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An Integer Programming Approach for Optimizing Street Food Snack Nutrient Intake Among College Students

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Abstract: Nutrition plays a very important role in the performance of students in school. It is defined as the provision of the materials necessary (in the form of food) to support life. It has been shown that there is a positive effect to the cognitive (arithmetic reasoning, reading, digital span recall, and attention) performance of the students whenever students eat nutritious food in their late afternoon snacks. Hence it is important to pay attention to the snacks that they eat for them to excel in their different learning fields.

Students are often faced with difficulty in choosing the right, that is, nutritious food. Moreover, due to their limited snack allowance, most students prefer to eat street foods since they are considered to be more filling yet cheap. This study aims to provide a guide to college students for deciding which street food to snack on so that optimal nutrient is obtained from their snacks.

In this study, the top ten most popular street food snacks in Cagayan de Oro City were considered. Mathematical models for optimizing nutrient intake of college students were formulated and solved. Results of the study provide various snack menus for students to choose from so that the recommended nutrient intake is optimized given their limited budget.

Keywords: Nutrition, snack, street food, optimization, integer programming.

1 Introduction

Humans need a wide range of nutrients to lead a healthy and active life. Nutrients have many important roles; including giving energy, building new tissues and repairing cells and helping the body's processes and systems run smoothly. The required nutrients for different physiological groups can only be derived from a well balanced and healthy diet. Components of the diet must be properly chosen to provide all the nutrients to meet the human requirements in proper proportions for the different physiological activities.

The amount of each nutrient needed for an individual depends upon a person's age, gender, state of health, and level of activity. For example, adults need nutrients for maintenance of constant body weight and for ensuring proper body function. Infants and young children, on the other hand, grow rapidly and require more nutrients than adults (Cooper & Chifamba, 2009).

A healthy diet is a diet that includes the appropriate number of servings in the essential food groups. Studies show that many individuals do not have adequate diets (Adair & Popkin, 2005; Cooper & Chifamba, 2009; Savige, et al., 2007). This does not mean that these people are hungry, but it does mean that they are not getting enough of the important nutrients found in food to keep in good health.

Diet formulation is generally carried out by first defining the food items or groups of food items to be used in the diet and then calculating the nutrient composition. If nutrient quantities do not fulfill the desired nutritional requirements, food quantities are altered or food items are exchanged and the composition recalculated. This is repeated until required levels of all nutrients are reached and a suitable diet is obtained. This iterative procedure is cumbersome and slow and, if this process is manual, often leads to compromises in the composition of the final diets (Sklan and

Dariel, 1993).

Nutrients are the substances that enrich the body. They are used to build and repair tissues, regulate body processes and are converted to and used as energy. These nutrients can be obtained mostly from the foods we eat. The dietary requirement for a micronutrient is defined as an intake level which meets a specified criteria for adequacy, thereby minimizing risk of nutrient deficit or excess (Fenstrom et. al., 2001).

The status of adolescent health in the Philippines, that is, those belonging to 10-14 and 15-19 age groups, has been studied by Conaco, et al. in 2003. An examination of the nutritional status of adolescents revealed that those aged 7-14 suffered from moderate and severe malnutrition. Moreover, they found out that food consumption of teens did not meet the recommended daily requirement, and that iron deficiency is prevalent among the youth.

Snacks are portion of food oftentimes smaller than that of a regular meal that is generally eaten between meals. In Asian countries, 86%, 71%, and 10% of Filipino, Russian, and Chinese adolescents, respectively, consume at least one snack per day (Adair & Popkin, 2005). In the Philippines, snacks provide 18% of the daily energy intake of adolescents (Savige et al., 2007).

Street food is ready-to-eat food or drink sold in a street or other public place, such as a market or fair, by a vendor, often from a portable stall. While some street foods are regional, many are not, having spread beyond their region of origin. Most street foods are also classed as both finger food and fast food, and are cheaper on average than restaurant meals (Civitello, 2011). According to the Food and Agriculture Organization (FAO), 2.5 billion people eat street food every day.

In the Philippines, street food vendors are easy to find. They are just outside churches, schools, recreational parks, or

jeepney terminals. They are also found in kiosks, makeshift stalls, or food carts. In suburbs, you will see vendors with their bicycles or push carts almost everywhere. Students and working adults looking for inexpensive meal often consider street foods since they satisfy their hunger for just half-the price of a meal in any popular fast-food restaurant (Civitello, 2011).

