Original Research

Sensory Acceptability and Nutritional Content of Cereal Bars Formulated with Adlay (*Coix lacryma-jobi* L.) Grains

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Abstract

In the Philippines, an underutilized crop known as adlay has been found to contain valuable nutritive potential. Given Filipinos' usual diet of snacks and ready-to-eat food items, the study aimed to provide an alternative choice for healthy snacks by utilizing adlay in developing cereal bars with an improved nutritional profile. The study developed cereal bars using varying proportions of oats and adlay grains as follows: control (100:0), treatment 1 (75:25), treatment 2 (50:50), and treatment 3 (25:75). The cereal bars were then subjected to sensory evaluation to determine their acceptability using a nine-point hedonic scale with 67 adult respondents. The control and the most acceptable treatment then underwent proximate and mineral analyses (iron and calcium). The sensory data was analyzed using Kruskal-Wallis H-Test with rank analysis, whereas the proximate and mineral content data were analyzed using the student's t-test at $p<0.05$. Results showed no significant difference between the control and all the treatments regarding sensory characteristics, and treatment 1 got the highest rank among all treatments. Proximate and mineral analyses revealed that treatment 1 has significantly higher crude protein (11.25 ± 0.66%), crude fiber (10.79 ± 1.22%), crude fat (17.82 ± 1.10%), and calcium (1.08 ± 0%), than the control made of pure oats. The findings, therefore, suggest that adlay can be used as a value-added ingredient in making sensory-acceptable cereal bars with an improved nutritional profile.

Keywords— *adlay, cereal bars, minerals, proximate, sensory*

1 Introduction

The diet of Filipino adults in the general population aged 20 years and older was observed to have an overall poor quality. Using the Alternative Healthy Eating Index (AHEI), it was found by Angeles-Agdeppa et al. [1] that three major dietary patterns existed, which include (1) meat and sweetened beverages, (2) rice and fish, as well as (3) fruit, vegetables, and snacks. The risk factors in the development of non-communicable diseases (NCDs) include food intake and nutritional status, with an emphasis on diet (dietary quality). Increased salt, saturated, and trans-fat intake is coupled with low consumption of fruits and vegetables, combined with sedentary physical activity and a stressful environment [2]. The poor quality of diet, as characterized above, can be caused by several factors, ranging from increased cost, poor access and availability, contamination of pesticides, a lack of knowledge regarding the benefits, and the unavailability of time, which is highly evident in working adults [3].

In a study conducted by Angeles-Agdeppa et al. [4], it was found that among young adults aged 19-49 years old and >50 years old, there is a high prevalence of inadequate intakes of iron, vitamin C, calcium, folate, riboflavin, thiamine, and vitamin A, respectively. Likewise, based on the mean intakes of the respondents, it was determined that females have a greater risk of inadequate intake of thiamine, niacin, vitamin A, vitamin B6, vitamin B12, folate, iron, calcium, and phosphorus. In contrast, males have an increased risk of vitamin C and zinc inadequacy. Meanwhile, Filipino working adults also have a high nutrient inadequacy for iron, folate, riboflavin, calcium, vitamin C, and thiamin. In totality, this study concluded that there is a sub-optimal intake in Filipino working adults, which might contribute to the triple burden of malnutrition.

There is also a huge volume in the pattern of Filipino food consumption going to cereals, followed by meat and fish consumption [5]. Similarly, based on the 8th National Nutrition Survey conducted by the DOST-FNRI [6], both cereal and cereal products make up much of the diet across all age and population groups, and these products contributed significantly to the energy, carbohydrate, protein, iron, thiamin, niacin, and riboflavin intake. With this, aside from consumption as a meal, cereals and cereal products can be incorporated into snacking. While Filipinos view snacking as a source of nutrition and prefer snacks with health and nutrition benefits, according to the Nielsen Global Survey of Snacking [7], this shift may be a tool to satisfy cravings and offer substantial health and nutrition benefits through snacking.

Correspondingly, people in developing countries are used to consuming rice and secondary food crops such as maize, cassava, and potato. Hence, there is a need for agricultural diversification by exploring other crops, one of which is the use of adlay (*Coix lacryma-jobi* L.) [8]. In the Philippines, adlay is known to be an underutilized cereal crop [9]. The endeavors of the Department of Agriculture (DA) aided in the increasing familiarity with the crop, which is promoted as a staple crop. In this case, the gulian variety is used since it is known as the most cultivated variety due to its increased yield, good eating quality, and larger grain size [10].

