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Computerized integer programming method: menu scheduling for critical illness patients

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Abstract. In this paper, critical illness patients are referred to breast cancer patients. This cancer is developed from the breast tissue. It is developed due to the erratic growth of cells of the breast tissue. In Malaysia, according to the statistics in 2017, one out of 20 individuals has the breast cancer in their life. In order to help the breast cancer patient in choosing the best food in their meal of a whole day, the way on how to use different mathematical programming methods to prepare a proper and healthy planning diet menu that fulfil all the nutrients constraints with the minimum cost for the breast cancer patient will be showed out. In the literature review, previous research for the menu planning, approaches used for the optimization are being reviewed in detail. In methodology, there are two mathematical programming methods that will be applied which are integer programming and binary integer programming methods. There are two sets of data which is 100 food items for small data model and 426 food items for big data model. At the end of this research, it should be able to provide a minimum cost one day menu and weekly menu for the breast cancer patients with the sufficient nutritional value.

Keywords. Breast cancer, menu planning and integer programming

1. Introduction

According to [13], breast cancer is the cancer which developed from the breast tissue. In general, most of the breast cancer is came from the inward coating of milk ducts or the lobules that supply the milk to the ducts. Breast cancer is developed due to the erratic growth of cells of the breast tissue. Cancer cells are in fact very similar as our normal body cells. This is the reason of why we cannot manage to detect the breast cancer easily during the early stages. However, during the early stage, if the breast



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cancer cells already being detected and the patients being treatment with a suitable treatment, the probability of being cured can be increased significantly compared with the one that being diagnosed as having breast cancer during last stage [35], [43], [44].

According to [17] and [45], breast cancer is one of the major concern nowadays. No matter in low-income countries or high-income countries, breast cancer is the most common type of cancer that happened to the women which can be considered as one of the cancer that more frequently being diagnosed out among the women and threatening their life. Cancer can be divided into many stages which are stage 0, I, II, III and IV [25], [46]. Stage 0 means cancer cells are not yet spread so it is highly curable. Stage I also known as early stage, is only a tiny tumor, same as stage 0 which not yet spread to the other part of bodies. Compared with Stage I, Stage II and III referred to consist of a larger size of tumor and maybe already start to spread while Stage IV also known as metastatic cancer, referred to the cancer cells already spread to other parts of bodies [12], [47].

There are many possible factors that lead to the patients delayed of getting treatment. For example, the patients lack of the awareness of the severity of symptom for breast cancer, some of them come from a poor families, they thought there are some alternative ways to cure it, afraid of the cancer treatment and do not have enough knowledge about the cancer treatment [2], [5], [42]. In order to cure this disease, in fact, there are many ways that have been proposed and carried out. For example, surgery, chemotherapy, radiotherapy, hormone therapy and targeted therapy [7], [48].

There are many types of approaches to diagnose the breast cancer. For example, Mammography, Ultrasound, Magnetic resonance imaging (MRI), Microwave imaging (MI) and Positron emission tomography (PET). Each of the approaches are associated with its advantages and disadvantages. By using these breast screening approaches, the breast cancer can be detected and cured more easily during the early stages [19]. After the patient undergoes the diagnosis and being confirmed as having a breast cancer, if the patient takes a longer time before getting the treatment, the probability of survivability will being decreased. In other words, it can be said that the faster that getting treatment, the higher the chance of survivability [40], [49].

According to [24] and [50], in fact, even male can develop the breast cancer. The difference is the probability that a man has a breast cancer is low which is only 0.5% until 1%. Thus, it can be considered quite rare. This is due to the reason of men had less amount of breast tissue compared with women. However, this does not mean that they can underestimate the potential effects of this disease towards them as for male, when they are being diagnosed as having breast cancer, normally already is in stage three or four. Thus, they still need to take care of themselves [16], [51].

When getting a breast cancer, there are many negative effects towards the patients other than their health level being affected which are they will have a financial problem in order to pay for the diagnosis and treatment fee, possibility to affect their work status as they need to spend time on the treatment in their daily life [18].