The aim of this study is to provide a guide to college students so that they get optimal nutrient from the street food snacks they eat. This paper is divided into the following sections. Section 1 provides a brief introduction. Preliminaries are presented in section 2. Section 3 gives the mathematical model formulated for this study while results are presented and discussed in section 4. A brief conclusion is given in section 5.

2 Preliminaries

This study considers the top ten most popular street foods in Cagayan de Oro. These street foods and their selling price are listed in Table 1. In this study, only four nutrients are considered and these are energy, protein, calcium, and phosphorus. The nutritional values of these street foods are shown in Table 2. These values are based on a 100g per serving.

Street Food	Description	Selling Price (in PhP)
Banana Cue	Deep-friend banana that is coated in caramelized brown sugar and skewered in bamboo stick	5
Fish balls	Deep-fried finely pulverized fish meats, usually flat in shape. Served with spicy vinegar, sweet and sour sauce, or sweet gravy.	10
Kikiam	Deep-fried ground pork and vegetables wrapped in bean curd sheets. Served with specially-made sauce.	10
Kwek-kwek	Hard-boiled egg dipped in orangey batter and fried until crispy	10
Siomai	Steamed dumpling, originally a Chinese dim sum, made with pork, beef, or shrimp.	5
Arrozcaldo	Rice porridge similar to Chinese congee that has chicken and egg, usually served with ginger and some herbs.	5
Barbecue	Marinated chicken and pork skewered and grilled over hot charcoal.	7
Banana fritter	Fried banana dipped in batter, usually served sprinkled with sugar.	5
Turon	Banana spring roll.	5
Proven	Chicken proventriculus coated with flour or corn starch, deep-fried and dipped in vinegar or a specially-made sauce (sweet and sour ketchup mixed with pepper).	5

Table 1. Top ten street foods.

Street food		Energy	Protein	Calcium	Phosphorus
		Kcal	g	mg	mg
1	Banana Cue	183	2	191	27
2	Fish ball	100	9	13	0
3	Kikiam	164	15	0	0
4	Kwek-kwek	170	13.9	73	180
5	Siomai	74	4	0	0
6	Arrozcaldo	171	26	0	0
7	Barbecue	250	17	0	0
8	Banana fritter	240	3	25	64
9	Turon	259	2.4	27	44
10	Proven	533	29	21	4

Table 2. Nutritive values (per 100g serving) of the top ten street foods . Source: The Philippine Food Composition Table. (Portugal et. al, 1997).

Table 3 shows the recommended energy and nutrient intake of male and female (ages 16-18 and 19-29) according to Department of Science and Technology (DOST) in 2002.

List of Nutrients	Male		Female	
	16-18 years old	19-29 years old	16-18 years old	19-29 years old
Energy (kCal)	2840	2490	2050	1860
Protein (g)	73	67	59	58
Calcium (mg)	1000	750	1000	750
Phosphorus (mg)	1250	700	1250	700

Table 3. Recommended energy and nutrient intake for male and female in their specific age brackets. Source: Recommended Energy and Nutrient Intakes for Filipinos 2002 (Barba et al., 2008) and Barrion & Hurtada (2006).

According to Savage et al. (2007), snacks contribute to 18% of the daily nutrient intake of the students. The corresponding recommended energy and nutrient intake for snacks are shown in Table 4.

Nutrients	Male		Female	
	16-18	19-29	16-18	19-29
Energy (kCal)	511.2	448.2	369	334.8
Protein (g)	13.14	12.06	10.62	10.44
Calcium (g)	180	135	180	135
Phosphorus (g)	225	126	225	126

Table 4. 18% of the nutrient requirement for male and female college students.

3 An Integer Programming Model for Optimizing Street Food Snack Intake

In order to obtain a menu for street food snacks that meets the required nutrient intake for college students at a minimum cost, an integer programming (IP) model is developed. In the IP formulation that follows, the objective function Z is the sum of the product of the costs of the street food snacks considered in this study.

In this formulation, x_i $(i = 1,2,\cdots,n)$ denotes the number of servings (at 100g per serving) of street food snack i. The costs for each street food snack (as shown in Table 1) is denoted by c_i while D_i, E_i, F_i, G_i, correspond, respectively, to the nutrient content of each of the street food snack, found in Table 2. The values on the right hand side of this IP model corresponds to the nutrient recommendations for male or female, ages 16-18 and 19-29, in Table 4.

