2022-06-23

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Kisighii, Happyness

Emerald Publishing Limited

https://doi.org/10.1108/NFS-01-2022-0020

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# Context-specific optimal dietary guidelines for managing cancer for hospitalized patients in Tanzania



Happyness Amani Kisighii and Jofrey Raymond
*Department of Food and Nutritional Sciences, Nelson Mandela African Institute of Science and Technology, Arusha, Tanzania, and*
Musa Chacha
*Department of Sustainable Agriculture, Biodiversity and Ecosystem Management, Nelson Mandela African Institute of Science and Technology, Arusha, Tanzania*

Received 19 January 2022
Revised 18 May 2022
Accepted 21 May 2022

## Abstract

**Purpose** – The lack of food-based dietary guidelines for managing cancer among hospitalized patients has led to an increasing economic burden on the government and families in low- and middle-economy countries. There have been increasing medical costs due to delayed recovery, readmission and mortality. The purpose of this study is to contribute in reducing these effects by developing context-specific food-based dietary guidelines to assist health-care professionals and caregivers in planning diets for cancer patients.

**Design/methodology/approach** – For seven days, the dietary intakes of 100 cancer patients in the hospital were recorded using weighed food records. Data on the costs of commonly consumed foods during hospitalization were obtained from hospital requisition books as well as nearby markets and shops. The information gathered was used to create optimal food-based dietary guidelines for cancer patients.

**Findings** – Most patients did not meet the recommended food group and micronutrient intake according to their weighed food records. Sugar intake from processed foods was (51 ± 19.8 g), (13% ± 2%), and calories (2585 ± 544 g) exceeded recommendations. Optimized models generated three menus that met the World Cancer Research Fund 2018 cancer prevention recommendation at a minimum cost of 2,700 Tanzanian Shillings (TSH), 3500TSH, and 4550TSH per day. The optimal dietary pattern includes nutrient-dense foods from all food groups in recommended portions and within calorie limits.

**Originality/value** – Findings show that optimal dietary guidelines that are context-specific for managing cancer in hospitalized patients can be formulated using culturally acceptable food ingredients at minimum cost.

**Keywords** Dietary guidelines, Optimal dietary pattern, Cancer, Linear goal programming, Hospitalized patients, Dietary Intake

**Paper type** Research paper

## Background

To the best of our knowledge, there are no food-based dietary guidelines for cancer management in hospitalized patients in Tanzania. This is due to a scarcity of trained clinical nutritionists and dieticians to plan suitable diets for cancer patients (Martin *et al.*, 2018).

The authors would like to express their great appreciation to Joshua Mwansunda for sharing their expertise on the application of linear programming in human nutrition. Furthermore, we would like to thank Fanuel Kiptoo and Alfred Sife for their valuable and constructive suggestions during this study.

*Funding:* This work was supported The African Center for Research, Agricultural Advancement, Teaching Excellence and Sustainability (CREATES).



0034-6659
DOI 10.1108/NFS-01-2022-0020

There have been no studies to determine whether most existing dietary guidelines provide inconsistent information for health-care professionals and nutritionists on what and how much to feed hospitalized cancer patients to supplement their medical treatments. Although efforts have been made to improve cancer treatment, the mortality rate from cancer remains unacceptably high and is expected to rise in the coming decades (Chakraborty *et al.*, 2020; WHO, 2000). Cancer has been reported to be the second leading cause of death worldwide (Mentella *et al.*, 2019). Cancer occurred in approximately 70% of lower and middle-income countries (Rajavel and Devi, 2019). For example, in 2018, there were 16,708 cancer deaths in Tanzania, with specific cancer incidences of 10.6%, 7.5%, 6.1%, 5.0% and 12.3% to colorectal cancer, prostate cancer, stomach cancer, liver cancer and breast and lung cancer, respectively (Mentella *et al.*, 2019). Cancer is expected to cause 30 million deaths and 21 million illnesses by 2030 (World Cancer Research Fund, 2018).

This has resulted in an increased financial burden on the country and families in the course of reducing morbidity, mortality and the impact of cancer risk factors (Chuwa, 2015). For example, the World Health Organization (WHO) reported 21000 cancer deaths in Tanzania in 2014 (Chuwa, 2015) and 96 million deaths globally in 2018 (Pop *et al.*, 2019). The patient and their families are responsible for the costs. Similarly, patients with leukemia (blood cancer) require approximately 500,000 per month to be treated, while the overall cost per patient for cervical cancer ranges from (US dollar) US$1,257.24 to US$3,692.70. The average direct cost for a hospitalized patient is US$2,301.75, and other costs (indirect costs) incurred during hospitalization are estimated to be US$374.25 per patient (Chuwa, 2015). Unfortunately, available medical therapies such as chemotherapy, which have been shown to improve treatment outcomes, have even higher prices per dose ranging from 2 to 8 million Tanzanian shillings (TSH) per patient (Chuwa, 2015). The National Health Insurance Fund covers about 22.8 of the 44 million Tanzanians is equal to 1%, so the majority of the financial burden is felt directly by individuals. As a result, subjecting these ridiculous prices to a poor Tanzanian is like adding fear to their already hopeless life (Tungaraza, 2018). Later, insufficient funds delivered to run cancer management programs resulted in increased cancer incidences in subsequent years (Kohi *et al.*, 2019), as patients were unable to cover cancer treatment costs.

