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Standard and special diets: algorithm to assist public nutritional administrators

Dietas padrão e especiais: algoritmo para auxiliar administradores públicos nutricionais

Dietas estándar y especiales: Algoritmo para ayudar a los administradores de nutrición pública

Jackeline Lucas Souza
Department of Accounting, Faculdade de Economia, Administração, Atuária e Contabilidade, Universidade Federal do Ceará (UFC), Fortaleza – Ceará (CE), Brazil. ORCID: https://orcid.org/0000-0002-0012-6717. E-mail: jackeline.souza@hotmail.com

Francisco Ivander Amado Borges Alves
Department of Accounting, Programa de Pós-Graduação em Administração e Controladoria, Universidade Federal do Ceará (UFC), Fortaleza – Ceará (CE), Brazil. ORCID: https://orcid.org/0000-0001-7633-2966. E-mail: ivandborges@gmail.com

Ana Gabrielle Peixoto Ferreira
Department of Accounting, Faculdade de Economia, Administração, Atuária e Contabilidade, Universidade Federal do Ceará (UFC), Fortaleza – Ceará (CE), Brazil. ORCID: https://orcid.org/0000-0003-0629-5076. E-mail: gabriellepeixoto999@gmail.com

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***Abstract:** Due to the advance of Covid-19, in-person classes were suspended, which led to the relaxation of the PNAE and made it possible to distribute "food kits" to students in the public school system. Despite the return of in-person classes, the need to provide school meals beyond the school term remains, due to the situation of economic vulnerability and food insecurity experienced by many students. With the increased responsibility for defining food items, this work proposes an algorithm to assist public administrators in formulating standard and special diets for high school students. The study, which has a quantitative and descriptive approach, uses linear programming. For the simulation, 89 foods were selected, and the nutritional needs of a high school student were identified, submitting the data to a linear optimization model. The result of the study is an algorithm that can be adjusted to generate balanced diets, meeting nutritional requirements, minimizing financial costs, and respecting restrictions on menu options.*

***Keywords**: algorithm; nutritional management; food kits; food insecurity.*

Resumo: *Diante do avanço da Covid-19, as aulas presenciais foram suspensas, o que levou à flexibilização do PNAE e possibilitou a distribuição de "kits alimentares" aos estudantes da rede pública. Apesar do retorno das aulas presenciais, permanece a necessidade de fornecer alimentação escolar além do período letivo, devido à situação de vulnerabilidade econômica e insegurança alimentar vivenciada por muitos estudantes. Com a ampliação da responsabilidade na definição dos gêneros alimentícios, este trabalho propõe um algoritmo para auxiliar administradores públicos na formulação de dietas padrão e especiais para estudantes do ensino médio. O estudo, de abordagem quantitativa e descritiva, utiliza programação linear. Para a simulação, foram selecionados 89 alimentos e identificadas as necessidades nutricionais de um estudante do ensino médio, submetendo-se os dados a um modelo de otimização linear. O resultado do estudo é um algoritmo que pode ser ajustado para gerar dietas equilibradas, atendendo às exigências nutricionais, minimizando o custo financeiro e respeitando restrições de opções nos cardápios.*

Palavras-Chave*: algoritmo; administração nutricional; kits alimentares; insegurança alimentar.*

Resumen: *Ante el avance de la Covid-19, las clases presenciales fueron suspendidas, lo que llevó a la flexibilización del PNAE y posibilitó la distribución de "kits alimentarios" a los estudiantes de la red pública. A pesar del retorno de las clases presenciales, persiste la necesidad de proporcionar alimentación escolar más allá del período lectivo, debido a la situación de vulnerabilidad económica e inseguridad alimentaria vivida por muchos estudiantes. Con la ampliación de la responsabilidad en la definición de los géneros alimenticios, este trabajo propone un algoritmo para apoyar a los administradores públicos en la formulación de dietas estándar y especiales para estudiantes de educación secundaria. El estudio, de enfoque cuantitativo y descriptivo, utiliza programación lineal. Para la simulación, se seleccionaron 89 alimentos y se identificaron las necesidades nutricionales de un estudiante de educación secundaria, sometiendo los datos a un modelo de optimización lineal. El resultado del estudio es un algoritmo que puede ser ajustado para generar dietas equilibradas, satisfaciendo las exigencias nutricionales, minimizando el costo financiero y respetando restricciones de opciones en los menús.*

Palabras clave: *algoritmo; gestión nutricional; kits de alimentos; inseguridad alimentaria*

1. Introduction

In light of the COVID-19 pandemic in Brazil, the country had declared a state of public emergency and established rules for the operation of essential and non-essential services. Including the suspension of in-person classes, the prohibition of events with large numbers of people, the reduction of public transportation, and the change in the rules for opening bars, restaurants, and other businesses (Beraldo, 2020).

The suspension of in-person classes has raised several concerns such as harm to learning, social interaction, and even significant risks to students' mental health and nutrition. For many Brazilian children, hunger is a daily and relentless reality (Amaral, 2021). Thus, the interruption of classes can compromise the nutrition of students, who often rely on school meals as their main meal. School meals are a right for all students in the public school system and a duty of the State, which must guarantee access to an adequate meal even in times of crisis (Pereira et al., 2020).

The National School Feeding Program (PNAE) provides school meals and nutritional education activities for students at all levels of public basic education. Furthermore, the program's legislation requires that the food be balanced and nutritionally adequate (so that legislation determines the minimum and maximum amounts of nutrients provided by school meals).