In particular, constraint (2) sets the maximum calorie intake at 20% above the recommended amount for each group. Constraints (3)-(6) reflect the nutrient requirements for the

respective age group, while (7) reflects the usual student budget for buying snack. Constraint (8) sets the limit for daily egg intake (which is at most 1 each day). Lastly, (9) ensures that the values of the decisions variables are nonnegative.

$$\text{minimize} \qquad Z = \sum_{i=1}^{n} c_i x_i$$

subject to

$$\sum_{i=1}^{n} x_i \leq (\text{Energy} + 0.20 * \text{Energy}) \qquad (2)$$

$$\sum_{i=1}^{n} D_i x_i \geq \text{Energy} \qquad (3)$$

$$\sum_{i=1}^{n} E_i x_i \leq \text{Protein} \qquad (4)$$

$$\sum_{i=1}^{n} F_i x_i \geq \text{Calcium} \qquad (5)$$

$$\sum_{i=1}^{n} G_i x_i \geq \text{Phosphorus} \qquad (6)$$

$$\sum_{i=1}^{n} c_i x_i \leq \text{available budget} \qquad (7)$$

$$x_4 \leq 1 \qquad (8)$$

$$x_i \geq 0, \text{integer}, \quad \text{for } i = 1,2,\cdots,10 \qquad (9)$$

4 Suggested Street Food Snack for College Students

This study considered the various combinations of the ten street food snacks taken 3 (4, 5, 6, 7, 8, 9, or 10 at a time) in order to come up with a snack menu that meets the minimum required nutrients while keeping the snack cost at a minimum (at most Php 20). The IP models were formulated by considering each possible street food combination and then solving the resulting IP models using the excel solver. Results obtained are shown in Table 5.

MENU	STREET FOOD SNACK	QUAN-TITY	ENER-GY	PRO-TEIN	CAL-CIUM	PHOSPHO-RUS	COST
			369	10.62	18	225	
FEMALE 16-18							
A	KWEK-KWEK	1	429	16.3	100	224	15
	TURON	1					
B	KWEK-KWEK	1					
	BANANA FRITTER	1	410	16.9	98	244	15
FEMALE 19-29							
A	BANANA CUE	1	353	15.9	264	207	15
	KWEK-KWEK	1					
MALE 16-18							
A	BANANA CUE	2	536	17.9	455	234	20
	KWEK-KWEK	1					
B	BANANA CUE	1	612	18.3	291	251	20
	KWEK-KWEK	1					
	TURON	1					
C	BANANA CUE	1	593	18.9	289	271	20
	KWEK-KWEK	1					
	BANANA FRITTER	1					
MALE 19-29							
A	BANANA CUE	2	536	17.9	455	234	20
	KWEK-KWEK	1					
B	BANANA CUE	1	524	41.9	135	207	20
	KWEK-KWEK	1					
	ARROZ-CALDO	1					

Table 5. Suggested menu for street food snacks among college students.

It can be seen from the results in Table 5 that the optimal snack menu for female ages 16-18 and 19-29 cost P15. Males, on the other hand, require P20 to meet the minimum required nutrient intake from street food snacks for ages 16-18 and 19-29. In terms of nutrient content, all menus obtained in this study exceed the recommended intake for each nutrient considered. These are illustrated in figures 1-4. It can be observed that all menus contain kwek-kwek, a snack made from chicken egg.

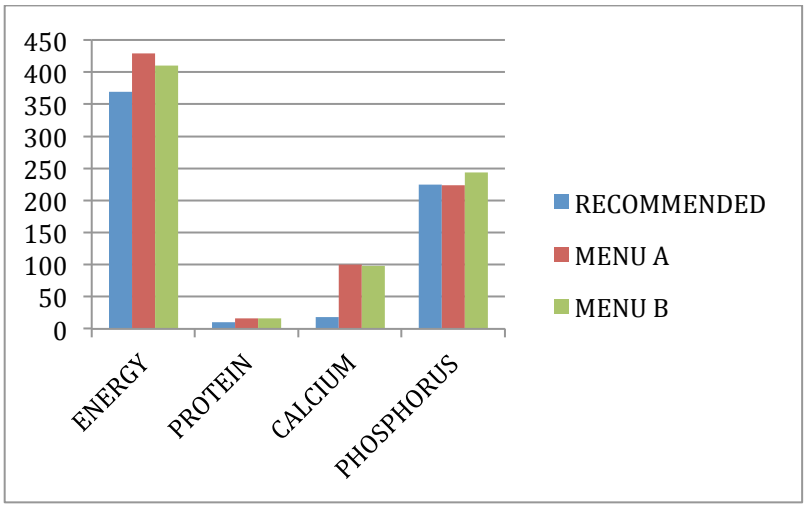

Figure 1. Nutrient contents of suggested street food snacks for female aged 16-18.

