Linear Programming Applied the Quantitative Analysis of the Nutrients of the Menus Served in Full-Time Daycare Centers

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ABSTRACT
Palmas, the capital of Tocantins, has 84 educational units, 30 as Municipal Center for Early Childhood Education - CMEI and 22 receive full-time children. This quantitative cross-sectional study aimed to analyze the amount of nutrients from the menus served in the CMEI's for macro and micronutrients to compare with the minimum recommendations given by the PNAE for the age group from 1 to 3 years old who attend full-time. Four meals are served daily from menus proposed as recommended by the National Program of Scholarship Alimentation - PNAE, minimum of 70% of nutritional needs for the age group 1 to 3 years old. The menus were submitted to a linear programming model to optimize the best combination of the proposed foods to ensure the quantitative intake of some nutrients such as protein, carbohydrates, iron, fiber, calcium and calories. It was concluded that the menus offered meet the vast majority of the recommended macro and micronutrient values. It was observed that the monitoring of the nutrition professional has been of great importance in every process from the acquisition of food to the provision of meals to children using technological monitoring resources. Alternatively, to the model proposed by the ministry, it is recommended to use mechanisms with technological tools/solutions for conference and/or nutritional adjustments in the preparation of menus.

Keywords
Food and Nutrition Security, Menu, Day Care

1. INTRODUCTION
In order to support families and guide public policies, the World Health Organization (WHO) recommends that governments develop national guidelines on food and nutrition in accessible language for all people, taking into account the cultures of countries and their populations (BRASIL, 2019) [1]. In this context, the National Program of Scholarship Alimentation (PNAE), is the oldest program of the Brazilian government in the area of school feeding and Food and Nutrition Security (SAN), being considered one of the largest and most embracing in the world with regard to universal care to schoolchildren and the guarantee of the human right to adequate and healthy food (FNDE, 2013). [2]

The report published by UNICEF on The World Situation of Childhood 2019 [3] shows that at least one in three children under the age of 5 – about 250 million – is malnourished or overweight. In this sense, Mascarenhas and Santos (2006) [4] highlight that since childhood it is very important to maintain a healthy diet, since it is at this stage that the basis of human formation is constituted, which includes eating habits in addition to that, preschool and school children are at high risk of anemia for iron deficiency. In this sense, Biscegli (2007) [5] says that it is important to provide adequate nutrition and care that result in improvements in the use and learning capacity, makes not only school content, but that support with food is paramount in contributing to child development.

Thus, this study presents the quantitative analysis of nutrients from the menus served in full-time day care centers, with four meals (breakfast, lunch, snack and dinner) based on the nutritional proposal recommended by the National School Feeding Program - PNAE, minimum of 70% of nutritional needs for the age group considering at least three meals.

2. METHODOLOGY
Initially, meetings were held with the technical team that prepares the menus and spreadsheets of management of them. The technical team of the nutrition sector of the Municipal Department of Education provided the menus, including school units in the category of full-time daycare in Palmas/TO, for children from 1 to 3 years old, offering four meals (breakfast, lunch, afternoon snack and dinner). The menus were prepared with the objective of supplying 70% of the daily nutritional needs of the child, as recommended by the PNAE (Law nº. 11,947/2009). [6]

To verify the nutritional quantity from the preparations offered, the mathematical model of linear programming supported by the GNU linear programming kit - GLPK was applied to show the optimized combinations of the data, in line with the recommendations of Resolution/CD/FNDE No. 26 of 2013, which provides for the age group of students, consists in the optimization of a certain problem with many possible solutions, through the maximization or minimization of a linear function (LARROSA et al., 2011) [7], subject to limitations in the amounts of required products or available resources (COLUSSI et al., 2013) [8].

After defining the variables, the objective function reveals the adjustment of the menu, prioritizing foods that meet the daily nutritional needs of children. To evaluate the adequacy of the executed menus, the results obtained and described mathematically were compared, having as parameters the estimated numbers for the following indicators and by the following organizations: a) energy value (energy): United Nations Food and Agriculture Organization (FAO, 2001); b) carbohydrates, proteins and lipids: World Health Organization (WHO, 2003); c) iron and vitamin A: Reference of Dietary Intake (DRI) of the American Institute of Medicine (IOM,

1997, 2000 and 2001), adapted source EAR - Estimated Average Requirement, as it is recommended to evaluate the adequacy and planning of dietary intake of population groups.