Given the poor diets and changing food habits of adults, one of the solutions that can be provided is the development and formulation of cereal bars which contain a wide variety of ingredients that provide energy, protein, fats, and carbohydrates. The combination of cereals, nuts, dried fruits, flavorings, and binders make up the base ingredients of each cereal bar [11]. Cereal bars are designed to deliver a quick energy boost while satisfying hunger demands, making them ideal for the working and busy adult population.

This study was conducted to optimize the varying proportions of adlay (*Coix lacryma-jobi* L.) and oats (*Avena sativa*) as the main constituent in the development of nutritionally improved cereal bars as a snack, combined with fixed amounts of other nutrient-dense ingredients. This study assessed the sensory characteristics and estimated the products' proximate composition, mineral content (iron and calcium), and energy content. The study can widen the selection of consumers regarding ingredients for cereal bars and provide various uses of adlay for food production and

processing. The study hoped to address the increasing demands for convenience and ready-to-eat food items with improved nutritional value, especially among adult professionals, and address undernutrition and micronutrient deficiencies among various populations, regardless of age, sex, and socio-economic status.

2 Methodology

2.1 Study Design

This study was divided into two parts. The first part included product development and sensory evaluation; the second was the proximate and mineral analyses. Primary data were obtained through research questionnaires and selected interviews with the untrained participants during the sensory evaluation to supplement their written responses. The research questionnaire used was based on published questionnaires in sensory evaluation and was modified to be appropriate for the product and target respondents. In terms of nutrient profiling, laboratory experiments were employed following established protocols.

2.2 Product Development

The adlay and oat grains, dried fruit, and nuts were procured from several online stores. Most raw ingredients are purchased at one time to minimize and avoid compositional differences that may contribute to the product's quality. The recipe formulation used in the cereal bars has been adapted and modified from the published cookbook of Saulsbury [12]. Before the preparation of the treatments for sensory evaluation, a sample of the product is manufactured, and the ingredients are adjusted accordingly. Regarding pre-processing treatment, the adlay grains are cleaned and washed using water, soaked for approximately 30 minutes, and then roasted in a microwave oven for 10 minutes.

The raw ingredients used in the production of the various formulations of the cereal bars include (1) rolled oats, (2) Adlay grains (*gulian* variety), (3) quinoa flakes, (4) honey, (5) virgin coconut oil, (6) vanilla extract, (7) cinnamon, (8) iodized salt, (9) unsalted pumpkin seeds, (10) unsalted sunflower seeds, and (11) dried blueberries. These ingredients were also chosen following the reported expectations regarding the formulation of cereal bars, wherein fruit and enrichment with protein, fiber, vitamins, and minerals are included [13]. This study utilized various proportions of adlay and oats to produce sensory-acceptable cereal bars with improved nutritional content. Table 1 presents the various proportions of each ingredient in the control and the three treatments.

The general procedure in preparing the cereal bars included three major steps: 1) measuring and mixing all the dry and wet ingredients, 2) rolling the mixture into the desired shape, and 3) baking the mixture in a preheated oven at 150°C for 15 minutes. The general procedure was only modified according to the cereal bar treatment ratio (oats:adlay), namely: control (100:0), treatment 1 (75:25), treatment 2 (50:50), and treatment 3 (25:75). Furthermore, each cereal bar is individually wrapped, assigned with specific control codes, and packaged in a neutral-colored food bag and distributed to the selected respondents for sensory evaluation.

2.3 Study Participants and Sensory Evaluation

The respondents in this research were 67 untrained adults aged 19-55 residing in selected municipalities of Laguna, particularly San Pablo City and the Municipality of Los Baños. The inclusion criteria involved the following: (1) the respondent must be non-pregnant and non-lactating (for women); (2) a generally healthy adult not experiencing cough, cold, or even sore throat during the conduct of the sensory evaluation; and (3) must not have an allergic reaction towards cereals (oats), nuts, blueberries, or any of the raw ingredients used in the cereal bar. Informed consent was secured before the start of the sensory evaluation. Table 2 shows that the age of the respondents was

Table 1. List of ingredients and corresponding amounts of the control and three treatments

