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Carbon, Water, Ecological Footprints, Energy and Nutritional Densities of Omnivore and Vegan Culinary Preparations

Thadia Turon Costa Da Silva[1], Bianca Biscacio Falco[1], Isis Gomes De Castro[1], Rita Barreira Zanon[1], Juliana Vidal Vieira Guerra[1], Karina Yuriko Yaginuma[2], Verônica Oliveira[1], Aline Gomes De Mello De Oliveira[1]

[1]Department of Nutrition and Dietetics, Josué de Castro Nutrition Institute, Federal University of Rio de Janeiro, Rio de Janeiro, Brasil
[2]Math and Statistics Institute, Fluminense Federal University, Niterói, Brasil
Email: thadiaturon@nutricao.ufrj.br

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Abstract

This study aimed to evaluate energy and nutritional densities, water, carbon and ecological footprints, cost, of omnivorous and vegan main courses served in a university restaurant in the city of Rio de Janeiro. A cross-sectional, analytical study was conducted with 40 main dish-type preparations, 20 of which are omnivorous and 20 vegans, served at lunch, to assess energy and nutritional densities, carbon, water and ecological footprints and cost of preparations. We propose a healthy and sustainable preparation index (HSPI) to evaluate from the list, the best preparation options considering the nutritional quality combined with the impact that the food causes on the environment. Preparations with the highest HSPI were considered the best options because they have a good relation between the nutritional profile and the environmental impact. **Results:** Regarding energy (ED), nutritional (ND) densities and water, carbon and ecological footprints, omnivorous preparations presented much higher values when compared to the vegan ones. The omnivorous preparations had the highest average cost (R$ 3.44). Regarding the HSPI, vegan preparations showed better rates than omnivorous preparations. Food services should promote healthy and sustainable choices by offering menus with low energy density preparations, high nutritional density, and low environmental impact, considering local realities and customer needs. **Conclusion:** This study was able to evaluate the best preparation options, considering the nutritional profile and the food impact on the environment, using health and sustainable indicators. Obtaining indicators of preparations regarding healthiness and sustainability, in practice, translates environmental aspects in menu planning, which contribute to changes in food consumption

patterns in food services, in addition to contributing to the reduction of the environmental impact. In this way, they can be used as tools added to the menu planning process for the analysis of the environmental impact of menus, in addition to nutritional and qualitative aspects.

Keywords

Food Services, Menu Planning, Environment, Carbon Footprint, Water Footprint

1. Introduction

Current food systems contribute to driving not only obesity and malnutrition pandemics, but also generate 25% - 30% of greenhouse gas (GHG) emissions, threatening public health and the planet [1]. In order to minimize these effects, profound changes are needed, mainly in the way agribusiness and the large food industries operate and organize themselves, with the strengthening of local, national and global public policies, to guarantee food and nutritional security, environmental sustainability and resilience of the planet [2] [3]. Among the main alternatives indicated to minimize greenhouse gas emissions are: the adoption of healthy diets with reduced consumption of ultra-processed foods, prioritization of land use for fair, clean and sustainable agriculture [4] [5] [6].

Adequate and healthy food must come from a socially and environmentally sustainable food system, considering, therefore, the impact of the ways of producing and distributing food on social justice and the integrity of the environment [7]. And it is recommended that natural or minimally processed foods, in great variety and predominantly of plant origin, be the basis of a nutritionally balanced, tasty, culturally appropriate diet that promotes a socially and environmentally sustainable food system [7]. However, it is observed that in the diet of the Brazilian population, the consumption of fruits and vegetables is still below the recommendations of the World Health Organization (WHO), and represents only 3.7% of the total calories consumed, despite natural foods and minimally processed account for nearly half of the total calories available [8] [9]. In addition, there is also a progressive increase in the consumption of processed and ultra-processed foods, which from 2002 to 2017 increased from 12.6% to 18.4% of calories [10].

In this sense, the potential of food services in propagating the adoption of healthier eating practices and habits is recognized, as well as the impact on the food system, due to the use of a large volume of food used to produce meals on a daily basis. Thus, careful planning of menus, which translates into the evaluation of nutritional criteria, quality, and food footprints, corroborates the production of meals aligned with sustainable agrifood systems [4] [11]. Thus, obtaining environmental indicators for the management of food services makes it possible to compare the impacts of meal production in relation to the environment, making it possible to minimize the consumption of natural resources or introduce tech-

nologies that reduce or eliminate the pollution load.