However, food prices are readjusted much more quickly, given inflation, than the PNAE resources are updated in the government budget. Thus, public administrators (nutritionists in charge, managers of public-school food funds, executive bodies, education departments and special legislative committees) are faced with the challenge of how to provide healthy food while maximizing the budget's usefulness. In other words, the impact of these administrators' management is on the quality of the food provided, both to satisfy the precept of the function they perform and to comply with the legislation and avoid administrative impropriety, especially the efficiency of the management of public resources and meeting social demands (Silva & Lima, 2023; Costa & Santos, 2021, Camargo & Guimarães, 2013).

From this scenario, the challenge arises of formulating an optimized diet, ensuring healthy and adequate nutrition for students, at the lowest possible cost. This problem can be solved by using linear programming applied to diet problems. Thus, the central question of this research is: what methodology can be applied to optimize the selection of items that make up a healthy diet, meeting the nutritional requirements of the PNAE and minimizing costs? Based on this issue, the objective of this work is to propose an algorithm to assist public administrators in formulating standard and special diets for high school students. The developed algorithm is flexible enough to be adapted to other stages of basic education.

In fact, public policy formulation involves the stage in which governments transform their purposes into programs and actions that will result in changes in the real world (Souza, 2006). School meals are a constitutional right guaranteed in Brazil, and the State must ensure them for all students enrolled in the public Basic Education network (Sperandio & Morais, 2021). However, the national school feeding program faces challenges for public management, among which academic literature mentions the composition of menus with varied foods, budgetary restrictions and logistics at times when classes are suspended (Issa et al., 2014; Pedraza et al., 2018; Pinto et al., 2024).

In addition to balancing budgets with the acquisition of nutritious foods, public administrators must also consider the fact that some students have special dietary needs, such as intolerances and allergies. Special menus are essential to ensure these students are not deprived of adequate nutrition (Cesar et al., 2018). In this way, program managers can achieve the constitutional principle of efficiency in public administration, as they seek to better spend resources to provide conditions for the entry, retention, and completion of studies for young Brazilians. Meanwhile, the PNAE (National School of Education) is one of the key programs for ensuring student retention in school, as it is essential to guarantee school meals that promote food and nutritional security (Ferreira et al., 2019; Pedraza et al., 2018).

Although Brazil has resumed in-person classes in public schools, this study remains relevant due to the growing demand for continued food distribution even during periods without classes, such as school vacations (Figueiredo et al., 2022). Several bills have already been proposed in this sense, such as Bill No. 3256/2019, which provides for the provision of school meals, basic food baskets or food cards during school vacations or recesses for students in the public school system of Guarulhos (SP) (Satelis, 2020).

Other proposals include Bill No. 0319.0/2020, which proposed the distribution of basic food baskets to students during the vacation period in Santa Catarina (Magagnin, 2020), and Bill No. 2735/18, approved in 2018 by the city councilors of Ariquemes, which created the Vacation Meal Program (Decom/Cma, 2018). In addition, in 2008, the municipality of Ibaté implemented the Vacation Meal project, regulated by Municipal Law No. 2,380, of March 6, 2008, guaranteeing food to all students in the municipal education system (Ibaté, 2008). These examples highlight the importance of school meals beyond the school term and reinforce the need for effective strategies to maintain them.

In addition to contributing to the formulation of diets in times of food vulnerability, this study is relevant because it offers a method to help define basic food baskets in cases where classes are suspended due to environmental disasters, social isolation, pandemics, or other public calamities. This work stands out for its practical and academic contributions. One of its main contributions is the definition and explanation of an algorithm that can be used by nutritional administrators in a simplified way, without requiring in-depth programming knowledge. Considering that these professionals, in general, are less familiar with programming, the algorithm was designed to be intuitive and require minimal editing, facilitating its application in food management. Thus, administrators will be able to define diets that meet the legal requirements for nutritional values, putting as little pressure on the government budget as possible.

It's worth noting that the developed algorithm can define diets that provide nutrients in adequate quantities for both individuals with and without dietary restrictions. This is particularly important because special diets (aimed at individuals with dietary restrictions) pose challenges for public administrators. Different menu types must be defined to include or eliminate certain foods that can cause health problems for students. Furthermore, school meals in public education institutions are a right of all students, regardless of their health conditions, and the government must adapt to providing a varied, balanced diet that meets students' needs. Lack of adequate nutrition cannot be a barrier to students remaining in the classroom.

Another merit is the approximation of academic and social contributions, since the study explores the problem of school meals based on a real case, showing that this issue remains relevant for academia and society. In addition, it demonstrates that solving this problem requires creativity in the design of robust codes, capable of finding solutions comparable to other techniques for defining basic food baskets. Finally, the research considers the current situation of high inflation, which puts pressure on government budgets, including those allocated to school meals.

2. Literature review

2.1. National School Feeding Program (PNAE)

Law No. 11,947 of June 16, 2009, states that the objective of the National School Feeding Program (PNAE) is to contribute to the biopsychosocial growth and development, learning, academic performance and the formation of healthy eating habits of students, through food and nutritional education actions and the provision of meals during the school year. Thus, during the school year, the PNAE transfers financial resources to states and municipalities to partially meet the nutritional needs of students.