Ingredient	Control (100:0)	Treatment 1 (75:25)	Treatment 2 (50:50)	Treatment 3 (25:75)
Rolled oats	120 g	90 g	60 g	30 g
Adlay grains (*gulian* variety)	0 g	30 g	60 g	90 g
Quinoa flakes	100 g	100 g	100 g	100 g
Honey	170 g	170 g	170 g	170 g
Virgin coconut oil	45 g	45 g	45 g	45 g
Vanilla extract	5 mL	5 mL	5 mL	5 mL
Cinnamon	2 g	2 g	2 g	2 g
Iodized salt	2.5 g	2.5 g	2.5 g	2.5 g
Unsalted and shelled pumpkin seeds	60 g	60 g	60 g	60 g
Unsalted and shelled sunflower seeds	30 g	30 g	30 g	30 g
Dried blueberries	75 g	75 g	75 g	75 g

well-distributed across age ranges, with 26- to 35-year-old respondents being the majority (31.34%). Meanwhile, in terms of sex, most of the respondents were female (76.12%). Regarding the proper sensory evaluation, coded samples were individually packed and distributed to the respondents for sensory evaluation. Public health and food safety standards were strictly followed throughout the study. The respondents evaluated the various cereal bar treatments according to color, aroma, texture, flavor, gloss, and overall liking using a nine (9)-point hedonic scale. Rank analysis based on personal preferences and selected personal interviews were also done to augment the results of the hedonic scale evaluation. In rank analysis, a score of one (1) means the most preferred cereal bar, whereas a score of four (4) means the least preferred. Thus, the lower total score in the ranking test indicates that the cereal bar is more preferred by the respondents.

The content of the administered sensory evaluation questionnaire was limited to the socio-demographic information of the respondents, which included the name, age, gender, address, contact number, email address, and occupation, as well as the questions related to the evaluation of several sensory characteristics rated using a nine-point (9) hedonic scale. The respondents were also instructed to sip water for palate cleansing before evaluating the next product. Furthermore, the comments of the respondents derived from answering the questionnaires were also gathered to support the sensory evaluation results.

2.4 Proximate and Mineral Analyses

The control and the treatment with the most acceptable sensory characteristics were subjected to determining the proximate composition and mineral content, specifically iron and calcium. The samples were analyzed by an accredited and ISO-certified analytical service laboratory in Lipa City, Batangas. The analyses were done in triplicate following the standardized protocols of the AOAC [14]. The energy content of the cereal bars was computed based on the values derived from the

Table 2. Demographic profile of the respondents

	Frequency (%), n=67
Age, years	
18-25	9 (13.43)
26-35	21 (31.34)
36-45	19 (28.36)
46-55	14 (20.90)
No Response	4 (5.97)
Sex	
Male	13 (19.40)
Female	51 (76.12)
No Response	3 (4.48)

results of the proximate analysis, using the equation below [13]:

$$Energy(kcal) = [crude\ fat(g)] * [9kcal/g] + [crude\ protein(g)] * [4kcal/g] + [total\ carbohydrates(g)] * [4kcal/g] \quad (1)$$

2.5 Statistical Analysis

Frequency distribution was used to summarize the demographic information of the respondents. The median and range of responses on the different sensory characteristics for the control and three (3) cereal bar treatments were reported. This was done to reflect the more valid responses of the participants, with little to no influence of outliers or extreme values. Kruskal-Wallis H-Test was used to test the significant difference among the sensory characteristics (color, aroma, texture, flavor, gloss, and overall liking) of the various cereal bar products. Additionally, the cereal bar treatments that the respondents most and least preferred were determined using rank analysis. The rank analysis augmented/validated the results of the hedonic scale evaluation. It was also used to determine the rank 1 "treatment" that will be subjected to proximate and mineral analyses together with the control.

The results of the proximate and mineral analyses were summarized using the mean ± standard deviation (SD). The proximate and mineral content data were analyzed using the student's t-test to determine significant differences between the control and sample at $p<0.05$. All data were analyzed using SPSS version 26.

3 Results

3.1 Sensory Evaluation of the Cereal Bars

The sensory evaluation results of the cereal bars revealed that all the treatments were generally acceptable regardless of the sensory parameter, with median scores ranging from 8 to 7, indicating "like very much" and "like moderately," respectively. Kruskal-Wallis H-Test showed no significant difference in all the sensory characteristics (color, aroma, texture, flavor, and gloss) between the control and cereal bar treatments (Table 3).

