of the flours used as raw material is the banana flour. It is locally available and produced from unripe cavendish banana. As studied by Cahyana et al. unripe banana flour contains high amount of resistant starch (RS) [4]. This RS fraction of starch can be considered as a functional starch when added to food because of its prebiotic properties. This kind of starch is considered to have many health benefits such as improved insulin sensitivity, lower blood sugar levels, reduced appetite, and various benefits for digestion[5]. With all the health benefits of resistant starch in the unripe banana flour, the researcher considered to use the locally available banana flour together with the cassava starch and all-purpose flour in the production of crunchies.

Cassava is one of the root crops with growing food and industrial applications. Its starch is used in many food products. Cassava starch is a natural raw material that enhances the strength of noodles and can change the texture of noodles [3]. Kasemsuwan et al. used cassava starch as an extender in mung bean noodles [6]. Shachat et.al. prepared a puffed and crisp snack product containing cassava starch and other ingredients [7].
All-purpose flour is a white flour milled from wheats or a blend of hard and soft wheats. It gives the best results for many kinds of products, including some yeast breads, quick breads, cakes, cookies, pastries, and noodles [8]. It contains a large amount of starch and other components like proteins, lipids, etc., which affect its properties [9].

Knowing the benefits of banana flour and food applications of cassava starch and all-purpose flour, it is the intent of the researchers to use it as pure or blend mixture to come-up with a crunchies that have a most acceptable sensory qualities using mixture design. Mixture design is defined as a special type of response surface methodology in which the factors are the components of a mixture, and the response varies as the proportions vary which means that the response is affected by the variation of the proportions [10,11]. The application of the mixture design methodology to the optimization problems in the food industry is common because of the methodology’s ability to provide effective information from a small number of experiments and evaluate the interactions among variables [12].

2. Materials and Methods

2.1. Experimental design

Mixture statistical design was employed using the augmented simplex lattice design with an addition of overall centroid and blends which were half-way between the center point and each vertex (Figure 1).

![Figure 1. Mixture design of the formulation of crunchies](image)

The percentages of banana flour, cassava starch and all-purpose flour in the formulation of crunchies were obtained by taking mixtures at vertices (points 1, 2 and 3); at the midpoints of each axis (4,5 and 6); at the center point (10) and the midpoints from the central point to each vertex (7,8 and 9) (Table 1).
Table 1. Percentage of banana flour, cassava starch and all-purpose flour of crunchies.*

| Treatments | Banana flour (%) | Cassava starch (%) | All-purpose flour (%) |
|------------|------------------|--------------------|-----------------------|
| 1          | 100              | 0                  | 0                     |
| 2          | 0                | 100                | 0                     |
| 3          | 0                | 0                  | 100                   |
| 4          | 50               | 0                  | 50                    |
| 5          | 50               | 50                 | 0                     |
| 6          | 0                | 50                 | 50                    |
| 7          | 16.67            | 16.67              | 66.67                 |
| 8          | 66.67            | 16.67              | 16.67                 |
| 9          | 16.67            | 66.67              | 16.67                 |
| 10         | 33.33            | 33.33              | 33.33                 |

*All treatments contained 50% potable water, 5% sugar, 2.5% garlic powder, 2.5% onion powder

2.2. Crunchies preparation
Banana flour, cassava starch, all-purpose flour, sugar, garlic powder and onion powder were added with potable water and formed into dough using an electric mixer. The dough was placed in a clean tray and flattened using a spatula. Then, the dough was steamed for 30 minutes. It was sliced into cubes and extruded in the cold extruder. The extruded dough was cut at an estimated length of 5 cm and placed in an oven dryer at 65°C for approximately 8 hours in which the water activity ranged from 0.45-0.47. The dried pellets were allowed to cool before packing in a polyethylene bag. Prior to sensory evaluation, the pellets were deep-fried at 160°C for at least 5-10 seconds before served and analyzed.