According to [28], the past research have shown that people with obesity and did not exercise at all will have higher possibility of having breast cancer. It will also lead to the death of the breast cancer patient and cause the recurrence of the breast cancer case. Since both male and female are potentially to have a breast cancer, so both of them need to have a lifestyle modification. In order to prevent from having breast cancer, there are many approaches that can being done which are by having some lifestyle habits of stop smoking, do not drinking alcohol, keep a normal weight and work out regularly [23].

According to the statistics that obtained from World Health Organisation (WHO) in year 2018, there are 2.1 million female that newly being diagnosed of having breast cancer which is one out of four females developed the breast cancer [11]. The number of patients of breast cancer are increasing over the years. Nowadays, breast cancer also being known as one of the leading cause of death among the cancer and it is very common type of cancer among female.

In Malaysia, the prevalence of breast cancer is growing rapidly among the female of all-aged. In 2017, one out of 20 individuals will have breast cancer in their life in Malaysia. However, early detection of breast cancer can cause their probability of survive being increase until 98% [34]. Breast

cancer is the cancer that most commonly occur and then followed by the colorectal cancer and third is the lung cancer [30], [32]. Hence, in order to decrease the number of patients died due to the breast cancer and prevent more people of getting breast cancer or the recurrence of having breast cancer again, precaution steps needed to be taken. One of the way is to having healthy lifestyle [28].

There are many researchers recommended the varieties of food that should be taken and avoid but there is no research mentioned about menu planning for the breast cancer patients. A good dietary intake behavior can significantly reduce the probability of recurrence and decrease the number of patients died due to the breast cancer [4]. Therefore, in order to help the breast cancer patient in choosing the best food in their meal of a whole day, a proper and healthy planning diet menu with the right proportion and the minimal cost will be developed in this study.

2. Literature review

2.1. Introduction

Breast cancer can be prevented through many kinds of ways. The most direct approach is through the lifestyle modification. The example of the lifestyle habits are stop smoking, having weight management, do some work out during daily life, avoid eating and also do not drink too much alcohol [20], [41].

In menu planning, there are some items need to avoided from eating which are the protein with high calories, western-style diets, having supplement during chemotherapy, dairy product with high fat [14]. For some food items, there are some conflicts exist which whether it can help to prevent breast cancer or it might worsen it. There are some research mentioned that soy product should be avoided if having a breast cancer as it may cause cancer cells to grow [22]. However, according to [37], they claimed that soy product can protect the public from getting breast cancer during early life. This is the reason why we need a menu planning in order to allow the public to know what they need to eat in whole day.

2.2. Menu planning

The menu planning can be done by many kinds of mathematical programming methods. There are many past research which tried to use different approaches to develop a menu for their targeted respondents. In the research of [15], he mentioned that common share goal of doing the menu planning is to develop a balanced diet with sufficient nutrients. In the research of [6], the researcher tried to solve a multi-dimensional knapsack problem in order to develop a seven days menu for the patients in hospital. They run for 700 food items with 10 groups. Since in this research consist of many infeasible solutions, so they decided to use Elitist Non-Dominated Sorting Genetic Algorithm (NSGA-II) to solve the problem.

The researchers tried to develop a 7 days menu in order to help the public to prevent heart disease from occurring. The model is being run by using computer software known as MenuGene which applied Genetic Algorithm (GA) and solve the constraints of the problem hierarchically. The data that used is a 569 dishes with 1054 ingredients along with its nutrient composition. The model is developed by taking in consideration of amount of nutrients needed, the food items consisted inside a meal is appetizing or not [3].

In research of [31], they tried to use Bayesian Optimization Algorithm (BOA) to solve an individual's nutrition problem. This algorithm is being introduced by [21]. It is the combinations between the methods in probabilistic models and method of Bayesian network. It is about building a Bayesian network by keep introducing new suitable candidates in each step. For each candidates, each time when it is being introduced, the conditional probability is being calculated.

In research of [31], their concerns were about how to fulfill the daily requirement of nutrients intake, produce a minimum cost diet menu and the proportion of the food items. At last, the result of this research was come up with a food items consisted in the breakfast and do the comparison between linear programming, Bayesian optimization approach and genetic algorithm.