As indicated by Meilgaard et al. [15], the sensory attributes are perceived in the following order:

Table 3. Sensory evaluation results for the cereal bar control and treatments

	Color	Aroma	Texture	Flavor	Gloss	Overall Liking
	Median (Range)					
Control	8 (9-3)	8 (9-4)	7 (9-3)	8 (9-3)	8 (9-2)	8 (9-4)
Treatment 1	7 (9-4)	8 (9-3)	7 (9-4)	8 (9-4)	8 (9-1)	7 (9-4)
Treatment 2	7 (9-3)	8 (9-5)	7 (9-3)	8 (9-4)	8 (9-1)	7 (9-5)
Treatment 3	7 (9-5)	8 (9-3)	7 (9-3)	7 (9-2)	8 (9-2)	7 (9-3)
p-value	*0.724*	*0.979*	*0.649*	*0.227*	*0.933*	*0.467*

Legend: 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

(1) appearance, (2) odor/aroma, (3) consistency and texture, and last is (4) flavor. The median score for the color of the control (100:0) is eight (8), while the other cereal bar treatments have a median score of seven (7). In terms of aroma, all the cereal bars obtained a median score of eight (8), and some of the respondents stated that the cereal products were aromatic and had a fruity, sweet, and nutty aroma. Meanwhile, some of the respondents' comments regarding the aroma include a sugary aroma and smells similar to herbs or cinnamon. On the other hand, the control and all three cereal bar treatments obtained a median score of seven (7) in terms of their texture, which is the lowest median score among all sensory characteristic parameters. This relatively lower median score in the texture may be associated with the characteristic of adlay grains having a soft and slightly chewy texture when cooked. This was aligned with the qualitative remarks of some respondents, who stated that a cereal bar must be firmer and more compact. Nonetheless, the median score for the texture of cereal bar treatments was still acceptable (7 - liked moderately).

Regarding the flavor, the control and treatments 1 and 2 have a median score of eight (8), while treatment 3 has a median score of seven (7). The flavor of the cereal bars, as described by the respondents, was tasty and comparable to commercially available cereal bars. The respondents also observed that the fruit and nut components contributed mostly to the overall flavor, suggesting that adlay did not impart any significant taste that could alter cereal bars' distinct and balanced flavor profile. Lastly, the median score in terms of the product gloss was eight (8) or liked very much among all the cereal bar formulations. Despite the addition of adlay in the formulation, this high score indicates an appealing glossy appearance of the developed products, one of the aspects being evaluated in cereal bars [16] and an ideal factor in cereal bars with high commercial impact and desired characteristics [17].

Aside from the sensory characteristics and their parameters, the overall liking of the respondents was also assessed using the 9-point hedonic scale. Table 3 also shows the overall liking presented in the median score and range. This table shows that the control obtained a median score of 8 (like very much), while treatments 1, 2, and 3 obtained a median score of 7 (like moderately). Very few respondents give low scores of 4 (dislike slightly) and 3 (dislike moderately), which accounts for only 1.70% of the respondents. According to the respondents, they based their ratings on their overall liking regarding palatability, texture, similarities with the commercially available cereal bars on the market, and compactness, among other criteria. Furthermore, no significant differences were found in all the sensory parameters, namely color, aroma, texture, flavor, gloss, and overall liking of respondents between the control and three (3) cereal bar treatments.

Furthermore, the rank analysis conducted showed that the treatment with the greatest to least ranking in terms of consumer preference was as follows: control, treatment 1, treatment 2, and treatment 3 (Table 4). The control and the treatment with the highest rank in terms of consumer preference were the ones subjected to proximate and mineral analyses.

Table 4. Overall liking of the four cereal bar treatment varieties

	1	2	3	4	Score	Rank
	Frequency					
Control	18	14	14	7	116	1
Treatment 1	14	12	18	9	128	2
Treatment 2	11	12	10	19	141	3
Treatment 3	9	11	16	16	143	4

Legend: 1 - most preferred; 4 - least preferred

3.2 Proximate and Mineral Analysis

Table 5 shows the proximate analysis of the control (100:0) and treatment 1 (75:25) and the test of the difference between the treatments with several parameters. Results revealed that the treatment one cereal bar has 0.91% more moisture, 1.12% more crude protein, 6.87% more crude fiber, and 12.78% more crude fat. In contrast, the control cereal bar contains 0.11% more ash and 21.56% more nitrogen-free extract.