To implement the PNAE, the Union transfers the resources monthly, from February to November, to the Executing Entities, which are the Education Departments of the States, the Federal District, the Municipalities and federal schools. The amount transferred per school day for each student varies according to the stage and type of education: R$ 1.37 for daycare students; R$ 0.72 for preschool students; R$0.86 for students in indigenous and quilombola schools; R$0.50 for elementary and high school students; R$0.41 for students in youth and adult education; R$1.37 for students enrolled in full-time education; still R$2.56 for full-time high schools; and, finally (Fundo Nacional de Desenvolvimento da Educação, 2024).

Regarding school menus, Law No. 11,947/09 establishes that the designated nutritionist is the technical manager (RT) and is responsible for preparing the menu using basic foodstuffs, respecting the eating habits, culture and food traditions of the locality (Brazil, 2009). If there are students who need individualized nutritional attention due to a specific health condition or status, the nutritionist must prepare a special menu based on medical and nutritional recommendations.

Special diets are intended for people with dietary restrictions, such as allergies and intolerances. Food allergy (FA) is an immune system reaction to certain foods, usually proteins or haptens (Mahan & Raymond, 2018). Foods that most frequently cause allergies include milk, eggs, nuts and seeds, shellfish, mollusks, fish, soybeans, and citrus fruits (Mendonça, 2014). Food intolerance (FI) corresponds to the biochemical inability to digest, absorb, and metabolize a specific component, as occurs in lactose intolerance, due to the total or partial absence of the lactase enzyme (Rangel et al., 2016). Food intolerances arise from excessive sensitivity to substances present in food, such as vasoactive amines found in fermented cheeses and chocolate, caffeine, lactose, fructose, and sorbitol present in chewing gum (Mendonça, 2014).

Since the beginning of the pandemic, Brazil has seen a 23.5% increase in the number of people experiencing food insecurity, reinforcing the importance of policies that guarantee basic access to food (Bentes & Moreira, 2021). As a measure to prevent the spread of COVID-19, classes were suspended in March 2020, and in order not to compromise students' access to school meals, the challenge of keeping the PNAE running began. Law No. 13,987/20 amended Law No. 11,947/09 and authorized the distribution of food items purchased to those responsible for students during the suspension of classes (Pereira et al., 2020; Brazil, 2020). However, it appears that there has been a deterioration in the quality of the food offered. (Lopes & Alves, 2021).

Furthermore, the literature suggests that the pandemic was particularly challenging for students. This is because, initially, there were budget cuts, contradictory guidelines on how to act during the pandemic, some implementing entities of the National Program for the Improvement of Adolescents (PNAE) had difficulty defining criteria for distributing food kits, and there were logistical problems in providing food to students (Corrêa & Helbig, 2025). It is worth mentioning that research suggests that there were academic losses due to the lack or poor distribution of food in schools, for those who depend on school for survival (Barbosa et al., 2022).

2.1. Diet problem and previous studies

Operational research (OR) uses the scientific method to investigate a problem, aiming to coordinate operations in an organization, and has broad application (Hillier & Lieberman, 2006). One of the techniques used by OR is linear programming or optimization (LP). According to Hillier and Lieberman (2006), the development of LP is considered one of the most important scientific advances of the 20th century. This technique emerged during World War II, when Dantzig formulated the structure to solve the problem of allocating limited resources to optimize objectives (Loesch & Hein, 2009).

Among the classes of LP problems is the diet problem, whose original objective is to determine a diet (omnivorous) that meets the minimum nutrient restrictions of a balanced diet, at the lowest cost. Its mathematical formulation considers a list of n foods, each of which has a unit cost and a quantity m of nutrients relevant to the diet. The goal is to obtain an adequate diet that provides the necessary amount of nutrients, at minimal cost. Thus, according to Tsuchiya and Furtado (2021), the original mathematical model is given by Eq. (1) to Eq(3).

$$\text{Min } Z = c_1x_1 + c_2x_2 + \ldots + c_nx_n \tag{1}$$

subject to

$$\begin{aligned} &a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n \geq b_1 \\ &\qquad \ldots\ldots \\ &a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n \geq b_m \end{aligned} \tag{2}$$

$$x_j \geq 0, j = 1, \ldots, n;\ b_i \geq 0, i = 1, \ldots, m \tag{3}$$

In a recent application, Oliveira et al. (2020) created a model to solve the problem of diet for the elderly, considering the foods usually consumed in the city of Monte Carmelo (MG), the average cost of these foods and the maximum and minimum recommendations for daily nutrient intake. For the study, 62 foods from the Brazilian Food Composition Table (TACO) and 19 nutrients were considered: Energy, Protein, Carbohydrate, Dietary Fiber, Calcium, Magnesium, Manganese, Phosphorus, Iron, Sodium, Potassium, Copper, Zinc, Vitamin A1 (Retinol), Thiamine, Riboflavin, Vitamin B6, Niacin and Vitamin C. A diet was obtained with a cost of R$ 6.92 in daily meals, considered cheap compared to the prices of meals in restaurants in the city.

Tsuchiya & Furtado (2021) worked with three types of vegetarian diets, considering six daily meals for one person, considering different amounts of nutrient intake and issues related to the bioavailability of Omega 3, Iron and Calcium, using integer linear programming. For the study, 143 foods from the TACO table and 10 nutrients were selected: Omega 3, Protein, Carbohydrate, Fat, Iron, Zinc, Calcium, Vitamin B12, Vitamin C and Omega 6. They used the price list for the northwest region of the Brazilian state of Paraná. Lacto-egg vegetarian, lacto-vegetarian and strict vegetarian diets were compared with the amount of foods needed to compose each diet and their daily cost, respectively: 22 foods and R$ 8.78; 26 foods and R$ 8.64; 29 foods and R$ 8.68. The study showed that as the diet becomes more restrictive, more food is needed to meet nutritional recommendations and the minimum cost increases.