In research of [33] tried to use self-adaptive hybrid genetic algorithm (SHGA) in order to develop a nutritious diet menu for the teenagers of 13 until 18 years old. The menu that developed fulfilled all the nutrients constraints with the minimum cost and maximized the ability of the chefs of the school to cook and the variety of the food that can be served. Equation (1) showed the objective function used which involved 409 food items consisted in 10 different types of groups of food items:

$$\text{Minimize Total Difference } z = B - \sum_{i=1}^{409} \sum_{k=1}^K C_i X_{ik} \quad (1)$$

where

Total Difference = allocated budget by government – total actual cost

B = sum of the available budget

C_i = cost for each food item

X_{ik} = variable of decision of food items i in k category of diet

In the research of [29], a menu in school was being generated for the students in Brazil. The objective function and the constraints were to produce a well-balanced meal with all nutrients needed, low cost and also the food quality and the variety of the food being taking care of.

2.3. Integer programming

There are many type of integer programming which the common one is mixed integer programming, mixed integer linear programming and binary integer programming [9].

Researchers in [36] used integer programming method in order to plan a menu for the secondary school students. The objective function was about minimizing the cost needed in order to prepare the menu. They also would like to maximize the variety types and the nutritive values of the food items. In the result, since the menu developed consisted of many kinds of choice for the school students to choose so the diet menu developed can be considered as nutritious.

In the research of [38], [39] mentioned that they used the 0/1 integer programming which is the binary programming method with genetic algorithm in order to develop a menu. The total food items used in the system are 1882 items which classified into 18 food groups. In the research of [26], it took into considerations of the 170 food items and its nutrients composition, price of each food item and the budget allocation from the school to the caterer of the school which is RM16 per day in order to design a one-day menu for the teenagers. After that, the Microsoft Excel Solver was being used in order to develop the model that applied the binary integer programming method.

For mixed integer linear programming, researchers for [8] used this method by taking into the considerations of nutrients intake for human bodies. They also tried to maintain the balance between those nutrients and the daily eating habits of people. They solved problem by using the simplex method. At last, they developed a general diet which consist of breakfast, lunch, dinner, daily diet and weekly diet along with their energy values that can be absorbed if an individual consumed the diets planned. The problem was solved by using manual calculation by applying the formula below which showed the objective function and its constraints used:

After that, there is a research made an improvement on the research which in 1993, manual calculation was being used. In the research of [27], computer-assisted approach was being used. The difference between these two research papers was the research paper in 1993 tried to come up with the food items in a meal while the research paper in 1995 developed a weekly recipe. In the paper of [27], it consisted of two objective functions which were to minimize the cost and the cooking and preparation time. Then, researchers also did a comparison between the least cost menu and least time used menu to see whether which type of menu can give more nutrients.

3. Methodology

3.1. Data description

The basic nutrients information is being obtained from the RNI 2017 and Nutrient Composition of Malaysian Foods [1], [10]. After that, the nutrients boundaries that needed to be adjusted for the breast cancer patients will be identified and confirmed after the discussion with the dietitian.

In this research, there are total of 426 food items with 10 types of food groups. The dataset is a secondary data which obtained from a research and there will be food items that are being newly added to be used in this research. These food items are the one that are being recommended by the dietitian which should be absorbed by the breast cancer patients' bodies. Additionally, there were nine nutrients involved in this research which are energy, protein, carbohydrate, calcium, iron, Vitamin B1, Vitamin B2, Vitamin C and Vitamin A. The nutrients that especially needed by the breast cancer patients are verified after seeking the advisory of dietitian.

There consist of a food requirement for each type of food group that should be served in each day. This could act as a basic requirement which in each day, the total dishes that being served equals to 18 which shown in Table 1.

Table 1: Food Requirement per Day

Type of food	No. of requirement per day
Beverage	6*including 2 plain water (x_9)
Cereal Flour Based	1
Rice Flour Based	1
Cereal Based Meal	2*including 1 plain rice (x_{104})
Meat Dishes	1
Seafood	1
Vegetable	2
Fruits	2
Wheat Flour Based	1
Miscellaneous	1
Total Dishes Per Day	18

In each day, there should be six meals with the 10 type of food group that mentioned just now which shown in Table 2.