Table 5. Rank Analysis of the four cereal bar formulations (n=53)

	Control (100 oats:0 adlay)	Treatment 1 (75 oats:25 adlay)
	Mean ± SD	
Moisture, %	16.33 ± 0.50	17.24 ± 1.05
Ash, %	1.85 ± 0.05	1.74 ± 0.12
Crude Protein, %	10.14 ± 0.60	11.25 ± 0.66*
Crude Fiber, %	3.92 ± 1.83	10.79 ± 1.22*
Crude Fat, %	5.04 ± 0.69	17.82 ± 1.10*
Nitrogen Free Extract, %$^{+}$	62.72	41.16
Energy, kcal per 100g^	336.8	370.02

*significantly different at $p<0.05$

$^{+}$computed by difference

^calculated based on carbohydrates, protein, and fat content

Moisture

Based on the Philippine Food Composition Tables [18], the water (g) content of the adlay and oat grains per 100-gram edible portion is 10.2 g and 4.2 g, respectively. The higher water content of adlay per gram basis could have contributed to the higher moisture (%) content of treatment one than the control. The moisture content of the various adlay nutrimeals, specifically cookies, yielded a total moisture content of 5.88%, having adlay flour as the main constituent, along with refined sugar, butter, eggs, vanilla, powdered milk, and baking powder [19]. The assessment of water activity is a more reliable measure of long shelf-life, and there is a direct proportional relationship between water activity and moisture content.

Moreover, adding adlay grains might have increased water absorption into the endosperm due to the gelatinization process, causing swelling [20, 21]. Anchored upon the respondents' comments, the cereal bars' various treatments have a soft, moist, and chewy texture, and such food items with the said sensory characteristics have a high water activity (Aw). With this, Blandino et al. [22] recommend lowering water activity (Aw) to maintain the crispness of the cereal bar. Cereal bars are generally formulated to have moisture between 10 and 15% (w/w) and Aw value less than 0.65 [23].

Ash

For a 100-gram edible portion of adlay and oats, the total ash content (g) was 0.9 g and 1.5 g, respectively [18]. For ash content, treatment 1 has a relatively lower value for ash content (%) as compared to the control. The ash content of food is an important aspect of its nutritional quality since increased ash content in a food sample would generally mean an increase in its mineral content. In related literature, various food products that utilized adlay, namely cookies, geelay (arroz caldo), champorado, chocolate cake, and ice cream, had a minimum and maximum range of percent ash equivalent to 0.27% - 2.8% [19].

Crude Protein

Regarding crude protein content, treatment 1 obtained a significantly higher value equal to 11.25% compared to the control, which is equal to 10.14%. This can be attributed to the higher protein content of adlay (13.1g per 100g) than oats (11.4g per 100g), as reported in the Philippine Food Composition Table (PhilFCT) [18]. Kutschera & Krasaekoopt [24] also reported an increase in protein content upon the substitution of adlay flour in making butter cakes from 6.9% to 10.9%, which is found to be significantly different.

Crude Fiber

In terms of the crude fiber content of the cereal bars, treatment 1 has significantly higher crude fiber content at 10.79% than the control with a value equivalent to 3.92%. This can also be attributed to the total dietary fiber content of adlay and cooked oats per 100-gram edible portion, which is at 9.0 g and 1.4 g, respectively [18]. It was evident that adding adlay grains significantly increased the crude fiber content almost three-fold that of the control. It was previously reported that adding adlay as the main ingredient in cereal bars [20] and butter cakes [24] resulted in a product with a relatively higher crude fiber content than the control counterpart. The recommended dietary fiber for Filipino adults 19 – 59 years of age is 20 – 25 grams per day [25]. Still, regarding gram fiber per calorie, Dahl & Stewart [26] indicated that the adequate intake for fiber is 14 grams per 1000 kcal intake. The significant contribution of adlay in increasing the fiber content of cereal bars can help achieve the required fiber intake among Filipinos.

Crude Fat

Based on the proximate results in Table 5, the crude fat content of the control and treatment 1 is 5.04% and 17.82%, respectively. The significantly higher fat content of treatment 1 might be

due to more than twice the fat content of adlay (2.5g per 100g) than cooked oats (1.1 g per 100g) based on the PhilFCT [18]. Given the plant-based nature of adlay, the higher fat content of cereal bars substituted with a portion of adlay would be beneficial in meeting the needs for the essential fatty acids in typical diets. It was found that adlay contains 50% of oleic acid, 28% of linoleic acid, and 14% palmitic acid [27]. Essential fatty acids, especially monounsaturated fatty acids (MUFA), have been reported to increase levels of HDL-cholesterol with a decrease in triacylglycerols, reduce systolic and diastolic blood pressure, and lower glycosylated hemoglobin among patients with type II diabetes mellitus [28]. On the other hand, the higher crude fat content of treatment 1 may be attributed to the uneven distribution of other raw ingredients that may contribute to the increased fat content, which includes virgin coconut oil and sunflower seeds.