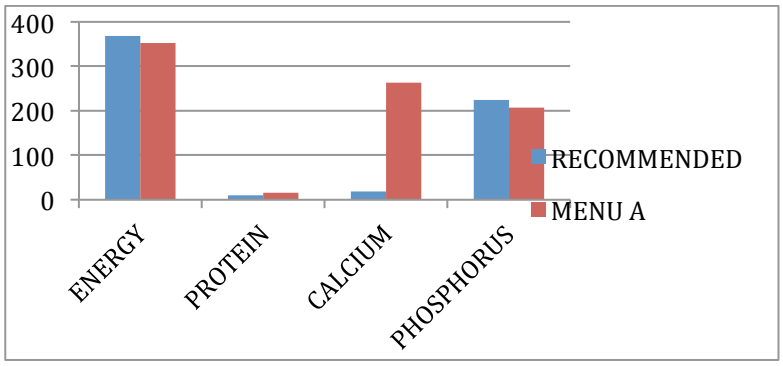

Figure 2. Nutrient contents of suggested street food snacks for female aged 19-29.

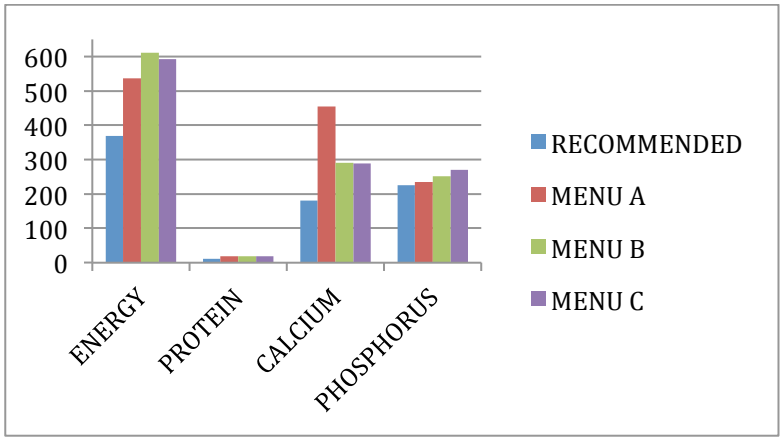

Figure 3. Nutrient contents of suggested street food snacks for male aged 16-18.

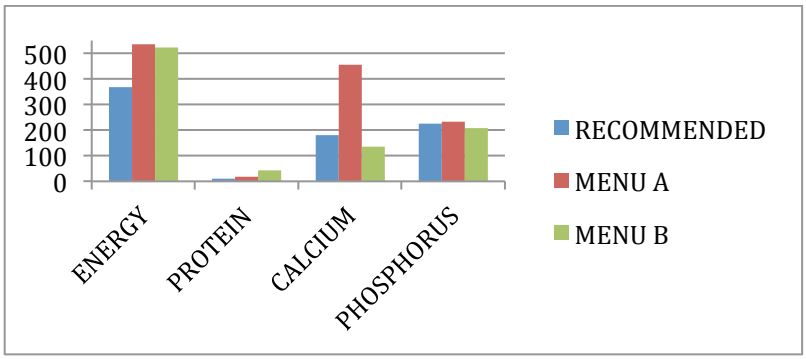

Figure 4. Nutrient contents of suggested street food snacks for male aged 19-29.

5 Conclusion

In this study, suggested menu for street food snacks for males and females aged 16-18 and 19-29 were obtained. In all these menus, the egg-based street food snack kwek-kwek is suggested to be a part of the snack in order to obtain optimal nutrient from the snack taken by college students. It can be seen from the nutrient content of these menus that the minimum required nutrient intake for the different age group is met.

It should be noted, however, that only energy, protein, calcium and phosphorus are considered in the formulation of the IP model used in this study. It might be interesting to include other nutrients in order to come up with more realistic snack suggestions.

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