Table 2: Food Items Consisted Inside Meals per Day

Meal	Type of Food Group	Amount
Breakfast	Beverages	1
	Cereal Flour Based	1
Morning Tea	Beverages	1
	Rice Flour Based	1
Lunch	Beverages	1
	Cereal Meal Based	1
	Vegetables	1
	Fruits	1
	Meat/Seafood	1
Evening Tea	Beverages	1
	Wheat Flour Based	1
Dinner	Beverages	1
	Cereal Meal Based	1

	Vegetables	1
	Fruits	1
	Meat/Seafood	1
Supper	Beverages	1
	Miscellaneous	1
	Total	18

3.2. Modelling

In this research, integer programming and binary integer programming methods will be used. There are total of 100 food items that will be chosen to be ran for the Small Data Model or can be known as pilot study results which by using integer programming. After that, all the food items will be used for the formal study which being used to develop the Big Data Model [10].

3.2.1. *General equation used for menu planning model.* The objective function can be defined as follow:

$$\text{Minimize cost needed} = \sum_{i=1}^N \sum_{j=1}^P \sum_{k=1}^Q c_i x_{ijk} \quad (2)$$

where

$$\text{Energy (kcal):} \quad LB_E \leq \sum_{i=1}^{426} \sum_{j=1}^{10} \sum_{k=1}^6 E_i x_{ijk} \leq UB_E \quad (3)$$

$$\text{Protein (g):} \quad LB_P \leq \sum_{i=1}^{426} \sum_{j=1}^{10} \sum_{k=1}^6 P_i x_{ijk} \leq UB_P \quad (4)$$

$$\text{Carbohydrate(g):} \quad LB_{Car} \leq \sum_{i=1}^{426} \sum_{j=1}^{10} \sum_{k=1}^6 Car_i x_{ijk} \leq UB_{Car} \quad (5)$$

$$\text{Calcium (mg):} \quad LB_{Ca} \leq \sum_{i=1}^{426} \sum_{j=1}^{10} \sum_{k=1}^6 Ca_i x_{ijk} \leq UB_{Ca} \quad (6)$$

$$\text{Iron (mg)} \quad LB_{Fe} \leq \sum_{i=1}^{426} \sum_{j=1}^{10} \sum_{k=1}^6 Fe_i x_{ijk} \leq UB_{Fe} \quad (7)$$

$$\text{Vitamin B1 (mg):} \quad LB_{vb1} \leq \sum_{i=1}^{426} \sum_{j=1}^{10} \sum_{k=1}^6 vb1_i x_{ijk} \quad (8)$$

$$\text{Vitamin B2 (mg):} \quad LB_{vb2} \leq \sum_{i=1}^{426} \sum_{j=1}^{10} \sum_{k=1}^6 vb2_i x_{ijk} \quad (9)$$

$$\text{Vitamin C (mg):} \quad LB_{Vc} \leq \sum_{i=1}^{426} \sum_{j=1}^{10} \sum_{k=1}^6 Vc_i x_{ijk} \leq UB_{Vc} \quad (10)$$

$$\text{Vitamin A (}\mu\text{g):} \quad LB_{Va} \leq \sum_{i=1}^{426} \sum_{j=1}^{10} \sum_{k=1}^6 Va_i x_{ijk} \leq UB_{Va} \quad (11)$$

x_{ijk} = decision variable for food items, i for food groups, j and meals, k

c_i = cost for each food item i

P = number of meal per day

Q = number of food groups

N = Number of food items

Besides that, the constraints in this research have divided into two parts: the general nutritional requirements and the food group requirements [36].

i. The constraints for the general nutritional requirements

$$LB_i \leq \sum_{i=1}^N \sum_{j=1}^{10} \sum_{k=1}^6 w_i x_{ijk} \leq UB_i \quad (12)$$

where

LB_i = lower bound for each nutrient content

UB_i = upper bound for each nutrient content

w_i = weight of each nutrient for the food

This research consist of multi-constraints which are nine of it. There are seven constraints of nutrients that consist of lower bound and upper bound values except for Vitamin B1 and Vitamin B2. These two vitamin only have the lower bound values. The constraints are expressed as the following way:

LB = lower boundary for nutrient intake

UB = upper boundary for nutrient intake

E_i = amount of energy in kilocalories for food item, i

P_i = amount of protein in gram for food item, i

Car_i = amount of carbohydrate in gram for food item, i

Ca_i = amount of calcium in milligram for food item, i

Fe_i = amount of iron in milligram for food item, i

$Vb1_i$ = amount of Vitamin B1 in microgram for food item, i

$Vb2_i$ = amount of Vitamin B2 in microgram for food item, i

Vc_i = amount of Vitamin C in milligram for food item, i

Va_i = amount of Vitamin A in milligram for food item, i

ii. The constraints for food group requirements

Beverages:
$$\sum_{i=1}^{37} x_{i,1} = 6, \quad (13)$$

where the plain water = 2

Cereal Flour Based:
$$\sum_{i=38}^{85} x_{i,2} = 1 \quad (14)$$

Rice Flour Based:
$$\sum_{i=86}^{113} x_{i,3} = 1 \quad (15)$$

Cereal Based Meal:
$$\sum_{i=114}^{126} x_{i,4} = 2, \quad (16)$$

where the plain rice = 1

$$\text{Meat Dishes:} \quad \sum_{i=127}^{158} x_{i,5} = 1 \quad (17)$$

$$\text{Vegetables:} \quad \sum_{i=159}^{212} x_{i,6} = 2 \quad (18)$$

$$\text{Fruits:} \quad \sum_{i=213}^{261} x_{i,7} = 2 \quad (19)$$

$$\text{Wheat Flour Based:} \quad \sum_{i=262}^{286} x_{i,8} = 1 \quad (20)$$

$$\text{Seafood:} \quad \sum_{i=287}^{324} x_{i,9} = 1 \quad (21)$$

$$\text{Miscellaneous:} \quad \sum_{i=325}^{426} x_{i,10} = 1 \quad (22)$$

3.3. Basic assumptions

- i. The standardized portion size of every food item is in integer form which are 0, 1 and 2 except plain rice and plain water.
- ii. The nutrients lost during the preparation of food are not account on the diet menu as the diet menu is described in integer form.

3.4. Develop of the model

The optimal solution will be developed starting from the linear programming methods and then followed by the integer programming methods. This will help the readers to know more about the difference of two different methods by comparing the amount of the food items required along with its total cost for a one-day diet menu.

4. Expected result

4.1. Introduction

The research objectives are expected to be achieved when the final results that fulfil all the nutrients constraints being obtained. After an interview with the dietitian or nutritionist, the boundaries for each nutrient constraint can be identified and confirmed. There will be a total of at least 426 food items that being take into consideration during the development of the menu for a day.

In order to help them in choosing the best food in their meal of the whole day, the proposed food items are expected to be the most suitable items that being consumed by the breast cancer patient which consist of all the nutrient needed for their bodies. The cost needed for the total meals per day should be the minimum price which can help the patients to consume a low price one day menu. By using different optimization approaches, there might be a difference in terms of the cost for the meals. Thus, a comparison can also being done in order to see which approach capable to produce a better result.

4.2. Pilot study

Table 3 showed the one day diet menu by using Integer programming method for the 100 data set.

Table 3: Diet menu using integer programming method

Meals	Food Item, <i>i</i>	Amount
Breakfast	Milk, cow, fresh	1
	Biscuit soda/plain	1
Morning tea	Green Tea	1
	Kuih lompong	1
Lunch	Plain water	1
	Rice, coconut milk	1
	Mengkudu	1
	Banana, common varieties	1
Evening tea	Fish curry, canned	1
	Sarsi	1
	Cake, swiss role	1
Dinner	Green Tea	1
	Rice, cooked	4
	Carrot	1
	Banana, common varieties	1
Supper	chicken_satay	1
	Plain water	1
	Cucur badak	1
Total number of food per day		18
Total cost (RM)		10.30

5. Conclusion

As a conclusion, breast cancer can be consider as one of the leading cause of death no matter in whole world or in Malaysia. This can be proven through the statistic that obtained from WHO. Thus, in order to reduce the number of people that died or relieve their pain during they are having the treatment, having a simple menu planning for one day and seven days are a very good starting. In this research, method integer programming and binary integer programming methods will being used and then compared in order to see which method is a more appropriate one.

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