2.3. Sensory evaluation
The sensory attributes considered for acceptability test were color, taste, and crunchiness including general acceptability. The untrained panelists were the students in the Food Technology department who had a background in sensory evaluation. They evaluated the acceptability of the product using 9-point hedonic scores. Each sample was coded with three-digit numbers and was presented in a randomized order in a sequential monadic way (one sample at a time) to each panelist. Water was provided between samples to cleanse the palate. Seventy-five panelists evaluated six samples out of the ten treatments as laid out in the Incomplete Block Design (IBD) arranged by Cochran and Cox [13]. The total number of acceptability scores for each treatment was forty-five.

2.4. Nutrition facts analysis
Nutrition facts of the most acceptable crunchies were analyzed at the Department of Science and Technology (DOST), Regional Standard Testing Laboratory Region XI.

2.5. Statistical analysis
The statistical significance of the variables, the pareto charts and ternary plots of the acceptability scores were analyzed using Statistica software version 13.5.

3. Results and Discussion
3.1. Sensory acceptability of crunchies
The product acceptability was evaluated in terms of its color, taste, crunchiness, and general acceptability.

3.1.1. Color acceptability. The color acceptability ratings ranged from 6.5 to 8 as shown in figure 2 which is described as “liked slightly” to “liked very much” categories of the 9-point hedonic scale. Figure 3 shows the linear and interaction effects of the main ingredients on the color acceptability of
crunchies. Among the main ingredients, all-purpose flour (APF) had the most significant impact on the color acceptability of crunchies. Figures 2, 4c and 4g showed that the formulations with more APF had higher acceptability scores. Also, it was shown in the pareto chart of standardized effect estimates that the interaction of cassava starch (CS) & APF, and the interaction of CS & banana flour (BF) had a significant negative effect on the color acceptability of crunchies. This simply means that when cassava is paired to both APF and BF, the color acceptability ratings were lower compared to the crunchies which contained pure APF, CS and BF. However, when the APF, CS and BF were mixed together, their interaction had a positive effect on the color acceptability of crunchies compared to the crunchies with only one main ingredient. Overall, the results implied that it is best to use a formulation with pure APF and a formulation with a mixture of APF, CS and BF to have a more acceptable color of crunchies.

Figure 2. Ternary plot of the color acceptability of crunchies

Figure 3. Pareto chart of the color acceptability of crunchies
Figure 4. Appearance of the different formulations of crunchies
3.1.2. Taste acceptability. The taste acceptability ratings ranged from 5 to 7 as shown in figure 5 and described as “neither like nor dislike” to “like moderately” categories of the 9-point hedonic scale. All three main ingredients had a significant positive linear effect on the taste acceptability of crunchies, but it was evident in figure 5 that the formulation with higher concentration of APF had a higher acceptability score. It was shown in the pareto chart (Figure 6) that all interactions were positive except the formulation with cassava starch and all-purpose flour which had a negative effect, which means that when they are combined, the taste acceptability of crunchies significantly decreased compared to the formulation with pure CS and pure APF. Additionally, it was shown in figure 6, that the formulation with a mixture of APF, CS and BF had a positive significant effect, which indicates that when these three main ingredients were combined, the taste of crunchies was more acceptable. Thus, for the taste of crunchies, it is better to use a combination of APF & BF and a formulation with a mixture of APF, CS and BF.

![Ternary plot of the taste acceptability of crunchies](image-url)
3.1.3. Crunchiness acceptability. Crunchiness is the textural attributes frequently associated with the freshness and firmness of natural produce and processed foods [14]. The crunchiness acceptability ratings of crunchies ranged from 4.25 to 8 as shown in figure 7, which is described as “dislike slightly” to “like very much” categories of the 9-point hedonic scale. In figure 8, the pareto chart showed that APF, BF and CS had a significant effect on the crunchiness acceptability of the product. However, the interaction of APF and CS was negative. The desirable crunchiness of the product was towards the combination of APF and BF. As observed, the formulations with more cassava starch were not crunchy because some portions of the crunchies were tough and difficult to eat (Figure 4b & 4h). The amylose of cassava starch provides surface and textural regularity, elasticity, and sticky characteristic [15].