Nitrogen-free Extract

Nitrogen-free extract (NFE) is derived from combining ash, moisture, crude fiber, and crude protein subtracted from 100 [13, 20]. The percent NFE reflects the amount of carbohydrates in food. The lower NFE content of treatment 1, compared with the control, may be associated with higher levels of crude protein, fiber, and fat. With regards to the amounts of carbohydrates reported in the PhilFCT, adlay, and oats have relatively comparable amounts at 73.3g and 73.8g per 100g edible portion, respectively [18].

Energy

The energy (kcal) for the control and treatment 1 was calculated using the values obtained from the proximate analysis. Based on the values calculated, treatment 1 has a greater energy content of 370.02 kcal than the control, which has a total energy value of 336.8 kcal. Adding the adlay grains increased the energy content of the cereal bars per gram basis, which may be associated with its higher crude fat and crude protein percentages.

Table 6 presents the result of the mineral analysis of both the control and treatment 1, specifically in terms of iron and calcium contents. The iron content of the control was higher than treatment 1, but treatment 1, even at a low proportion of 25% adlay to oats ratio, obtained a calcium content of approximately 40% more than the control. Aside from iron and calcium, adlay grains also contain essential nutrients such as phosphorus, vitamin B1, vitamin B2, and vitamin B3, along with various types of fatty acids [18].

Table 6. Proximate Analysis result between the Control (100:0) and Treatment 1 (75:25) cereal bar treatment variety per parameter

	Control (100 oats:0 adlay)	Treatment 1 (75 oats:25 adlay)
	Mean ± SD	
Iron (Fe), mg/kg	66.68 ± 1.59	62.02 ± 1.92*
Calcium, %	0.68 ± 0	1.08 ± 0*

*significantly different at $p<0.05$

The study computed the estimated percent contribution of the cereal bars to the nutrient needs of Filipino adults, specifically carbohydrates, protein, fat, fiber, iron, and calcium [25], upon consumption of a serving size of the cereal bar (Table 7). The carbohydrate and fat percent contributions were calculated using the acceptable macronutrient distribution range (AMDR), and RNI was used for protein, fiber, iron, and calcium. Without considering the rate of bioavailability, one serving of

the control cereal bar (35g) can provide more carbohydrates compared to treatment 1, wherein the range of percent contribution is from 5.59-7.91%, while treatment 1 only provides 3.67-5.19%. On the other hand, the cereal bars from treatment 1 obtained a greater percent contribution for protein, fat, fiber, and iron. For protein, the percent contribution of the control treatment across all ages for males ranges is 5.00% for males and 5.72% for females, while treatment 1 provides approximately 5.55% for males and 6.35% for females. Meanwhile, in terms of fat, treatment 1 provides an approximately threefold increase in fat as compared to the control across all age groups. Similarly, the percent contribution of fiber in males and females across all ages of treatment 1 was also approximately three times higher (15.11%) than the control (5.49%).

Table 7. Percent Contribution of the 1 serving (35g) of Cereal Bars to the Nutrient Requirements of Filipino Adults

Nutrients^		19-29 years old		30-49 years old		50-59 years old	
		Male	Female	Male	Female	Male	Female
Carbohydrates (%)	C	5.59	7.62	5.87	7.91	5.87	7.91
	T1	3.67	5.00	3.85	5.19	3.85	5.19
Protein (%)	C	5.00	5.72	5.00	5.72	5.00	5.72
	T1	5.55	6.35	5.55	6.35	5.55	6.35
Fat (%)	C	2.36	3.21	2.48	3.34	2.48	3.34
	T1	8.33	11.37	8.76	11.80	8.76	11.80
Fiber (%)	C	5.49					
	T1	15.11					
Iron (%)	C	19.42	8.32	19.42	8.32	19.42	23.3
	T1	18.09	7.75	18.09	7.75	18.09	21.7
Calcium (%)	C	31.73	31.73	31.73	31.73	31.73	29.75
	T1	50.4	50.4	50.4	50.4	50.4	47.25

**C – control (100:0) oats to adlay ratio; T1 – treatment 1 (75:25) oats to adlay ratio*

^nutrient requirements were based on the Philippine Dietary Reference Intakes [25]

Furthermore, consuming a 35-gram serving of treatment 1 can provide approximately 18.09% of the RNI for iron across adult male age groups and about 7.75% for females aged 19-49 years old (Table 7). In terms of calcium, the consumption of a 35-gram cereal bar of treatment 1 can provide approximately 378 mg of calcium which is 50.4% of the RNI for calcium among 19-59-year-old males and 19-49-year-old females. For females 50-59 years of age, treatment 1 can contribute a slightly lower percentage to the RNI for calcium at 47.25% due to the increased need for calcium of females in this age group [25].