As indicators of menu sustainability, there are the water, carbon and ecological footprints of both food and culinary preparations [12]. Footprints propose to measure, respectively, the total amount of water used directly or indirectly during the product and service life cycle phases; the total amount of greenhouse gas emissions that are directly or indirectly caused by the activity or are accumulated over the course of the life cycle; in addition to assessing the consumption pressure of human populations on natural resources, which allows comparing different consumption patterns, and verifying whether they are within the ecological capacity of the planet [13] [14] [15].

When planning menus, the selection of healthy, sustainable, and low-cost preparations is a major challenge for nutritionists who work in the collective food sector and is essential for the promotion of health and environmental care, which reinforces the importance of this study [13]. Therefore, the objective was to evaluate the energy and nutritional densities, water, carbon and ecological footprints, and the cost, of omnivorous and vegan main courses served in a university restaurant in the city of Rio de Janeiro.

2. Materials and Methods

This is a cross-sectional study, carried out from the menu of a university restaurant in the city of Rio de Janeiro served for 01 month to evaluate the cost, energy density, nutritional density, and water, carbon and ecological footprints of 40 main courses served at lunch, with 20 omnivorous preparations, based on beef, poultry, fish or pork and 20 vegan preparations.

2.1. Food Service and Menu

The university restaurant is open from Monday to Sunday and produces, on average, 8000 meals a day, for lunch and dinner for university students and employees. The production process of meals is carried out by a third-party company, which is responsible for all stages, from the acquisition of raw materials to the distribution of ready-to-eat meals. The standard menu is of the popular type and consists of: starter, side dish, main course (omnivore), vegan option for main course, dessert and drink. The menu is planned by the outsourced company's nutritionists together with the fiscal nutritionists of the said university's food system, considering the specifications of the contract's term of reference.

2.2. Cost, Energy and Nutritional Density of Preparations

To calculate the cost of preparations, the gross per capita values of food recorded in the daily requisition form for goods and the 2019 price quotations from CEASA, Fundação Getúlio Vargas and on food supplier websites were used.

The energy value of the preparations was calculated using food centesimal composition tables [16] [17] [18] [19]. And the energy density (ED) of the respective preparations was calculated by dividing the total energy value of the preparation (Kcal) by its weight in grams (g) as described by RICARDO &

CLARO (2012). ED is defined as the amount of energy provided per gram of food weight [17]. The preparations were classified according to the Centers for Disease Control and Prevention (CDC) as: high energy density (4 to 9 kcal/g), medium energy density (1.5 to 4 kcal/g), low energy density (0.7 to 1.5 kcal/g) and very low energy density (0 to 0.6 kcal/g) [20] [21].

To calculate the nutritional density (ND), which refers to the nutritional content of the preparation in relation to the number of calories it provides, the following micronutrients were considered: retinol equivalents, vitamin D, vitamin E, thiamine, riboflavin, vitamin C, niacin, vitamin B6, vitamin B12, folate, phosphorus, iron, potassium, calcium, magnesium, selenium and zinc. To calculate the ND of the preparation, the content of vitamins and minerals present in each food were added up and, subsequently, the value of the sum of micronutrients was divided by the weight of the portion of the preparation [19]. It was decided to use the portion size to calculate the nutritional density of the preparations, as Drewnowski & Fulgoni (2014) [22] report that models based on portions performed better than those based on 100 g of food.

2.3. Water, Carbon and Ecological Footprints

The calculation of water, carbon and ecological footprints was performed using Equation (1). The values from the table proposed by Garzillo *et al.* (2019) [13] with the footprints of food and culinary preparations consumed in Brazil. The results obtained for nutritional density, energy density, cost and environmental footprints were described in mean, minimum and maximum values. In addition, costs were compared between preparations served with meat and vegan options.

$$\text{Preparation footprint} = (\text{serving weight} \times \text{footprint (water or carbon or ecological)})/100 \quad (1)$$

2.4. Healthy and Sustainable Preparation Index and Statistical Analysis

Based on the nutritional density and the values of the water, carbon and ecological footprint of the preparations, a set of indexes was calculated which were called the healthy and sustainable preparation index (HSPI) based on the study by Smedman *et al.* 2010 [14]. The HSPI was proposed to list the best options for preparations taking into account the nutritional quality combined with the impact that the food has on the environment. The preparations that presented the highest HSPI-h, HSPI-c, HSPI-e were considered the best options because they presented a better combination of nutritional profile and lower environmental impact. HSPI calculations were performed from Equations (2).