Despite the fact that diet has been reported to be one of the modifiable risk factors in cancer management as well as prevention (Stepien *et al.*, 2016) due to the presence of anticancer compounds such as phytochemicals (Pop *et al.*, 2019; Rajavel and Devi, 2019; Shankar *et al.*, 2017), there are no consistent and uniform food-based dietary guidelines for cancer management in Tanzania. Inadequate intake, cancer therapies and cancer outcomes are common problems reported to be faced by the majority of cancer patients (Blauwhoff-Buskermolen *et al.*, 2016). These problems have been associated with poor patients' treatment outcomes, which leads to reduced appetite, smell, taste and ability to absorb adequate nutrients (Patients *et al.*, 2012) all of which are associated with malnutrition (Atkinson and Atkinson, 2021; Salas *et al.*, 2017). Furthermore, as a result of increased illnesses and mortality, low serum iron, vitamin C, zinc, folate and thiamin levels, as well as the presence of cancer cachexia, reduce nutrient metabolism (Arends *et al.*, 2016; Maccio *et al.*, 2021). Adequate diet plays a critical role in multimodal cancer care, particularly in all stages of cancer care from diagnosis to therapeutic pathways and treatments. For example, in the USA, providing adequate diet to cancer patients resulted in a 30% reduction in cancer patients (Stepien *et al.*, 2016; Ward *et al.*, 2016; Warr *et al.*, 2018).

Specific food groups used in this study were plant-based foods like fruits, vegetables (especially non-starchy vegetables), whole grains and legumes as have been recommended by various guidelines, including the WHO, European Society for Clinical Nutrition and

Metabolism (ESPEN) dietary manual and Malaysian manuals on cancer dietary management (Alaini *et al.*, 2019; Tullio *et al.*, 2021; World Cancer Research Fund, 2018). Whole grain has been shown to contain bran and germ, which are high in bioactive nutrients and compounds (non-nutrients) with anti-carcinogenic properties, such as zinc, selenium, copper, vitamin E, dietary fiber, phenolic compounds and phytoestrogens (World Cancer Research Fund, 2018). Unfortunately, as shown in Table 1, patients frequently consumed refined grains such as white loaves of bread, rice, refined maize and pasta while hospitalized, with less intake of whole grains.

This study aimed to fill the identified gap by using linear goal programming to develop optimal food-based dietary guidelines for cancer management. In a low-resource setting such as Tanzania, locally available food ingredients were used to ensure affordability, cultural traditions and personal preferences. The generated dietary guidelines were then translated into understandable measurements for patients.

## Materials and method

*Setting of the study*

A cross-sectional study was carried out in the oncology departments of five purposively selected hospitals in Northern Tanzania. The main hospitals treat cancer patients and provide food services to the hospitalized patients. The research was conducted between June and April of 2021.

*Study participants*

The study included 100 cancer patients from the selected hospitals' oncology departments, regardless of type, stage, age or gender. The participants were cancer patients who were

| Food group | Subgroup (Intake amount in grams) | Observed dietary pattern | Initial optimization | Recommended intake |
|---|---|---|---|---|
| Energy (kcal) | | 2260* | 1600 | 1700 |
| Vegetables | | *72.8[a]* | *315* | 200–300 |
| | Dark-green vegetables | 10a | 1.18 | *36.4* |
| | Red and orange vegetables | 3a | 2.6[a] | 150 |
| | Beans, peas and lentils | 20a | 2.42 | 290 |
| | Starchy vegetables | *0.2[a]* | *0.5* | *21.4* |
| | Other vegetables | 10.8a | 2.3[a] | *50.8* |
| Fruits | | 0[a] | 0[a] | 300 |
| Grains | Whole grains | *120a* | 912 | 85.1 |
| | Refined grains | 893* | 2.3 | 0.0 |
| Dairy | | 0[a] | *5.3[a]* | 720 |
| Protein foods | | 3a | 13.3[a] | *85.1* |
| | Meat | 28.3 | 20.5[a] | 105.3 |
| | Poultry, eggs | 0[a] | 0 | 147 |
| | Seafood | 0[a] | 0[a] | 32.4 |
| | Nuts, seeds, soy products | 0[a] | 0[a] | *20.2* |
| Oils | | 17.4 | *12.5* | 27 |
| Total cost TSH (US$) | | *2000 (0.87)* | *2700.5 (1.16)* | |

**Notes:** [a]Inadequate intake of a defined food group; *Excess intake of a defined food group

**Table 1.** Observed daily dietary intake among hospitalized cancer patients

receiving daily food services provided in the hospital during their hospitalization. Patients on parenteral nutrition were not eligible. Before being assigned to a treatment group, patients were given written informed consent and a statement confirming their willingness to publish. The Ethics Review Committee of the School of Life Sciences and Bioengineering at The Nelson Mandela African Institution of Science and Technology (NM-AIST) granted ethical approval for this study.

### *Anthropometric measurements*

Anthropometric measurements, such as the patients' height and weight, were extracted from their medical records. The obtained height and weight were used to calculate each patient's body mass index (BMI). BMI is calculated by dividing a person's weight in kilograms by their height in meters squared ($kg/m^2$). To better understand the nutritional status of hospitalized cancer patients included in the study, body mass indices were classified based on World Health Organization (WHO, 2000; Silveira *et al.*, 2020; FAO & WHO, 1998) standards for adults.