Figure 6. Pareto chart of the taste acceptability of crunchies

Figure 7. Ternary plot of the crunchiness acceptability of crunchies
3.1.4. General acceptability. The general acceptability ratings of crunchies ranged from 5 to 8 as shown in figure 10, which is described as “neither like nor dislike” to “like very much” categories of the 9-point hedonic scale. In figure 11, the pareto chart showed that the positive linear effect of APF, BF and CS were all significant which means that when the level was increased, the general acceptability also increased but up to some extent only because when combined with other ingredients the general acceptability shifts towards more on the combination of APF and BF. Same with the crunchiness trend, an estimated 75% - 100% APF yields a general acceptability rating of 8 which means “like very much” in the 9-point hedonic scale.

As to the interaction of APF, BF and CS, the effect on the general acceptability was positive. The results suggest that it is better to mix these three main ingredients to yield a most acceptable crunchies than to use them 100% in the formulation. When only APF and CS were combined, the interaction had a negative effect which resulted to a lower acceptability rating. The results also showed that the combination of BF and CS had a lower general acceptability rating. As observed, the panelist rated the general acceptability of crunchies based on the color, taste and crunchiness of the product since it was clear on the results that all the sensory attributes’ acceptability including general acceptability had almost the same trend. Overall, the results suggest that the most acceptable formulation was the mixture of APF, BF and CS that had the higher concentration of APF.
Figure 9. Ternary plot of the general acceptability of crunchies

Figure 10. Pareto chart of the general acceptability of crunchies
3.2. Optimum region of crunchies

In determining the optimum region, the researchers superimposed the region of each sensory attributes that had an acceptability scores of $\geq 7$ (Figure 11). The treatments inside the optimum region were treatment 3 (100% APF), treatment 4 (50% APF; 50% BF) and treatment 7 (66.67% APF; 16.67% BF; 16.67% CS). Based on the superimposed ternary plots and mean acceptability scores presented in table 2, the best formulation was the mixture of 66.67% all-purpose flour, 16.67% banana flour and 16.67% cassava starch (Figure 12). It was shown in the optimum region that the color and taste were the limiting factor for the optimum formulation which means that the color and taste acceptability are critical parameters on the panelists’ evaluation of the product and that is because as studied by Leon et al. food appearance determined mostly by surface color is the first sensation that the consumer perceives and uses as a tool to either accept or reject food [16]. The taste also is considered as critical determinant of food choice and preference [17].

![Figure 11. Superimposed ternary plots of sensory acceptability scores $\geq 7.00$](image1.png)

![Figure 12. Best formulation of crunchies](image2.png)

| Banana flour (%) | Cassava starch (%) | All-purpose flour (%) | Color | Taste | Crunchiness | General acceptability |
|------------------|-------------------|----------------------|-------|-------|-------------|---------------------|
| 0.00             | 0.00              | 100.00               | 8.00  | 7.68  | 7.91        | 7.79                |
| 50.00            | 0.00              | 50.00                | 7.09  | 7.21  | 7.20        | 7.21                |
| 16.67            | 16.67             | 66.67                | 8.04  | 7.88  | 8.23        | 8.12                |
The best formulation of crunchies contained carbohydrates, fats and protein which are main nutrients for the body to function [18]. Also, based on the percent daily values computation as shown in figure 13, the best formulation had a zero-percent sodium which is a better alternative to a high-sodium content snacks available in the market. As mentioned in the article, the World Health Organization (WHO) advocates dietary sodium reduction as a highly cost-effective measure to decrease blood pressure levels and reduce the risk of cardiovascular diseases [19].

Figure 13. Nutrition facts of the best formulation of crunchies

4. Conclusion
Banana flour, cassava starch, and all-purpose flour had a significant effect on the color, taste crunchiness and general acceptability of crunchies. The formulations inside the optimum region were treatment 3 (100% all-purpose flour), treatment 4 (50% all-purpose flour; 50% banana flour), and treatment 7 (66.67% all-purpose flour; 16.67% banana flour; 16.67% cassava starch). The best formulation was the mixture that contained the three main ingredients but with higher amount of all-purpose flour.

5. Recommendation
Verification and shelf-life study are recommended for this research. Also, there is a need to study further for the large-scale production since this was conducted on a laboratory scale only.

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