Kripka & Peccati (2014) investigated a model to optimize the diet problem, aiming to determine a weekly diet that minimizes calorie intake. The research was conducted at the University of Passo Fundo, in the Brazilian state of Rio Grande do Sul. To do this, they conducted interviews with a nutritionist to obtain data on a real diet that would promote the nutritional reeducation of a patient. The nutritionist provided the foods with their quantities, as well as the minimum and maximum amounts of nutrients to be ingested per day, in addition to the percentage values per meal. A total of 57 foods and 11 nutrients were selected: Carbohydrates, Protein, Vitamin A, Vitamin B1, Vitamin B2, Vitamin B3, Vitamin C, Lipids, Calcium, Iron and Dietary Fiber. Using the LINGO software, the results obtained satisfied the restrictions for a healthy diet, with lower caloric values than those practiced by the nutritionist, making the programming diet even more efficient.

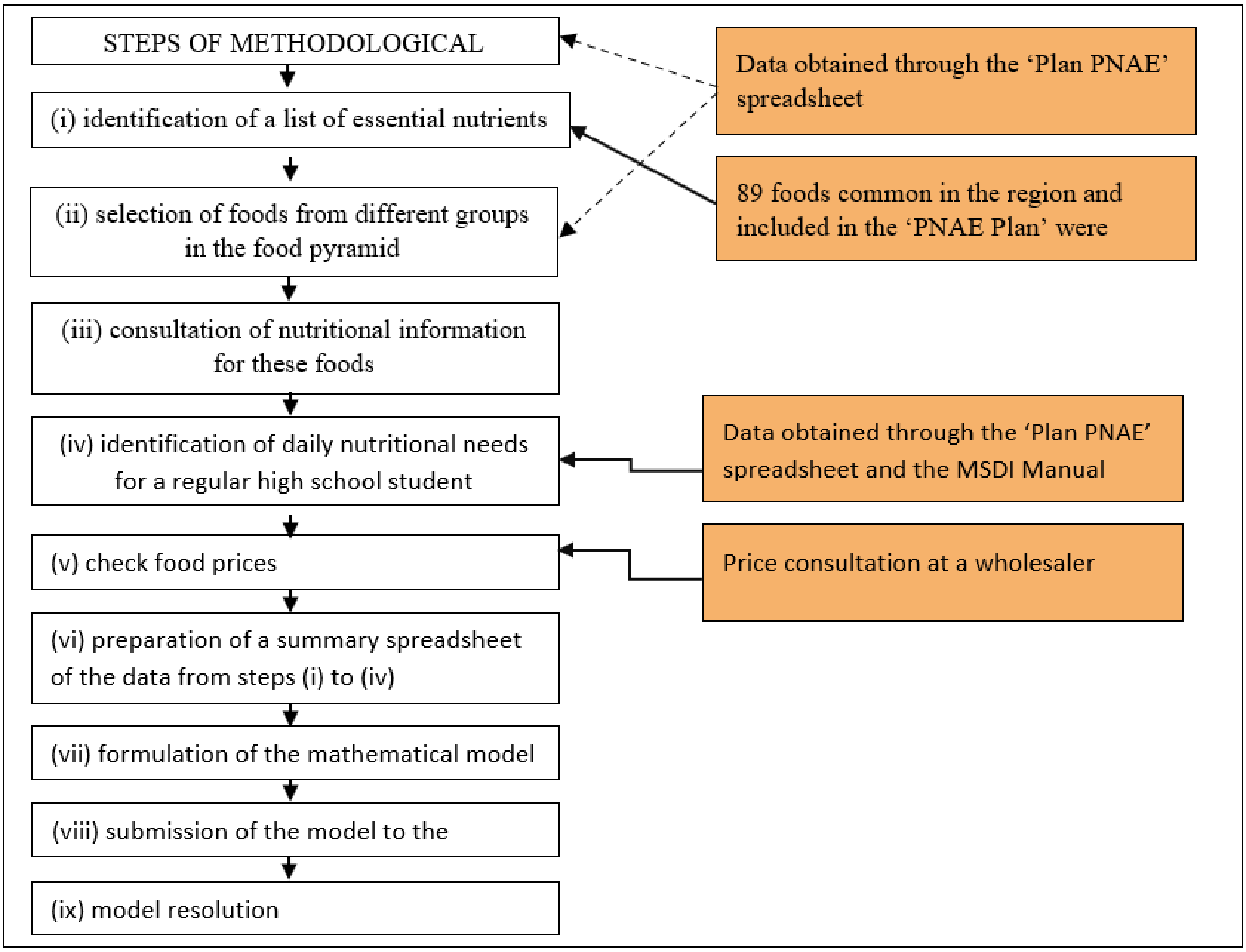
Zailani et al. (2019), in their study in Malaysia, demonstrated that the use of the integer linear programming technique would allow solving the problem of diet for Paralympic athletes with autism, minimizing the outlay on food. Although they do not present a specific diet, the authors developed a model that can be used from the selection of 426 foods, including several essential nutrients in a meal.