The variables used in the model were determined based on the menu performed in the units, considering the amounts of calories, carbohydrates, proteins, lipids, iron and vitamin A present in the Brazilian Table of Food Composition (TACO). [9]

3. RESULTS AND DISCUSSIONS

The values presented in tables 1, 2, 3 and 4 represent the optimization of the best combination of the variables (foods/preparations) exposed in the linear programming model for the menus practiced at school, as well as the borderline values proposed by the FNDE.

Table 1. Values generated from linear programming model

Nutrients	MENU 1 - Values optimized by linear programming model					Total	Weekly Average
	Monday	Tuesday	Wednesday	Thursday	Friday		
Protein (g)	21,900	11,181	21,900	21,900	21,900	98,781	**19,756**
Lipids (g)	9,282	5,000	15,418	14,189	17,500	61,389	**12,278**
Carbohydrate (g)	114,900	87,579	107,447	114,900	94,529	519,355	**103,871**
Fiber (mg)	5,701	6,347	8,321	6,857	3,988	31,214	**6,243**
Ca (mg)	154,774	140,020	202,151	100,000	185,697	782,642	**156,528**
Mg (mg)	45,745	40,429	40,807	53,696	56,000	236,677	**47,335**
Fe (mg)	1,778	1,400	2,273	2,561	2,968	10,980	**2,196**
Zn (mg)	1,677	2,100	1,612	1,435	1,778	8,602	**1,720**
Vit C (mg)	12,000	12,000	12,000	12,000	12,000	60,000	**12,000**
Vit A (mcg)	88,300	89,860	108,300	75,400	86,900	448,760	**89,752**
Energy (Kcal)	**630,738**	**440,040**	**656,150**	**674,901**	**623,216**	**3.025,045**	**605,009**

Table 2. Values generated from linear programming model

Nutrients	MENU 2 - Values optimized by linear programming model					Total	Weekly Average
	Monday	Tuesday	Wednesday	Thursday	Friday		
Protein (g)	13,544	21,900	21,900	21,900	21,900	101,144	**20,229**
Lipids (g)	5,939	17,500	10,395	17,500	12,535	63,869	**12,774**
Carbohydrate (g)	114,900	72,169	114,900	96,574	114,900	513,443	**102,689**
Fiber (mg)	3,966	6,032	4,319	6,707	6,288	27,312	**5,462**
Ca (mg)	116,537	108,784	135,993	180,281	117,165	658,760	**131,752**
Mg (mg)	27,766	56,000	167,545	51,468	19,498	322,277	**64,455**
Fe (mg)	4,900	1,400	1,636	3,030	1,807	12,773	**2,555**
Zn (mg)	2,100	1,946	1,348	2,100	1,264	8,758	**1,752**
Vit C (mg)	12,000	12,000	12,000	12,000	12,000	60,000	**12,000**
Vit A (mcg)	101,010	101,030	100,030	99,900	99,860	501,830	**100,366**
Energy (Kcal)	**567,227**	**533,776**	**640,755**	**631,396**	**660,015**	**3.033,169**	**606,634**

Table 3. Values generated from linear programming model

Nutrients	MENU 3 - Values optimized by linear programming model					Total	Weekly Average
	Monday	Tuesday	Wednesday	Thursday	Friday		
Protein (g)	21,900	9,851	21,177	21,900	21,900	96,728	**19,346**
Lipids (g)	14,541	17,202	6,124	5,598	14,863	58,328	**11,666**
Carbohydrate (g)	114,900	105,610	114,133	114,900	114,900	564,443	**112,889**