4 Discussion

This study investigated the various proportions of adlay and oats in making sensory-acceptable cereal bars with improved nutrition profiles. With this, several parameters were presented, including sensory evaluation, proximate and mineral analyses, and the percent contribution of the cereal bars to the RNI of Filipino adults. Based on the sensory evaluation using several parameters, namely color, aroma, texture, flavor, gloss, and overall liking, it was found that there was no significant

difference in all sensory parameters between the control and treatments 1, 2, and 3. Hence, all the cereal bar treatments have high sensory acceptability at par with cereal bars made usually from pure oats. Median scores from all the sensory parameters ranged from 8 to 7, indicating that the respondents either liked or liked very much the cereal bars. Additionally, the control and treatment 1 were subjected to proximate and mineral analyses to determine the changes in the macronutrient, iron, and calcium content of the cereal bar upon partial substitution of oats with adlay grains.

Moreover, statistical analyses showed significant differences between the control and treatment 1 in terms of crude protein, crude fiber, crude fat, calcium, and iron content. The proximate and mineral analysis revealed that the control had relatively greater ash and nitrogen-free extract content, while treatment 1 contained significantly higher crude protein, fiber, and fat. Additionally, the study also computed the percent contribution of consumption of cereal bars in the nutrient needs in terms of carbohydrates, protein, fat, fiber, iron, and calcium in males and females across the age range of adults.

Whole grains, like adlay and oats, are significant sources of carbohydrates in many dietary patterns [29]. Carbohydrates play a role in the Filipino diet. In fact, rice is the country's most consumed commodity, making it the predominant energy source among working adults as concluded by Angeles-Agdeppa & Custodio [30]. In the same study, some of the energy sources in the typical Filipino working adult diet, along with rice, include pork, fats & oils, chicken, as well as bread. Furthermore, there is inadequate consumption of nutrient-dense food items, making energy and nutrient intake sub-optimal.

The Philippines is home to abundant species of fruits, vegetables, and grains that can be considered native to the country. Most of these crops are still underutilized, despite their potential to alleviate the nutritional problems in the country–one of which is adlay (*Coix lacryma-jobi* L.). In general, people prefer other grains over adlay due to several reasons. Compared to rice, it is a staple food in many countries that has been consumed for generations, leading to a strong cultural preference [31]. Furthermore, as indicated by Park et al. [32], rice is more extensively available and accessible than adlay, which is known to be an underutilized crop in the Philippines.

However, compared to rice, adlay is a crop that can survive in strong rainfall and dry spells [33]. This crop is typically characterized as an herb that can grow up to three feet, a freely branching upright herb that uses seeds to propagate. Some advantages of seed propagation include increased grain yield, better tolerance to drought, and deeper rooting [34].

Generally, the adlay seed kernels are wide or have an oblong shape with their surface described as milky white and smooth. Adlay seed kernels can also have a yellowish-brown seed coat. In various food products such as salads and soups, the adlay grain contributes to the creamy, chewy, and sweet flavor [35]. Its tear-like shape grain ranges from white to brown [36]. The flavor of adlay grains is described as mild, making it a suitable addition to food products [37].

Given the sensory qualities of adlay, several studies have investigated the properties of adlay in terms of nutrition and physicochemical properties and showed that it could be a suitable primary constituent in product development with improved nutritional content [38]. With this, numerous pieces of literature explored the potentials of adlay in various food formulations, from milk drinks [39], tea [40], nutrimeals like adlay-veggie meals [41] and cookies, porridge, and cakes [19], pasta [42], breakfast cereals [21], biscuits and flakes [43], rice blends [13], among others. These studies have generally shown positive sensory characteristics towards adlay and the food products developed from it.