Türkmenoğlu et al. (2021) proposed a diet using cooked dishes. The authors collected data from the IT department of Istanbul Technical University, selecting 356 dishes. Two nutrients were considered in the study: energy and protein. To investigate the behavior in different types of users, two cases were designed. In the first case, 25-year-old male non-vegetarian and lacto-egg vegetarian users were considered. In the second case, a 65-year-old female user and a 25-year-old male user were considered. The results showed that the protein and energy intake values for lacto-egg vegetarians are lower than those for non-vegetarians. Furthermore, since the nutritional needs are different, the average protein and energy intake values for the 65-year-old female individual are satisfied with lower values than those for the 25-year-old male individual. The researchers concluded that the proposed model can be used to optimize specialized daily menus for different users depending on their preferences, age, gender, and body index.

3. Methodology

This research can be characterized as quantitative (regarding the problem), descriptive (regarding the objective) and uses linear programming/optimization as an analysis technique. The first two characteristics are consistent with linear optimization, since the latter consists of using calculations to solve a system of inequalities (restrictions), aiming to optimize an objective function. In this way, the quantities of food that satisfy nutritional needs at the lowest possible cost are demonstrated, having direct practical application in times when there is a normative determination to enable the delivery of food products to those responsible for students. The methodological design is developed in nine steps, as illustrated in Figure 1.

Figure 1 – Steps of the methodological design of the research



Source: Prepared by the authors (2025).

Steps (i) to (v) consider the data needed to define the objective function and the model restrictions; in turn, step (vi) gathers the collected data to (vii) formulate the mathematical model, which will be (viii) implemented in the algorithm to be (ix) solved. The list of essential nutrients was obtained from the Plan PNAE spreadsheet, which can be found on the website of the National Fund for the Development of Education (FNDE), in the section on support materials for nutritionists. Within this spreadsheet, there is a table with the foods arranged in rows and the nutrients organized in columns. Thus, the intersection of rows and columns informs the quantity of 100g of the food that provides a specific nutrient. Therefore, these quantities were divided by 100 to obtain the nutrition provided in unitary terms of one gram (1g) of food. In this way, all the nutrients shown in the spreadsheet were identified, except carbohydrates (solving step 1), that is: energy (in kilocalories - kcal), protein (in grams - g), lipids (g), calcium (in milligrams - mg), iron (mg), retinol (in micrograms - mcg), vitamin C (mg) and sodium (mg). Since a large part of the energy comes from carbohydrates, the purpose of not including this was to avoid redundancy. The adoption of this spreadsheet instead of other sources is justified because it is an official material, created by the program's funding agency precisely with the aim of subsidizing the choice of foods by the RT. The second and third steps can also be made using the PNAE Plan, as it contains a list of 583 food items (the term 'item' was used here because, in some cases, it was the same food in different presentations or cooking methods). From this list, 89 items (15.27% of the list) were selected, along with information on the nutritional quantity provided by each of them. This limitation in the final sample is due to the fact that some foods are prohibited or restricted from consumption by the program, others are difficult to access in the Southeast states, and still others are not sold by wholesalers. It was also required that all foods provide at least one of the nutrients from step i. Water was not considered among the items, as it is a basic resource for human survival and, therefore, it does not make sense to subject it to a selection method, just as salt was not considered, as it has no nutritional requirement, except for sodium.

Next, in step iv, the daily nutritional needs of a regular high school student (16 to 18 years old) were consulted, required by FNDE Resolution No. 06/20, except for sodium, verified through the MSD Manual, as this information was not available in the standard. The regulation states that school meals must provide 20% of the daily nutritional requirement in one meal for this type of student. Since the objective is to put together a biweekly kit to be distributed to those responsible for the students, these required quantities were multiplied by fifteen. An additional precaution was that the current Resolution presents these requirements in acceptable minimum and maximum ranges for some nutrients but omits information on vitamins and minerals - unlike the regulation for daycare centers, which presents the complete table. Therefore, the previous regulation was consulted to supplement this information.

The prices were collected from the website of Cornershop, a supermarket delivery company, accessing prices for the cities of São Paulo and Rio de Janeiro in a wholesale chain present in all Brazilian states, listed on the B3 and with over six decades of existence. However, it was not possible to collect the prices of all the selected foods through this website. Therefore, the chain's own website was also used. The choice of a wholesaler instead of a retailer or directly with suppliers is justified because the wholesaler charges competitive prices, makes negotiated prices publicly available and allows the government to purchase lots with larger quantities of food. Some considerations are important for data quality adjustments: (a) the negotiation prices were for different quantities per type of food, so all quantities were converted to grams and the price was divided by the total number of grams obtained, thus obtaining the cost of one gram of that food; (b) if the same item was sold as a unit or package (with several units inside), the one with the lowest unit price was always considered; and (c) whenever possible, preference was given to fresh fruits and vegetables instead of frozen or other forms.

All this information was tabulated in a Google Sheets spreadsheet (step vi), with a layout similar to that of the PNAE Plan, that is, the foods were organized in rows, with the nutrients provided by each of them and their respective converted prices arranged in columns. In addition, a row was added to record the daily nutrient requirements that the biweekly kit should provide. The food information is available in Appendix B: https://www.dropbox.com/s/5vxil51p5di8o6w/codigo%20e%20base%20de%20dados.pdf?dl=0

Once these data collection steps were completed, the theoretical mathematical model (vii) was formulated, which can be obtained by substituting the data from the previous step into functions (1) to (3) of the previous subsection. Where c_j corresponds to the price of one gram of the food x_j. In turn, x_j is a label for each of the 89 foods, that is, it varies from x_1 at x_{89}. The set of elements a_{ij} refers to the amount of nutrient i that one gram of the food x_j provides. The sum (2) can be divided into eight inequalities, each dedicated to one of the nutrients i and its daily intake requirement (b_i). Clearly, it would not make sense to represent in full how the substitution of the data from step vi into these functions would be, since there would be 89 unknowns in each of them, and the set of inequality (2), in fact, would be eight functions, since there are eight nutrients that have minimum and/or maximum quantities to be met by the food kit resulting from the model.