### *Dietary assessment*

During the study period, we conducted a dietary assessment to estimate food intake (type and quantity of food), nutrient intake and dietary patterns of hospitalized cancer patients. Each patient's energy intake was also assessed using dietary assessment. Diet optimization was based on data from observed food intakes, nutrient intakes and dietary patterns.

*Food intake.* To obtain the daily distribution of intakes provided in hospitals, a weighed food record (WDR) was used to measure the amount of each type of food and beverage consumed by cancer patients during hospitalization for 7 days. A digital electronic weighing scale was used to weigh foods and beverages. To assist with food weighing, all research assistants were given food weighing utensils such as plates and cups. The obtained food intakes data were then converted into daily energy and nutrient intake using Tanzania, Kenya and Uganda Food Composition Tables (Lukmanji *et al.*, 2008). The information was then entered into an Excel 2013 spreadsheet for nutrient analysis.

*Dietary pattern.* A diet index-based pattern was used to assess the quantity, variety and frequency of various foods consumed by hospitalized cancer patients (Zhao *et al.*, 2021). The pattern was then used to assess the quality or adequacy (in terms of nutrient density) of diets provided to cancer patients while they were hospitalized.

*Dietary diversity.* Dietary diversity score (DDS) was calculated by adding the quantity of any foods within each food sub-group that patients consumed at least once per day while hospitalized. Food ingredients used in the calculation of DDS were classified according to Food and Agriculture Organization (FAO) guidelines (Kennedy and Ballard, 2010). The DDS was calculated using 13 food sub-groups: whole grains, refined grains, green leafy vegetables, red and orange vegetables, starchy vegetables, beans, lentils and peas, other vegetables, fruits, dairy, oils, fish and seafood, nuts, seeds and soy products, meat, poultry and eggs.

*Nutrient intake.* The energy and nutrient intakes from each food item were calculated using nutritional databases such as food composition tables and nutrient databases, and the median intake for each patient was calculated. To determine nutrient adequacy and the quality of dietary patterns among cancer patients, the median calculations for each nutrient intake were compared with daily recommended nutrient intakes (RDI).

### Food market survey

A food market survey was conducted on nearby markets and shops to validate food prices and identify other nutrient-dense local foods that were missing from the hospital food catering menu. The information was used to develop optimal dietary patterns for cancer patients in the hospital. The price was calculated using raw food ingredients.

### Formulation of optimal dietary pattern

The mathematical approach was used to calculate optimal dietary patterns, which were then converted into food-based dietary guidelines for cancer management. A linear goal programming model was developed to generate the optimal diet for cancer inpatients. In this model, nutritional reference levels of essential nutrients as recommended by WHO, the ESPEN manual and other authorized available reports in cancer management were set as constraints. Cultural traditions and individual preferences were taken into account by ensuring that the foods included in the model corresponded to common food patterns in hospitals. When selecting food items, the minimum and maximum value of essential nutrients were set based on the ESPEN manual and other authorized published reports (Alaini *et al.*, 2019; Arends *et al.*, 2016) to ensure a menu generated per meal avoids repetition of food items. Food groups were restricted based on recommended food patterns for cancer patients, taking into account costs, culture, personal preferences, food accessibility, availability and affordability.

*Constraints.* The model was programmed with minimum and maximum nutrient and energy constraints. The findings were used to develop food-based dietary guidelines for cancer patients. The following constraints were imposed on all food ingredients and nutrients:

$$\mathrm{Y}i \leq \sum aiw\mathrm{xw} \leq \mathrm{Y}i \text{ and } \mathrm{xw} \geq 0 \quad (1)$$

where Y represents the RDI for a specific nutrient; Yi represents the minimum or maximum acceptable quantity of nutrient *I; aiw* denotes the amount of nutrient *i* in one portion of food item w; The weight of food item is represented as *aw*. All essential nutrient minimum and maximum values were determined using WCRF or WHO, and ESPEN guidelines (Arends *et al.*, 2016; WHO, 2015; World Cancer Research Fund, 2018) and Bapen guidelines (Osman *et al.*, 2021). Table 2 contains over 150 food items used in the optimization of diet for cancer patients.

*Decision variables.* Food ingredients used to prepare meals for the patients during hospitalization were termed as decision variables. These were presented as follows:

$$\mathrm{Xw} = \text{weight (g) of a certain food item}, \ \mathrm{w} = \text{type of food ingredient (name)}$$

*Objective function.* The objective was to keep the cost of the food items used to prepare diets for hospitalized cancer patients as low as possible while meeting nutritional requirements for each individual as recommended.