In terms of the improved nutrition profile of products supplemented with adlay, the composite of adlay-veggie nutrimeal from the study of Imperial [41] found that the utilization of adlay increased the carbohydrate and other essential nutrients which increased the overall nutritional value of the food item. Meanwhile, gluten-free pasta made from adlay contains increased amounts of energy (kcal), along with protein and dietary fiber – compared to both commercial pasta and non-gluten

pasta [42]. The proximate analysis also revealed that it contains approximately 2.70% ash content. The high ash content of the product is from the high mineral content of the adlay flour used, which contains magnesium, calcium, and phosphorus, along with traces of iron. Moreover, Laciste [20] reported that using adlay in making breakfast cereal snacks increased protein and fiber content. Lastly, other food items such as butter cakes with adlay flour increased fiber and protein content, equivalent to 10.9% and 0.89%, compared to butter cakes made from cake flour [24].

Aside from improving the nutrient content of food products, adlay is also known to have several health benefits. As specified by Chung et al. [44], adlay grains are utilized in Asia as a traditional treatment for conditions ranging from warts, chapped skin, rheumatism, and neuralgia. Meanwhile, in mice models, seed extracts from adlay can improve metabolic dysfunction and alleviate nonalcoholic fatty liver disease [45]. Some levels of antioxidant activity were also detected in adlay by the study of Tensiska et al. [46] after using ethanol as a solvent. Tseng et al. [47] also found an improvement in insulin sensitivity and hepatic glucose metabolism, exhibiting antidiabetic effects in mice models. Furthermore, in a recent review article, adlay was reported to possess anti-tumor, antibacterial, anti-inflammatory, analgesic, blood sugar-lowering, and blood lipid-lowering properties [35]. Not only that, but epidemiological studies also show that diets incorporated with wholegrain cereal food items aid in reducing diet-related diseases, including cardiovascular diseases, diabetes, and obesity, among others [48].

Given that several studies already showed the potential of adlay in food product development with acceptable sensory qualities and improved nutrient density, the results of the present study provide an alternative use for adlay in healthy product development. In addition, cereal bars are known for their versatility. They can be used by adults, athletes, people on a specific diet, or even adults consuming irregular meals. Similarly, increased demands for nutrients may be met through cereal bars since they provide additional energy and nutrient benefits on top of their convenience [48]. This study also suggests that adlay can be considered an excellent raw material for cereal bars due to its good nutritional content and the potential health advantages given its higher essential fatty acid, crude protein, crude fiber, and calcium content than oats.

Adlay utilization for cereal bar development can also benefit both the supply and demand sides of the market. It can potentially promote the economic significance of adlay, leading to additional income for adlay farmers. Cereal and snack bars were also great food items for quick nutrition during emergencies [49, 50]. Given the popularity of cereal bars, the present study introduced an alternative way to improve cereal bar nutrient profile through the use of locally-available and nutrient-dense crop adlay. Additionally, adlay-supplemented products could be useful in addressing concerns about obesity and associated metabolic disorders given their high amounts of fiber and other essential nutrients.

5 Conclusion

The study has shown that the cereal bars made from varying proportions of adlay and oats were of acceptable sensory quality at par with the sensory acceptability of cereal bars made from pure oats. Even at a low concentration of 75 oats: 25 adlay formulations, there were already significant improvements in the nutrient profile of cereal bars with adlay compared to the control, particularly in crude protein, crude fiber, crude fat, and calcium. The findings suggest that using locally-available and underutilized crops such as adlay course serves as a value-added ingredient in making cereal bars with acceptable sensory characteristics and improved nutritional content. Given the nutritional benefits of adlay and its feasibility in cereal bar development, the study hopes to contribute to promoting the current health and economic utilization of adlay, which is beneficial for both adlay farmers and consumers.

Statements and Declarations

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This research receives no funding.

Conflicts of Interest

The authors declare no conflict of interest.

Ethical Considerations

Informed consents were secured from all the participants before the start of the sensory evaluation. The researchers ensured that the sensory evaluation had minimal to no risk to the participants by making sure that the cereal bars were manufactured under hygienic conditions and were safe for consumption. The researchers emphasized participants' voluntary involvement and their right to withdraw from the study at any point. In compliance with the Data Privacy Act of 2012 (Republic Act No. 10173), all information collected were treated with utmost confidentiality.

Data Availability

Data is available upon request from the authors.

Authors Contributions

Nia Allison C. Juliano: conceptualization of the study, procurement of materials, data collection, data processing and analysis, drafting of the final manuscript. **Paul Alteo A. Bagabaldo**: conceptualization of the study, data analysis, overall supervision, review and revisions to the final manuscript.

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