To increase the flexibility of the algorithm that intends to solve the model, in addition to the regular kit, additional models will be considered to serve students who have dietary restrictions, specifically for students with wheat allergy and milk allergy. To identify which foods (x_j) contain these ingredients (V) in their composition, two more columns will be added with binary variables (x_j^V) that assume the value 1 when the offending item is present and 0 otherwise, requiring the addition of a new restriction Eq.(4) to indicate that the kit cannot contain the offending ingredient. Necessary clarification for the reader: oats do not contain wheat, but, because producers grow the two crops close together, mutual contamination may occur. Therefore, oats received a score of 1 in the variable "presence of wheat".

$$x_j^V \neq 1, V = 1, 2 \quad (4)$$

So far, it has become clear that solving these models, which have an objective function (function 1), which minimizes the cost of 89 foods, respecting all restrictions (inequations 2, 3 and 4), is, at the very least, a complicated task for human beings. Hence the justification for the use of computational power via algorithms. And, as the problem becomes more complex (more variables, more restrictions, different types of restrictions, stochastic price ranges or nutritional requirements), algorithms that restrict themselves to approximate solutions (good solutions, but not exactly the best) will be necessary, given the computational limit. With the theoretical model in hand, one can proceed to implement this model in a linear optimization algorithm, programmed in Python, using the PuLP and Pandas libraries for resolution.

4. Results

Using the problem of diet, this article illustrates how to find the best food “kit” that meets nutritional needs at the lowest possible cost. This is particularly important because the PNAE legislation requires public administrators to use resources to provide a balanced diet, meeting a series of nutritional requirements, while the daily value provided for school meals is fixed.

Therefore, public administrators need to manage these financial resources to purchase food for students, maintain at least the minimum nutrition required by law and optimize the limited budget. Waste here would not be tolerated since it would disrespect the constitutional principle of efficiency (Silva & Lima, 2023; Costa & Santos, 2021, Camargo & Guimarães, 2013). Furthermore, it would also prevent the administrator from providing a diverse and healthy menu, that is, it would pervert the function entrusted to him, thus potentially leading to suspicion of administrative impropriety, in the last resort.

In this sense, what tool could be used by administrators to comply with the law, while at the same time not overloading the limited budget? Furthermore, the tool needs to be adaptable so that the manager can easily change the programming parameters, since food prices are constantly changing, given the recent high inflation. With this in mind, this article presents an algorithm applied to a simulated scenario for defining a food kit that considers the legal requirement for students attending regular high school (16 to 18 years old), that school meals must cover at least 20% of the daily values to meet the PNAE standards. Appendix B presents the values of the nutritional requirements and food prices for the cities of São Paulo and Rio de Janeiro.

For the implementation, Google Colab was accessed and the spreadsheet containing the data from Appendix B was imported. Then, the algorithm commands were inserted, presented in Appendix A (available at the same link as Appendix B). For the analysis, a diet for 15 days was established, since there are perishable foods with an approximate shelf life of two weeks. The maximum quantities of each selected food were also established: 100g. In addition, eight unique models were developed, each of which was developed twice (once for each city), resulting in 16 models, Table 1.

Table 1 – Comparison among models

<table>
<tr><th>Model</th><th>Maximum restriction on grams of each selected food</th><th>Restriction on maximum values for energy, protein and lipids</th><th>Restriction on wheat</th><th>Restriction on milk</th></tr>
<tr><td>1</td><td rowspan="2">No</td><td>No</td><td rowspan="4">No</td><td rowspan="6">No</td></tr>
<tr><td>2</td><td>Yes</td></tr>
<tr><td>3</td><td rowspan="6">Yes</td><td>No</td></tr>
<tr><td>4</td><td>Yes</td></tr>
<tr><td>5</td><td>No</td><td rowspan="2">Yes</td></tr>
<tr><td>6</td><td>Yes</td></tr>
<tr><td>7</td><td>No</td><td>No</td><td rowspan="2">Yes</td></tr>
<tr><td>8</td><td>Yes</td><td>No</td></tr>
</table>

Note: All models refer to food kits to meet nutritional needs for 15 days.
Source: Prepared by the authors (2025).

It was observed that, although models 2, 4 and 6 differ from models 1, 3 and 5, respectively, by the definition of maximum values for energy, protein and lipids, the selected foods and quantities, as well as the price of the kit, were not changed. Table 2 presents the results of models 1 to 6 for São Paulo (SP) and Rio de Janeiro (RJ).