$$\begin{aligned} \text{HSPI-h} &= \frac{\text{Nutritional Density}}{\text{water footprint}} \\ \text{HSPI-c} &= \frac{\text{Nutritional Density}}{\text{carbon footprint}} \\ \text{HSPI-e} &= \frac{\text{Nutritional Density}}{\text{Ecological footprint}} \end{aligned} \quad (2)$$

The differences obtained between the medians of the HSPI of the omnivorous and vegan main courses, as well as between the dishes based on beef and other types of meat (poultry, fish, and pork) were evaluated. For the analysis of the indexes, the normality distribution of the variables was verified using the Kolmogorov-Smirnov and Shapiro-Wilk test. Considering that some indexes presented non-parametric distribution, the Mann-Whitney U test was used to verify if there was a statistically significant difference between the medians of the indexes and costs, considering a significance level of 95% and p-value < 0.05. To carry out the statistical analysis, the SPSS program (Statistical Package for Social Sciences), version 13.0, was used. Data are presented as median and interquartile range.

3. Results and Discussion

The cost of the main courses served in the university restaurant ranged from R$0.04 to R$8.24. Meat-based preparations had a higher average cost (R$3.44) while vegan preparations had a lower average cost (R$0.20) (Table 1). Abreu *et al.* (2019) [16] point out that the foodstuffs that most contribute to the increase in menu costs are those of animal origin. In a study carried out by Verly-Junior *et al.* (2021) [23] it was verified that in the menus in which large amounts of meat and fruit were offered, there was a higher cost. However, these menus were not necessarily the ones with the best nutritional quality.

Table 1 presents the average values, minimum and maximum cost values, energy densities, nutritional density, and environmental footprints of omnivorous and vegan main courses. The preparations served as an omnivorous main courses had a higher ED when compared to the vegan preparations, this result may be associated with the fat content present in the composition of the meats (Table 1). Of meat-based preparations, most 70% (14 preparations) were classified as medium ED and 30% (6 preparations) as low ED. The ED of the preparations: Thai chicken or chicken with paprika was 1.52 kcal/g, the Italian drumstick with tomato sauce had an ED of 2.24 kcal/g. However, the fish-based preparations: Fish Stew and Fish Steak with Escabeche Sauce had low energy density

Table 1. Average values, minimum and maximum values of cost, energy densities, nutritional density, and environmental footprints.

Classification of Preparations	Main course Omnivorous	Main course Vegan
Cost (BRL) average (minimum-maximum)	3.44 (0.33 - 8.24)	0.20 (0.04 - 0.58)
Energy Density (Kcal/g)	1.8 (1.08 - 2.72)	1.37 (0.48 - 3.04)
Nutritional Density (g/Kcal)	966.1 (561.5 - 1327.6)	536.6 (172.7 - 1082.3)
Water Footprint (L)	2032.6 (38.2 - 4361.9)	410.2 (53.8 - 2742.9)
Carbon Footprint (gCO^2eq)	2258.9 (616.4 - 4919.8)	519.2 (25.8 - 3156.6)
Ecological Footprint ($g{\cdot}m^2$)	16.1 (3.4 - 41.0)	2.9 (0.2 - 25.1)

(1.08 kcal/g) and those composed of beef the ED ranged from 1.17 kcal/g (Catchupa) to 2.72 kcal/g (Kibbeh) (Table 2). ED is understood as the amount of energy available per unit weight (kcal/g) of food, meals, and diets, being influenced by the water and fat content, playing an important role in satiety, energy consumption and, in the long term, in the body weight of individuals. Considering that the world is going through a global syndemic in which obesity and malnutrition go hand in hand, offering preparations with low ED can be strategic in controlling obesity [19] [20].

Regarding the average values of the cost of the preparations, the great difference found between the omnivorous and vegan main course reflects the high value of animal foods, when compared to plant foods. Abreu *et al.* (2019) point to the importance of main courses of animal origin, meat, poultry, and fish, in the financial management of food services, highlighting these material resources, such as those with the highest cost for the execution of planned menus [16].