The following equation demonstrates this:

$$\mathrm{Min\,C} = \sum \mathrm{X}_i w_i$$

where c is cost; Xi = weight (g) of a certain food item; $w_i$ = type of food ingredient (name)

| Food group (FAO) | Sub-food group (examples) |
|---|---|
| Vegetables | Dark green vegetables (amaranth leaves, beet greens, broccoli, chard, collards, cress, dandelion greens, kale, mustard greens, romaine lettuce, spinach, watercress, nightshade, pumpkin leaves, cowpea leaves, spinach, etc.)<br>Red and orange vegetables (kabocha, carrots, chili peppers, red or orange bell peppers, sweet potatoes, pumpkin, tomatoes and butternut.)<br>Beas, peas and lentils (black beans, black-eyed peas, chickpeas, cowpeas, edamame, kidney beans, lentils, lima beans, mung beans, navy beans, pigeon peas, pink beans, pinto beans, split peas, soybeans and white beans<br>Starchy vegetables (cassava, lima beans, immature or raw (not dried) peas (e.g., cowpeas, black-eyed peas, green peas, pigeon peas), plantains, white potatoes, yam)<br>Other vegetables (asparagus, bean sprouts, beets, Brussels sprouts, cabbage (all kinds) cauliflower, celeriac, celery, chayote, cucumber, eggplant, garlic, ginger root, green beans, lettuce, mushrooms, okra, onions, peppers (chili and bell types that are not red or orange) radicchio, sprouted beans (e.g. sprouted mung beans) |
| Grains | Whole grains (example, amaranth seed, barley (not pearled), brown rice, buckwheat, millet, oats, popcorn, whole-grain cornmeal, whole-wheat bread, whole-wheat chapati, whole-grain cereals and crackers and wild rice)<br>Refined grains (white bread, refined-grain cereals and crackers, corn grits, cream of rice, cream of wheat, barley (pearled), pasta and white rice) |
| Fruits | Apples, bananas, grapefruit, lemons, limes, mandarin oranges, dates, mangoes, watermelon, papaya, passion fruit, figs, grapes, jackfruit peaches, pears, pineapple, plums, pomegranates, guava, starfruit, tamarind, blackberries and strawberries |
| Protein foods | Meats (Meats include beef, goat, lamb, pork, rabbit and turkey, Organ meats include brain, chitterlings, giblets, gizzard, heart, kidney, liver, stomach, sweetbreads, tongue and tripe<br>Poultry (Poultry includes chicken, dove, duck, game birds (e.g. ostrich, pheasant and quail))<br>Seafood and fish (crab, salmon, sardine, tilapia, mackerel, tuna and whiting), flounder, haddock, hake, herring, lobster, mullet, oyster<br>Eggs (Eggs include chicken eggs and other birds' eggs) |
| Nuts and seeds | (1) Seeds: Sesame Seeds, Pumpkin Seeds, Sunflower Seeds, etc.<br>(2) Nuts: almond, cashew nut, peanut, walnut, etc. |
| Dairy | Yogurt, sour milk, fresh whole milk |
| Oils | Olive oil, sunflower oil, flaxseed oil, corn oil |

**Table 2.**
Foods and food groups used to develop optimal dietary patterns for cancer patients

*Preparation of mathematical calculations*

Linear goal programming was used to model the food-based dietary guidelines for cancer patients hospitalized in northern Tanzanian hospitals into everyday healthy food choices. Local foods commonly consumed were identified to be used in mathematical modeling. Local foods that are commonly consumed were identified for use in mathematical modeling. Local nutrient-dense foods were included in the development of low-cost healthy dietary patterns for cancer management.

*Excel solver.* To create a linear programming model, the Solver-add-inns from Microsoft Excel 2013 were installed. Linear programming is used to optimize daily nutrients based on the references provided while keeping costs to a minimum.

*The dietary guidelines development process*

An interdisciplinary technical working group was formed and tasked with developing food-based dietary guidelines for cancer management in hospitalized patients in Tanzania. The technical working group comprised nutritionists, food scientists, agriculture, health, education and research experts. Concerning the development of guidelines, the key evidence-based dietary recommendations for addressing cancer among patients hospitalized in various health facilities were evaluated. The obtained dietary patterns were then translated into consumer-friendly guidelines based on cultural appropriateness, acceptability, comprehensibility and practicability by taking into account key issues for developing food-based dietary guidelines according to FAO and WHO (FAO & WHO, 1998).

*Statistical analysis*

The nutritional assessment data were entered into an Excel sheet to allow statistical analyses to be performed using the Excel solver. All data were checked for accuracy. Dietary intakes were first analysed using nutritional databases such as food composition and nutrient value tables from Tanzania and Kenya food composition Tables (FAO/GOK, 2018; Lukmanji *et al.*, 2008) then compared to reference dietary intake (RDI) recommendations from WHO, ESPEN guidelines and other authoritative recommendations. Demographic information was presented in the form of mean and standard deviations, as well as percentages.

## Results

*Study participants*

One hundred patients were evaluated for their dietary intake while hospitalized, with the majority of participants being female ($n = 65$) and a few males ($n = 35$). Their mean age and BMI were $60 \pm 19$years, and $27 \pm 8$ kg/m$^2$, respectively. Their ages ranged between 45 and 72 years old. Patients with breast cancer were ($n = 20$), esophageal cancer ($n = 8$), colorectal cancer ($n = 15$), lung cancer ($n = 6$), rectal cancer ($n = 18$), stomach cancer ($n = 12$), liver cancer ($n = 3$) and cervical cancer ($n = 18$) were included.

*Food intake*

From the daily hospitalized cancer patients' menus, only 25 food items were obtained. White bread, chapatti, rice, whole maize flour, raw banana, cabbage, carrots, green pepper, onions, tomatoes, ginger, garlic, potatoes, beef, margarine, beans, salt, vegetable oil, eggs, chicken and amaranth, tea leaves, sugar, and milk are among the foods identified. Grains were consumed 90.2% of the time, vegetables 44.6 g/d (14 g dark green vegetables, 10.6 g red and orange vegetables) and 20 g legumes per day and meat 30.3 g/d.