Table 2 – Results of models 1 to 6

Food	SP		RJ	
	Models 1 and 2 (in g)	Models 3, 4, 5 and 6 (g)	Models 1 and 2 (g)	Models 3, 4, 5 and 6 (g)
Rice, type 1, raw	1020.39	988.73	-	-
Potato, sweet, raw	325.03	318.98	276.36	278.14
Coconut, raw	496.57	459.71	245.92	256.80
Beans, carioca, raw	202.34	226.35	43.49	30.10-
Cow's milk, skimmed	1639.68	1500.00	-	-
Lemon, Tahiti, raw	2573.63	1500.00	-	501.51
Flour, corn, yellow	-	-	1176.05	1193.23
Orange, pear, raw	-	767.55	1857.93	1500.00
Milk, cow, whole, powder	-	60.87	376.37	358.14
Price for 15 days (R$)	20.07	20.39	18.44	18.58
Daily value (R$)	1.34	1.36	1.23	1.24

Source: Prepared by the authors (2025).

In models 1 to 6, the cost of the food kit in Rio de Janeiro is always lower than in São Paulo. Although there is a difference in the list of foods, the nutritional values of the kits are very similar, all providing 543 kcal of daily energy. The main difference is in the sodium value: for models 1 and 2, the Rio de Janeiro basket provides 120.35 mg of sodium per day, while in São Paulo the value drops to 65.45 mg, a difference of 54.90 mg. For models 3 to 6, the Rio de Janeiro meal provides 117.47 mg of sodium, while the São Paulo meal provides 72.49 mg, a difference of 44.98 mg. Table 3 summarizes models 7 and 8 for both cities.

Table 3 – Results of models 7 and 8

Food	SP		RJ	
	Model 7 (g)	Model 8 (g)	Model 7 (g)	Model 8 (g)
Potato, sweet, raw	329.52	258.00	329.52	189.20
Coconut, raw	455.31	-	455.31	482.57
Beans, carioca, raw	1500.00	1323.94	1500.00	1189.82
Lemon, Tahiti, raw	1500.00	1500.00	1500.00	1500.00
Orange, pear, raw	764.52	-	764.52	-
Beans, black, raw	928.99	-	928.99	-
Brown sugar	-	688.11	-	360.88
Pork lard	-	202.83	-	-
Butterhead cabbage, raw	-	448.83	-	878.02
Price for 15 days (R$)	24.46	26.38	26.01	29.40
Daily value (R$)	1.63	1.76	1.73	1.96

Source: Prepared by the authors (2025).

Regarding model 7, the optimal meals found for both cities have the same selection of foods, quantities and nutritional values. The main difference between the kits is the cost, since in São Paulo the meal is cheaper than in Rio de Janeiro. For the results of model 8, it can be observed that the selection of foods is similar, except for some items. In São Paulo, the meal includes lard, while in Rio de Janeiro, raw coconut was chosen. The cost of the meal in São Paulo is also lower than in Rio de Janeiro. In nutritional terms, the number of proteins, lipids and calcium are identical in both kits. However, the energy provided in São Paulo is higher, with a difference of 98.70 kcal per day, possibly due to the presence of lard. In addition, the meal in Rio de Janeiro provides 97.71 mg of vitamin C per day, while in São Paulo 70.00 mg is provided, like the other models analyzed.

Comparing the models, the cheapest in terms of daily cost are models 1 and 2, with a cost of R$1.23 in Rio de Janeiro and R$1.34 in São Paulo. These models differ from the others in that they do not limit the maximum quantity of each selected food. This results in some foods with quantities exceeding 100 g per day, such as skimmed cow's milk and Tahiti lime in São Paulo, as well as yellow corn flour and pear orange in Rio de Janeiro. Among all scenarios, models 1 and 2 presented the highest sodium value in Rio de Janeiro, providing 120.35 mg, although this value does not exceed the maximum recommended limit for daily sodium consumption in a meal, according to Appendix B.

Regarding the variety of foods, models 1, 2, 7 and 8 present meals composed of six different items. Models 3, 4, 5 and 6 include eight foods in São Paulo and seven in Rio de Janeiro. Thus, the models that impose maximum quantity limitations and wheat restrictions offer kits with greater food diversity. However, despite this greater variety, the models do not present significant differences in relation to the other models about the nutritional values provided.

In terms of food selection, lard, black beans, brown sugar and kale were the least recurrent items in the assembled kits, appearing only in models 7 and 8, which stand out for their restriction on milk. The difference between models 7 and 8 is the limitation of nutritional values for energy, proteins and lipids. The foods present in all meals of these two models are sweet potato, coconut, carioca beans and Tahiti lime. After the imposition of the restriction of maximum values for energy, proteins and lipids, orange pear and black beans are no longer part of the meal, being replaced by lard, brown sugar and kale.

The foods that appear most frequently in almost all kits are raw sweet potatoes, black beans, coconuts and limes, probably due to their low cost and nutritional value. Sweet potatoes, for example, are responsible for providing 36.37 mcg of retinol per gram, an essential nutrient for growth, cell differentiation, the immune system, the visual cycle and the reproductive system. Limes, in turn, are the main supplier of vitamin C, providing 0.38 mg per gram. Black beans stand out for being the largest source of protein, calcium and iron, with 0.20 g of protein, 1.23 mg of calcium and 0.08 mg of iron per gram. Coconut, in addition to being the largest source of energy, providing 4.06 kcal per gram, also contributes 0.42 g of lipids and 0.15 mg of sodium per gram. These foods, with their nutritional variety, are ideal for creating an optimal diet that meets nutritional requirements at a reduced cost.