Fiber (mg)	8,356	8,082	9,029	5,491	3,846	34,804	**6,961**
Ca (mg)	183,891	202,507	136,313	142,467	171,618	836,796	**167,359**
Mg (mg)	56,000	56,000	56,000	48,789	48,239	265,028	**53,006**
Fe (mg)	4,301	2,834	1,400	1,400	2,258	12,193	**2,439**
Zn (mg)	1,993	1,517	1,942	1,485	1,523	8,460	**1,692**
Vit C (mg)	12,000	12,000	12,000	12,000	12,000	60,000	**12,000**
Vit A (mcg)	88,800	108,200	108,800	99,900	99,800	505,500	**101,100**
Energy (Kcal)	**678,069**	**616,662**	**596,356**	**597,582**	**680,967**	**3.169,636**	**633,927**

Table 4. Values generated from linear programming model

Nutrients	**MENU 4 - Values optimized by linear programming model**					**Total**	**Weekly Average**
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**		
Protein (g)	21,900	21,900	17,978	21,900	21,900	105,578	**21,116**
Lipids (g)	12,103	5,000	11,565	17,061	17,500	63,229	**12,646**
Carbohydrate (g)	114,900	114,900	114,900	114,900	59,186	518,786	**103,757**
Fiber (mg)	6,022	7,834	6,468	3,800	5,660	29,784	**5,957**
Ca (mg)	145,368	124,435	164,425	167,307	139,518	741,053	**148,211**
Mg (mg)	36,272	36,775	38,468	28,224	39,235	178,974	**35,795**
Fe (mg)	1,604	1,880	4,042	2,427	3,273	13,226	**2,645**
Zn (mg)	1,761	2,017	2,100	1,101	1,113	8,092	**1,618**
Vit C (mg)	12,000	12,000	12,000	12,000	12,000	60,000	**12,000**
Vit A (mcg)	108,980	99,800	89,900	72,900	73,800	445,380	**89,076**
Energy (Kcal)	**656,127**	**592,200**	**635,597**	**700,749**	**481,844**	**3.066,517**	**613,303**

The model indicated the need to adjust the non-energy nutrients, vitamins and minerals (calcium, zinc, iron, vitamin C and A) to ensure the recommended nutritional intake. In this context, PEDRAZA, et al. (2013) [10] states that these micronutrients become fundamental for the developing child so that there are no sequelae in both, the growth and performance of cognitive functions

Iron deficiency is the most prevalent nutritional deficiency in the world, affecting mainly children of early age, and zinc is essential for growth, development and immune function (SARNI, et al, 2010) [11]. Iron, is a mineral that prevents anemia, it had it´s values demonstrated by the coordination of nutrition within normal levels, however, with the adjustments of a more protein and rich in iron food, found by the program used for menu planning, this nutrient reduced, and in a substitution proposal following the model optimized by linear programming, it is suggested the inclusion of low-cost alternative foods such as chicken mellow. Esposito (2009) [12] after analyzing, cost, protein and iron content of this food (3.19mg/100g-Table IBGE-2011) concluded that the inclusion of the chicken gizzard would benefit greatly, and would increase the nutritional quality of school meals, especially in public schools, where low-income children are found and who often suffer from malnutrition and practically perform their daily meals in schools.

The energy values shows in the weekly averages values below the necessary contribution for the children considering the 70% proposed. Moreover, also on the calories it is noted that: Friday of the 4th menu of CMEI: sandwich, rice, beiju, potato, beetroot twice. Or on Friday of the 3rd menu: hot dog bread, rice, beans twice, potato, corn, hominy or even on Monday of the 3rd menu: rice couscous, rice, bean tutu, pumpkin, beetroot, bread; all contribute to increasing calories, but not proportionally to micronutrients or nutritional quality. In fact, they could contribute to increased weight, glycemia and low iron absorption. As a reflection of high energy consumption, there is a higher frequency of overweight and obesity, in addition to micronutrient deficiencies due to the low quality of the diet. (CARVALHO. et al,2015) [13].

Observing the amounts of calcium, values well below the recommended range, on average from 150 to 200 mg when the recommended is 350 mg per day, for the age group under study. Thus, the menu requires an intervention to recombine the food in order to achieve this nutrient.