*Dietary pattern*

Foods were classified based on the recommendation of a healthy dietary pattern to determine the amount of each food group and subgroup consumed by cancer patients during hospitalization. Whole grains accounted for 10%, vegetables 5% and legumes 2% of the total (Figure 1). Fruits, nuts, seeds, seafood, poultry and low dairy products were not present.

*Dietary diversity*

The mean dietary diversity score (DDS) was 3.8 based on observed consumption of foods from different food groups among cancer patients participating in this study.

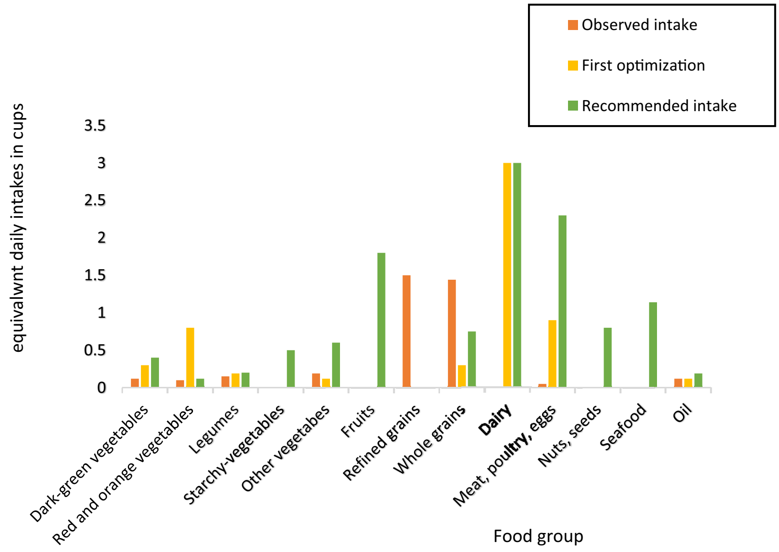


**Figure 1.**
Average daily food group consumption versus optimization among hospitalized cancer patient

*Nutrient intake*

Based on the observed intake, macronutrients distribution such as protein and fats met the recommended intake among patients. No subject met the requirement for some specific micronutrients, which increases the risk of cancer progression. These nutrients include iron and folic acid (Table 3). Other micronutrients were also low including calcium, vitamin B3, B12, vitamin C, vitamin E, vitamin K and beta-carotene. The healthy eating index for cancer patients revealed that the majority of these patients consume insufficient micronutrients. All patients did not meet the recommended zinc and selenium intakes 0.11 ± 2 mg and 4.02 mg, respectively. The average macronutrient intake including sugar was 8 ± 19.8 g, which exceeded the recommendation, fiber was below recommendation. Other nutrients intakes among cancer patients were as follows 0.3 mg beta-carotene 28.9 ± 1.4 folate, 460 ± 3.2 mg calcium, 0.4 ± 0.4 $\mu$g zinc, 250 $\mu$g copper, 1.5 ± 0.8 iron, 20.2 ± 1.5 $\mu$g selenium, 76 ± 3.1 mg vitamin C and 2585 ± 544 g sodium (Table 3).

*Cost constraints*

The daily average cost from the observed dietary pattern per patient intake was approximately 2782 Tanzanian shillings (US$1.20), and it was 2867 Tanzanian shillings (US $1.24) after optimization.

*Optimization of healthy dietary patterns*

The following were the diet optimization model results for amounts of each food group based on daily intake recommendations among cancer patients: 220 g vegetables and 250 g fruits 48.04 g whole grains (excluding refined grains), 473 ml/d (only low-fat milk and milk products) and 98.2, 30.3, 32.5 g for meat, poultry, eggs, seafood, nuts, seeds and soy products, respectively (Table 4). Whole grains accounted for 85 g, with vegetable subgroups increasing to 143, 158, 43 and 115 g for green-leafy vegetables, red and orange vegetables, legumes and other vegetables, respectively. The pattern obtained by optimizing existing dietary patterns was 0 g of fruits, three cups of dairy products, and 53.3 g of protein foods (Table 1).