An additional challenge for public administrators is that the PNAE indicates that school meals must consider the needs of students, such as local customs and dietary restrictions, such as allergies and intolerances. The algorithm was also parameterized to consider these specificities, which are constant realities in practice. Regarding restricted diets, it is observed that the diet with milk restriction is the one with the highest cost. Despite this restriction, it offers the highest nutritional values in models 7 and 8, both in terms of energy, proteins and iron, and the lowest sodium value, providing only 7.73 mg of sodium per meal in model 7. Even with dietary restrictions, both diets meet the necessary nutritional needs, thus complying with the legislation in this regard. In addition, it is important to highlight that neither model includes meat, which makes the meals suitable for students who do not consume this type of food.

Finally, a real concern of public administrators is the cost of these meals. It is worth remembering that food should be healthy, but there are budgetary restrictions, and the price of food tends to change according to inflation. In this regard, when comparing the daily costs found with the amount transferred by the Union for each high school student (R$0.50 per school day), it is observed that the amount transferred is not enough to cover the cost of meals in any of the models analyzed, since the lowest cost found was R$1.23. Therefore, local management would need to cover, per student, at least R$0.73 per day. If there are any dietary restrictions, as in model 8 in Rio de Janeiro, the daily cost may increase to R$1.96, requiring an additional R$1.16. In addition, due to inflation, the cost may increase for program administrators and not using an optimization algorithm may lead to greater budgetary pressure.

In summary, the findings show that the cost of food baskets in Rio de Janeiro is lower than in São Paulo when there are no dietary restrictions. The special diet models offer a greater variety of foods, although they do not vary significantly in nutritional values, except for a few specific cases, such as a higher energy intake (in São Paulo) and vitamin C (in Rio de Janeiro) when milk and dairy products are restricted. Furthermore, foods in Rio de Janeiro generally contain more sodium, although they do not exceed the recommended daily allowance per meal. Finally, the amount of protein, lipids, and calcium tends to be virtually the same between the cities. These findings indicate the robustness of the algorithm for defining diets even under extremely restrictive conditions, important considerations for public administrators to be able to act efficiently in defining menus that balance the public budget while maximizing the quality of service provided to society through the nutrition of young students.

5. Conclusion

The objective of this study was to propose an algorithm that would assist public administrators in formulating standard and special diets for high school students. The relevance of the topic is evident, since it aims to ensure the food security of students not only during the school year, but also in future situations, such as the suspension of classes, when it may be necessary to provide basic food baskets.

The linear optimization technique was used to develop an optimal diet that would meet all the nutritional requirements required for a meal at the lowest possible cost. The essential nutrients were identified from the “Plan PNAE” spreadsheet. To demonstrate the application of this technique, 89 foods from different groups in the food pyramid were selected, whose nutritional information was consulted and their prices obtained from a wholesaler.

The resolution of the model resulted in the proposal of four different diets for each city, demonstrating the possibility of creating food kits with different restrictions. The presented algorithm aims to demonstrate the practicality of this methodology, allowing the nutritionist-administrator to use it only to update the initial parameters of the code with the actual data of the foods of interest. In this way, it is possible to generate several diet models in a short time by updating only the initial data. Thus, the work contributes to the optimization and acceleration of decision-making by nutritionist-administrators.

This research contributes theoretically by adding to the body of previous work demonstrating the importance of adequate nutrition for society, including in the context of public education policies. It corroborates previous studies, such as those by Tsuchiya and Furtado (2021), which indicate that restrictive diets tend to have greater food variability (which may be positive to some extent) and increased cost (a barrier to these special diets).It also argues that nutrition policies should consider developing food kits that take into account the specific needs of individuals, such as the minimum or maximum requirements for a given nutrient group, as practiced in the study by Türkmenoğlu et al. (2021) and Kripka & Peccati (2014).

Academic research has already identified challenges to providing adequate nutrition in schools, such as food diversification, budget constraints, and the logistics involved in food distribution (Issa et al., 2014; Pedraza et al., 2018; Pinto et al., 2024). This study recognizes that these challenges make decisions involving public nutrition management complex, especially when managers must be efficient in maximizing the quality of food offered while also managing public spending constraints. Therefore, the findings demonstrate that it is possible to envision public nutrition policies that adapt to overcome these challenges and thus provide a welcoming school environment for Brazilian students.

The limitations of this research include the number of foods considered, as well as the regional aspect, since the analysis was restricted to two locations in the country. Another limitation would be the possibility of including models in which food has a mandatory minimum participation in the food mix. Additionally, the perception and taste of the beneficiaries in relation to the kit provided were not considered, nor the possibilities of dishes that the food mix could generate. Other limitations that could be mentioned relate to the opinions of end users (such as students and families) on the acceptability of the proposed food list. If there are disagreements about the presented kit, the algorithm can be adjusted by defining minimum quantities for removing a food (amount of food X = 0) or for mandatory addition (defining a quantity in grams for the food).

Indeed, school nutrition directly interacts with public policymaking, and more than creating technical tools to train administrators, it is necessary to involve the community in these decisions. Involving school administration, food preparation staff, student representatives, and parent councils is crucial for any food proposal to be effectively implemented and more widely accepted by students. These limitations, however, represent opportunities for future advances in research on this topic.

Empirical validation is valid; therefore, future studies can apply the model to a school (whether a single school or a region) and monitor the results in terms of budget, nutrition, and the perceptions of the stakeholders (teachers, administrators, nutrition professionals, and students). Thus, rather than applying the model being a top-down decision, there will be an interactive process in which all participants can effectively work toward providing adequate and nutritious school meals. In fact, one cannot think of a next step other than expanded empirical validation, since this is one of the elements that reinforces the solution and makes it more attractive to public policy makers.

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