The fibers presented a low weekly average (between 5g and 6g) in view of the recommended value of 13.3g per day. They are nutrients that contribute to the optimization of food combinations and as a suggestion, once again the Brazilian Savanna has to contribute to the fruit of bacabeira. SILVA, et al, (2019) [14] describe the fiber content of bacaba (51 grams per 100), even suggest its inclusion in school feeding not only by nutritional value, but also by low cost and regionality. In the FNDE guidelines Article 2 on school feeding item I says that:- the use of healthy and adequate eating, comprising the use of varied, safe foods that respect culture, traditions and healthy eating habits, contributing to the growth and

development of students and to the improvement of school performance, in accordance with their age group and health status , including those in need of specific attention. (BRASIL, 2009) [6].

Bernaud and Rodrigues, 2013 [15] presented in a review study that the consumption of soluble fiber can reduce the postprandial glycemic response when consuming carbohydrate-rich meals and that the insoluble fiber intake from cereals and whole grains is consistently associated with the reduced risk of type 2 DM (Diabetes Mellitus), and therefore the intake of this nutrient is extremely recommended.

Considering that 1 gram of lipid provides 9 Kcal and that the weekly averages presented (Chart 8, 9 and 10) still allow room for increase in the amounts of this nutrient, it is suggested the insertion in the menu of Brazilian Savanna´s fruits as foods such as the nuts found abundantly in the region (cashew, baru, pequi) and with the advantage of promoting production to family farmers. MARTINS, et al., (2019) [16] present baru as a good alternative for healthy eating, demonstrating that the almond is characterized by being rich in lipids with 41mg in 100grams of the product.

The feeding habit for preschool children becomes an important factor for future eating patterns for both healthy nutritional status and predicted chronic problems. In this context, the National School Feeding Program (PNAE) aims to contribute to the growth and biopsychosocial development, learning, school performance and the formation of healthy eating habits of students, through food and nutrition education actions and the provision of meals that cover their nutritional needs during the school period. (BRASIL,2009) [6].

The menus under study seem to meet the recommendations of the PNAE in the scope of the variety of foods offered and in the use of regional preparations and even of own culinary creation, the result of internal dynamics as explained by the professionals of the sector. What is certain is the need for redistribution of food and/or preparations on weekdays so as not to concentrate nutrients.

By observing in Chart 14, the optimized values generated from the linear programming for the same menus demonstrated the reduction of protein foods, changing the total kilocalories and consequently increasing the levels in percentage of carbohydrates, notwithstanding the percentages, in grams having remained. It should be emphasized, however, that this change continued to keep carbohydrate levels within the limits recommended by the FNDE.

Table 5 -Weekly averages of nutrients optimized by linear programming

Optimized Values	Total	Average of distributed nutrients per standard week		
	Energy (Kcal)	Protein (g)	Lipid (g)	Carbohydrate (g)
Week 1	605,009	19,750	12,270	103,870
	86,43%	**13,06%**	**18,25%**	**68,67%**
Week 2	606,634	20,220	12,770	102,680
	86,66%	**13,33%**	**18,95%**	**67,70%**
Week 3	633,927	19,340	11,660	112,880
	90,56%	**12,20%**	**16,55%**	**71,23%**
Week 4	613,303	21,110	12,640	103,750
	87,61%	**13,77%**	**18,55%**	**67,67%**

When observing the percentage of insertion of a food in the diet so that the combination proposed by the nutrition team is optimized and reaches the necessary nutrient sum, the linear programming model indicated foods in small amounts or even zeroed for not adjusting in the overall calculation of nutrients. Thus, it is important to highlight that the need to rethink the food or preparation to be offered without, however, promoting a disharmony in the combination, but making a lot of storage for the person who prepares the food.

4. CONCLUSION

The menus offered in full-time day care centers for the age group of 1 to 3 years old, reach the vast majority of macro and micronutrient values aligned with that recommended by FNDE. However, the linear programming model allowed the identification of the amounts of nutrients used in relation to the recommended quantities and, concomitantly, presented suggestions to rebalance the analyzed menus as close as possible to the recommendation. The model can be applicable in the planning and evaluation of the menus allowing nutritional adjustments as well as the production of meals using recommendations and economic monitoring.

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