**Table 3.** Comparison between average observed and optimized nutrients content from hospitals' food ingredients

| Nutrients | Recommended intake | Observed intake | Optimized nutrients content |
|---|---|---|---|
| calories *kcal* | 1500– 2200 | 2000 ± 1.3[b] | 1650 |
| Protein *g* | 39–100 | 42 | 45 |
| Fat *g* | 31.7–68 | 60.9 | 60 |
| Omega-3 *g* | 100–1.2 | 89.2 | 102 |
| Omega-6 *g* | 12–10 | 140 | 15 |
| Fiber *g* | 28–35 | 10 ± 7.5[a] | 30 |
| Sugars | 45 | 60b | 74[b] |
| CHO *g* | 45–300 | 334 ± 1.3[b] | 60 |
| Ca *mg* | 1320–2000 | *460 ± 3.2* | 2000 |
| Fe *mg* | 10–45 | 1.5 ± 0.8[a] | 113 |
| Mg *mg* | 240–500 | 98 | 364 |
| P *mg* | 1250–4000 | 2023 | 1800 |
| K *µg* | 4.5–1000 | 2.628 | 7.4 |
| Na *g* | 1000–2300 | 1139 | 1.2 |
| Zn *mg* | 8–40 | **0***0.4 ± 0.4*[a] | 12.4 |
| Se *µg* | 40–400 | 20.2 ± 1.5[a] | 60.1 |
| Cu *µg* | 700–4000 | *250* | 904 |
| Fluoride *mg* | 2–10 | 60.2 | 20 |
| Mn *mg* | 1.6–11 | 120.4 | 1.69 |
| Cr *µg* | 21 | 1.9 ± 1.2[a] | 21 |
| vit A *RE* | 1700–3000 | *980 ± 2.5*[a] | 2000 |
| VitB1 *mg* | 6–15 | 0.3 | 1.2[a] |
| B2 *mg* | 200 | 164a | *198* |
| B3 *mg* | 150 | *124*a | 1500 |
| B6 *mg* | 35 | 19.3 | 350 |
| B9 *µg* | 60–100 | 135 | 605 |
| B12 *µg* | 400–1000 | 28.9 ± 1.4[a] | 600 |
| Pant *µg* | 10.5–14 | 1.4a | 100 |
| Vit c *mg* | 3–67 | 0.4 | 4 |
| vit D *µg* | 50–2000 | 76 ± 3.1[a] | 500 |
| Vit E *mg* | 100 | 52.9a | 100 |
| vit. K *µg* | 600–1000 | 45.4 ± 2[a] | 603 |
| Choline *µg* | 9–28.9 | 12.9 | 90 |
| Biotin *µg* | 550–3500 | 18 ± 1.5[a] | 20 |

**Notes:** [a]Inadequate intake of targeted nutrients; [b]excess intake of a certain nutrient

## Discussion

The types of cancer and their prevalence differed between males and females, with males having colon, lung cancer, rectal cancer and esophageal cancer and females having breast cancer, cervical cancer and a few patients having tumors such as stomach and liver. These findings are in agreement with a similar study by furthermore, colorectal cancer was found to be more common in men than in women in the UK (White *et al.*, 2018).

Cancer patients undergo a variety of treatments, depending on the type and stage of cancer, such as surgery, radiotherapy and pharmacological therapy, and may experience a variety of side effects that impair dietary intake, such as loss of appetite, change in taste, vomiting, nausea, malabsorption of nutrients and fatigue (Kapucu, 2016; Roshanmehr *et al.*, 2022; Vanoh *et al.*, 2021), patients failed to complete the meal given. These side effects may put patients at risk of inadequate nutrient intake, resulting in malnutrition during or after treatment completion, other studies also have reported the effect of cancer on nutrition

**Table 4.**
Sample individual diet plans generated from an optimized dietary pattern for the management of cancer

| Diet plan 1 | Diet plan 2 | Diet plan 3 |
|---|---|---|
| Breakfast<br>1 ounce whole grains<br>½ cup fruit<br>½ cup dairy | Breakfast<br>1 ounce whole grains<br>1 cup dairy<br>1 ½ ounce protein foods | Breakfast<br>1 cup fruit<br>1 cup sairy |
| Morning snack<br>1ounce whole grains<br>1 cup fruit | Morning snack<br>1 cup fruit<br>½ cup dairy | Morning snack<br>1ounce grains<br>½ cup dairy<br>1 ½ ounce protein foods |
| Lunch<br>2 ounces grains<br>1 cup vegetables<br>½ cup fruit<br>1 cup dairy<br>2 ½ ounces protein foods | Lunch<br>2 ounces grains<br>1 cup vegetables<br>½ cup dairy<br>2 ounces protein foods | Lunch<br>2 ounces grains<br>1 cup vegetables<br>1 cup dairy |
| Afternoon snack<br>½ cup vegetables/vegetable salad<br>½ cup dairy | Afternoon snack<br>1 ounce grains<br>¼ cup nuts/ seeds | Afternoon snack<br>1 ounce grains<br>½ cup vegetables<br>½ cup dairy<br>2 ounces protein foods |
| Dinner<br>2 ounces grains<br>1 cup vegetable<br>1 cup dairy<br>3 ounces protein foods | Dinner<br>2 ounces grains<br>1 cup vegetables<br>1 cup fruit<br>1 cup dairy<br>2 ounces protein foods | Dinner<br>2 ounces grains<br>1 cup vegetables<br>1 cup fruit<br>2 ounces protein foods |

status of patients (Rios *et al.*, 2021; Salas *et al.*, 2017). Furthermore, the tumor's location and proximity to the gastrointestinal tract may have direct nutritional implications (De Melo Silva *et al.*, 2015). About 18% of hospitalized patients were malnourished on admission, this has supported the fact that 15–20% of cancer patients have been reported to be malnourished on at the time of cancer diagnosis, increasing to 85–90% at the terminal stage (de las Peñas *et al.*, 2019; De Melo Silva *et al.*, 2015).

The observed diets were deficient in vegetables, fruits, legumes and whole grains. About 90% of hospitalized patients consumed refined grains, primarily Ugali (maize stiff porridge), white rice, and white bread, similar study was conducted by Alaini (2019). Refined cereals have been linked to the development and progression of some cancers, including gastric and colon cancer as they have been reported to provide source of energy to tumor cells (Gaesser, 2020; Tullio *et al.*, 2021), The world cancer research fund has emphasized provision of whole grains to cancer patients (World Cancer Research Fund, 2018) so they were excluded from the model when creating diets for cancer patients. Overall, 44.6 g of vegetables were consumed daily, primarily kidney beans for legumes, cabbages, fewer amaranth leaves and mustard for green-leafy vegetables, and carrots for red and orange vegetables.