In a study carried out by Oliveira *et al.* (2010) in a Food and Nutrition Unit (FNU), meat-based preparations were also classified as medium ED. The shredded roast chicken had a higher ED, 2.36 kcal/g, due to the characteristics of the cuts used: thigh and drumstick, which have a higher fat content, and the cooking method used in the preparation, roast, which favors the loss of water during cooking, concentrating the preparation and favoring an increase in ED [24].

Of the vegan main courses, 35% (7 preparations) were classified as medium ED, another 35% (7 preparations) as low ED and 30% (6 preparations) with very low ED (Table 2). The ED of the vegetarian preparations ranged from 0.48 Kcal/g observed in the preparation thai eggplant-tomato extract, tomato sauce, peanuts, ginger and curry) and 3.04 kcal/g for the Chickpea Bobó, made with coconut milk, cassava, tomato sauce, coriander and palm oil, lentil-based preparations such as: spring lentils (lentils, green olives, green, yellow and red peppers and carrots) and lentil pie with carrots (lentils, carrots, parsley and olive oil), in addition to having a low cost of R$ 0.19 and 0.15, they also had a very low ED of 0.57 kcal/g and 0.60 kcal/g, respectively (Table 1).

Study carried out by Canella *et al.* (2011) [25] [26] who evaluated the ED of meals provided by companies that adhered to the Worker's Food Program (WFP) reported the existence of a positive correlation between preparations with

Table 2. Frequency of energy density of main courses according to CDC classification (2005).

ED classification	Parameter (CDC, 2005)	Omnivore Main Course n (%)	Vegan Main Course n (%)
High	4 to 9 kcal/g	-	-
Average	1.5 to 4 kcal/g	14 (70%)	7 (35%)
Low	0.7 to 1.5 kcal/g	6 (30%)	7 (35%)
Very low	0 to 0.6 kcal/g	-	5 (30%)

high ED and the offer of total fats on the menu. This result suggests that the fat content of the preparations was responsible for the high ED. Thus, reducing the supply of fatty foods leads to a decrease in the ED of the menu.

When analyzing the Nutritional Density (ND) of the preparations: Italian style drumstick with tomato sauce (drumstick, tomato sauce, tomato extract, basil, and starch) and meatball with sugo were the ones that presented the highest ND, both with 1327.6 g/Kg. Thus, these preparations have a high amount of nutrients in relation to the energy value, promoting a higher intake of vitamins, minerals, fibers, polyunsaturated fatty acids, and other essential nutrients, with fewer calories [18] [19].

Another aspect to be considered during menu planning is the environmental impact caused by the foods present in the preparations, and it is important to assess the water, carbon, and ecological footprints in order to help offer environmentally sustainable preparations [21] [24].

The preparations that had the highest environmental footprints were Meat in Lisbon (PH: 4361.9 L; PC: 4919.8 gCO^2eq; PE: 27.3 $g{\cdot}m^2$) and sugo meatballs (PH: 3350.6 L; PC: 3805.7 gCO^2eq; PE: 21.0 $g{\cdot}m^2$), as they had the highest footprint values (**Table 3**). In a study carried out by Strasburgo and Jahno (2015) [27] that evaluated the water footprint of meals served in a University Restaurant (UR), it was found that beef had the highest water footprint value, corroborating the results found in the present study.

Chicken stroganoff, Meat in Lisbon, Pot steak, Mexican style meat, Steak with roty sauce, Meatball with tomato sauce were the preparations that presented the highest values for the three footprints analyzed (**Table 3**).

The fish stew had the highest carbon footprint while the fish fillet with marinade sauce had the highest ecological footprint (**Table 3**). Most preparations made from beef had a negative environmental impact. It is noted that almost all preparations in this category had water and carbon footprints greater than 3000 L and ecological footprint values greater than 21 $g{\cdot}m^2$.

In a study carried out by Oliveira (2010) [24], who evaluated the impact on the environment with the implementation of "Meatless Monday" in university restaurants on the Unicamp/Campinas campus, the author found that there was a reduction of 20%, the emission of methane (CH_4), twenty times more harmful than carbon dioxide, in addition to saving water that is spent on a large scale in refrigerators, reaching millions of cubic meters. There was a gross reduction of 1 billion liters of water per year and the equivalent of 2440 tons of CO_2 emitted. Therefore, in the menu planning phase, the assessment of the environmental impact caused by the offer of preparations must be considered, in order to minimize environmental damage and encourage the formation of healthier and more sustainable eating habits.