Meat consumption was 28.3 g/d, while fruits, dairy products, nuts, seeds, poultry and seafood were not available on all hospital menus (Table 1). However, monotonous commonly consumed diets with small amounts of fruits and non-starchy vegetables, fruits and legumes are reported to be deficient in essential nutrients, accelerating the progression of cancer complications to the patients (World Cancer Research Fund, 2018).

Dietary patterns have been reported to influence health outcomes more than individual nutrients or foods. The references and recommendations came from the World Health Cancer Research Fund, the ESPEN manual, WHO recommendations, and other authorized scientific-based publications. (Alaini *et al.*, 2019; Arends *et al.*, 2016; World Cancer Research Fund, 2018). The analysis of dietary patterns among cancer patients hospitalized in the studied hospitals provided an understanding of the available dietary patterns given to the patients with their treatment outcomes because diet is the main in complementing medications (Zhao *et al.*, 2021). The observed dietary pattern contributes to 17% of nutrient-dense foods, indicating that patients did not meet adequate nutrients as recommended.

The dietary diversity score based on the observed dietary pattern among cancer patients was 3.4. A dietary diversity score has been reported to be a good predictor of nutrient intake in individuals' daily food consumption (Arimond *et al.*, 2010). Our findings had less DDS showing that hospital dietary pattern did not include all food groups as per recommendation. Similar findings was observed from Alaini *et al.* (2019). Grains food groups such as rice, white bread and stiff porridge contributed the majority of the foods consumed. This has been shown by most of studies conducted to assess dietary pattern among cancer patients and other population, for instance Alaini *et al.* (2019) reported poor dietary pattern among the Malaysian population in relation to their risk to cancer, Raymond *et al.* (2018) reported inadequate dietary pattern among pregnant and lactating women; similarly, Mwanri *et al.* (2020) reported inadequate dietary pattern among pastoralists. Only 5% of vegetables consumed in hospitals were cabbages, kidney beans, and fewer leaf mustard leaves (Figure 1). Furthermore, 2% of patients consumed meat, while poultry, dairy, fish, seeds and nuts were not on their menus. It also has an impact on an individual's balanced diet (Arimond *et al.*, 2010; Bandoh and Kenu, 2017; Tavakoli *et al.*, 2016). A dietary diversity score of less than 4 indicates that diet variations are poor due to insufficient nutrient intake (Kennedy and Ballard, 2010).

Some nutrients, such as beta-carotene, folate, calcium, zinc, copper, iron, selenium and vitamin C, have been linked to lower risk of cancer by the World Cancer Research Fund because they contain antioxidant components that protect against free radicals and other carcinogenic compounds (Alaini *et al.*, 2019; World Cancer Research Fund, 2018). Poor nutrient intake is linked to a variety of complications in cancer patients including an increased inflammatory response, tumor progression that increases the risk of colorectal cancer, insufficient oxygen to the mitochondria, hemoglobin synthesis and immune function due to decreased T cell proliferation and interleukin production. These have been linked to increased morbidity and hospitalization. Readmissions, increased length of hospital stay and increased mortality worldwide. Many patients were on either readmission three times per month or stayed in hospital for mor than one week and more. Similar, it has been reported by Childs *et al.* (2019).

Adequate intake of these nutrients promotes immune function by activating enzymes such as glutathione peroxidase and selenoproteins, hemoglobin synthesis, cell proliferation, differentiation, transportation, and metabolism and expression in Deoxyribonucleic acid (DNA) methylation enzymes, decreasing tumor suppression genes and preventing oxidation and inflammation (childs *et al.*, 2019). However, the observed intake in this study was insufficient for these nutrients. Similarly, Alaini *et al.* (2019) found that cancer patients' intake of essential nutrients such as fiber, vitamin C and beta-carotene was low in comparison to the RDI. Similarly, Alaini *et al.* (2019) found that cancer patients' intake of essential nutrients such as fiber, vitamin C and beta-carotene was low in comparison to the RDI.

Diet optimization model results for amounts of each food group based on daily intake recommendations among cancer patients achieved 51.2% and 71.3% for daily recommended intake of fruits and vegetables, respectively. Green-leafy, red and orange vegetables, beans, peas and lentils were increased. Refined grains were excluded from the model due to high glycemic index. To promote adequate protein to cover the increased rate of metabolism, the model included 3 ounces of sea food and 2 cups of fat free dairy products like milk. In comparison to red meat, only poultry meat and meat without skin received more attention. To ensure adequate distribution of all food groups, nuts, seeds and soy products were increased by 50% (Table 5). As shown in Table 6, the dietary patterns developed had recommended calorie amounts and limits for cancer patients, with a maximum of 1800 kcal.

The model excluded deep-fried, grilled, barbequed and baked meats because they have been shown to produce high levels of carcinogenic by-products known as heterocyclic amines when heated to high temperatures (Alaini *et al.*, 2019). Excessive salt and salt-containing foods, sugar and oily foods, red meat and processed meats like bacon, ham, sausages, preserved foods like pickles, jams, salted mustard green and century eggs all contain carcinogenic nitrites (Alaini *et al.*, 2019; World Cancer Research Fund, 2018). The model also avoided alcohol and vitamin supplements because they can interfere with cancer treatments like chemotherapy.

Surprisingly, the optimal dietary pattern for cancer management was chosen from the model using food ingredients that meet the patient's nutritional requirements. Sample diet plans in (Table 4) using optimal dietary pattern generated diets with slightly varied food ingredients (inclusion of at least one food ingredient from each food group) to avoid repetition of the same diet per meal, which may affect patients' appetite. A variety of food ingredients were obtained by replacing the selected ingredients with new items or removing them entirely and allowing the linear goal programming to generate a new diet plan. Dietary patterns allow a variety of different food groups to enhance individuals' diet plans based on their preferences, cultures, affordability, accessibility and food available in their context.

**Table 5.** Optimized dietary pattern using additional food ingredients

| Food group | Subgroup amount (g) | Optimization | Recommended intake |
|---|---|---|---|
| Vegetables | Per day | *502* | 200–300 |
| | Dark-green vegetables/w | 300 | *36.4* |
| | Red and orange vegetables/w | 1105 | 75 |
| | Beans, peas and lentils/week | 302 | 43.8 |
| | Starchy vegetables/w | *143* | 140 |
| | Other vegetables/w | 804 | *50.9* |
| Fruits | g/d | 550 | 200–300 |
| Grains | g/day | *85* | *170* |
| | Whole grains | *85* | *85* |
| | Refined grains/d | 0.0 | 0.0 |
| Dairy | g/d | 360 | 720 |
| Protein foods | | | |
| | Meat, poultry/ w | *652* | *105* |
| | Eggs/w | *85.1* | *85.1* |
| | Seafood/w | *226* | 32.4 |
| | Nuts, seeds, soy products/w | *142* | 20.24 |
| Oils | | 27 | 27 |
| Total cost TSH (US$) | | *3256 (1.40)* | |

**Notes:** Optimization included all food groups to generate adequate nutrients except refined grains

| Nutrients | RDI | Model 1 | model 2 | Model 3 |
|---|---|---|---|---|
| calories *kcal*[a] | 2000–2200 | *1648* | 1816 | *1800* |
| Protein *g* | 56–100 | *6584* | 111 | *143* |
| Fat *g* | 36.7–8 | *1651* | 2443 | *267* |
| omega 3 *g* | 0.6–1.2 | *8311* | 76434 | *74909* |
| omega 6 *g* | 5–10 | *3683* | 37301 | 4593 |
| Fiber *g*[a] | 10–35 | *40.4* | 30.9 | 26.09 |
| CHO *g*[a] | 130–300 | *398* | 1339 | *377* |
| Ca *mg*[a] | 1000–2000 | *1057* | 1704 | 1989 |
| Fe *mg*[a] | 29–45 | *167* | 396 | 654 |
| Mg *mg*[a] | 420–500 | *597* | 798 | 906 |
| P *mg* | 700–4000 | 8987 | 864 | 2823 |
| K *µg* | 55–1000 | 3203 | 3233 | *1384* |
| Na *g* | 1000–1500 | 1332 | 486 | 1002 |
| Zn *mg*[a] | 11–40 | *730* | 957 | 991 |
| Se *µg*[a] | 55–400 | *483* | 259 | *384* |
| Cu *µg* | 900–10000 | *900* | 900 | 900 |
| Fluoride *mg* | 4–10 | 60.7 | 4 | 4 |
| Mn *mg* | 2.3–11 | 783 | 989 | 9743 |
| Cr *µg* | 30 | 4542 | 4119 | *5005* |
| vit A *RE*[a] | 900–3000 | 4245 | 4105 | *3650* |
| VitB1 *mg* | 1.2 | 765 | 747 | *50.2* |
| B2 *mg* | 1.3 | 543 | 701 | *625* |
| B3 *mg* | 14–35 | 56.7 | 55.8 | *25.8* |
| B6 *mg* | 1.5–100 | 100 | 100 | 715 |
| B9 *µg*[a] | 400–1000 | 887 | 875 | *583* |
| B12 *µg*[a] | 2.4–14 | 3.71 | 3.71 | *2.40* |
| Pant *µg* | 5–67 | 417 | 407 | 359 |
| Vit c *mg*[a] | 200–2000 | 1294 | 1535 | 1472 |
| vit D *µg* | 15–100 | 100 | 100 | 219 |
| Vit E *mg*[a] | 15–1000 | 1000 | 1000 | 1000 |
| vit. K *µg* | 90–28.9 | 218 | 2993 | 3749 |
| Choline *µg* | 550–3500 | 184 | 1388 | 8979 |
| Biotin *µg* | 3–4.5 | 31203 | 2743 | 2739 |
| *Cost constraint (TSH)* | | *4550* | *2700* | *5760.65* |

**Notes:** [a]Represents all nutrients optimized in these models

**Table 6.** Nutrient content among three produced models using optimized dietary patterns

## Conclusion

Findings of this study show that optimal dietary guidelines for managing cancer in hospitalized patents can be formulated using culturally acceptable food ingredients at minimum cost using linear programming approach.

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## Corresponding author

Happyness Amani Kisighii can be contacted at: amanihappy9@gmail.com