Although meat-based preparations are recognized as having the greatest impact on environmental footprints, it is important to emphasize that a detailed study of the menu served must be carried out by food service managers.

Table 3. Environmental footprints of omnivorous preparations.

Preparations	Water Footprint (L)	Carbon Footprint (gCO^2eq)	Ecological footprint ($g{\cdot}m^2$)
Roast Chicken*	1308.3	1159.1	7.8
Chicken with Spanish Sauce	785.0	632.0	4.7
Thai Chicken	981.2	789.5	5.9
Italian chicken drumstick with tomato sauce	1308.3	1052.7	7.8
Chicken in paprika sauce	785.0	616.4	4.7
Chicken Stroganoff	3182.2	3704.8	20.7
Fish stew	38.2	1056.0	32.9
Fish fillet with marinade sauce	38.2	734.2	41.0
Sweet and sour pork tenderloin stew	1106.9	1100.9	7.7
Catchupa (pepperoni sausage and pork loin)	857.37	728.04	3.438
Steak with roti sauce	3489.6	3935.8	21.8
Kebab	1792.0	2047.8	7.3
Meat in Lisbon	4361.9	4919.8	27.3
Meatball in tomato sauce[a]	3350.6	3805.7	21.0
Mexican beef	3489.6	3935.8	21.8
Pot steak	3489.6	3935.8	21.8

a. This preparation was served 3 times, on different days and weeks, during the period of the evaluated menu.

Table 4 presents the HSPI of omnivorous and vegan preparations. The indexes show a statistically significant difference in that the HSPI of vegan preparations are higher than those considered omnivorous.

In Table 5, the main courses based on beef presented lower indexes. Therefore, among dishes based on animal meat, it is observed that the consumption of poultry, fish and pork is nutritionally and environmentally more advantageous.

Food services should promote healthy and sustainable choices by offering menus with low energy density preparations, high nutritional density, and low environmental impact and that reflect the reality of these places and the needs of their clientele, modifying the food environment in such a way [27] [28] [29] [30].

As observed by Smedman (2010) [14], the indexes presented are value tools that allow, in practice, to consider environmental aspects in the planning of menus where until then they were evaluated only in relation to nutritional, energetic, financial and sensorial aspects. Ultimately, they can facilitate changes in food consumption patterns to lessen the environmental impact.

Table 4. Environmental footprints of omnivorous preparations.

	Average		Standard Deviation		H_1: <
	Omnivorous	Vegan	Omnivorous	Vegan	p-value
HSPI - h	3.06	4.06	7.57	2.92	0.00022977
HSPI - c	0.72	7.41	0.45	6.49	0.000002916
HSPI - e	97.88	1002.44	66.19	711.42	0.000004295

Table 5. Comparison of HSPI of preparations based on beef and other meats (poultry, pork, and fish).

	Average		Standard deviation		H_1: <
	Bovine	Others	Bovine	Others	p-value
HSPI - h	0.27	4.92	0.11	9.46	0.00005557
HSPI - c	0.24	1.03	0.10	0.28	0.00005557
HSPI - e	48.96	130.50	29.44	64.15	0.009286

Menus in food and nutrition units can be prepared for periods defined as weekly, fortnightly, or even monthly, considering food harvest, availability of material and financial resources, clientele acceptance, physical-functional structure, and productive capacity. Furthermore, the menus can be replicated throughout the year of services provided, which in practice is observed by the repetition of preparations, which in this study was also reflected in the low number of preparations analyzed from the HSPI, a limitation of the study.

4. Conclusions

Preparations served as an omnivorous main course had a higher ED compared to vegan dishes. Most meat-based preparations were classified as medium ED. Of the vegan main courses most were classified as medium and low ED. By calculating the water, carbon, and ecological footprints, it was possible to measure the impact of each preparation served on environmental resources. And in this way, the preparations that had the greatest impact on the environment were those prepared with beef: meat in Lisbon and meatballs in tomato sauce.

From the evaluation of the HSPI-h; HSPI-c; HSPI-e, is recommended to prioritize vegan main courses, poultry, fish, and pork-based preparations when planning menus, and restricting the use of beef-based preparations, in order to meet the requirements of healthy and sustainable eating. The indexes obtained seem to be efficient to assist in the planning of menus in food services. However, further research is suggested to test the HSPI with a greater number of preparations.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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