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Environmental and nutritional assessment of the “New Brazilian Food Pyramid”: a comparison with popular diets

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RESUMO

A dieta ocidental depende de sistemas de produção de alimentos (SPA) com altas emissões de Gases de Efeito Estufa (EGEE), alocando um fardo expressivo e crescente sobre a saúde humana e ambiente. Nosso objetivo foi avaliar o perfil nutricional e as EGEE da dieta da “Nova Pirâmide Alimentar Brasileira” (NPAB), comparando-a a cinco dietas populares mediante um escore unificado. Os dados de EGEE provém de uma meta-análise global dos impactos da produção de alimentos; as dietas foram compiladas em listas de alimentos típicos. Avaliamos se dietas desbalanceadas e acrescidas de alimentos de origem animal elevam impactos ambientais e na saúde. Os resultados indicam que dietas que enfatizam alimentos vegetais e integrais (Vegana, Vegetariana), tem *score* melhor que uma dieta rica em proteína animal e gordura saturada (Cetogênica). A NPAB obteve *score* menor, similar às dietas Mediterrânea e Paleolítica. Isso sugere que há necessidade de atualizar as recomendações, com incremento de vegetais para uma NPAB nutricionalmente e ambientalmente sustentável.

Palavras-chave: padrões alimentares; dietas; emissões de gases de efeito estufa; sustentabilidade; índice SNRF

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ABSTRACT

The Western diet relies on food production systems with high Greenhouse Gas Emissions (GHGE), placing a significant and increasing burden on human health and the environment. Our goal was to examine the nutritional profile and GHGE of the "New Brazilian Food Pyramid" diet (NBFP), and how it compares to five popular diets using an unified score. The GHGE data used was a global meta-analysis of food systems impacts and the diets were structured as typical food lists. We ask if imbalanced diets and increased consumption of animal foods contribute to greater environmental and health impacts. Our results indicates that plant-based diets, prioritizing whole foods (vegan, vegetarian), scored as more nutritious and sustainable than a diet high in animal protein and saturated fat (ketogenic). The NBFP had a lower, similar score as the Mediterranean and Paleolithic diets. This indicates that there is a need to update the recommendations, by increasing plant foods for a nutritional and environmentally more sustainable NBFP.

Keywords: dietary patterns; diets; greenhouse gas emissions; sustainability; SNRF index.

INTRODUCTION

The food industry has placed a significant and increasing burden on the environment and human health. The Western diet relies on a mode of agricultural production that negatively impacts ecosystems (MEJÍA et al., 2018; POORE; NEMECEK, 2018). Agriculture is the sector with the highest Greenhouse Gas Emissions (GHGE) (AIKING, 2019). According to POORE & NEMECEK (2018), agribusiness accounts for 81% of GHGE from food (including deforestation), 79% from acidification and 95% from soil eutrophication; more than 50% of freshwater withdrawal is for irrigation (QIN et al., 2019).

In recent decades, more people are exposed to the Western lifestyle, with high consumption of caloric foods with emphasis on animal and processed foods. Current epidemiological data suggest a "double burden of disease" (POPKIN; CORVALAN; GRUMMER-STRAWN, 2020). On one hand, there is malnutrition, which leads to premature child mortality, weakened immunity, suboptimal physical development and low cognitive ability; the long-term consequences include obesity, chronic diseases morbidities, and high mortality (RAJ, 2020). Moreover, the combination of increased metabolic risks and an aging population is likely to continue to drive these trends worldwide (GREGER; STONE, 2015; POPKIN; CORVALAN; GRUMMER-STRAWN, 2020; SWINBURN et al., 2019).

Recent data also indicate a rise in demand for these foods with high environmental impacts. For instance, the demand for animal products increased by 62% from 1993 to 2013, compared to a population increase of only 29% (SWINBURN et al., 2019). It is now widely agreed that food choices link environmental sustainability and human health (STENVINKEL, 2020; TILMAN; CLARK, 2014). Thus, more sustainable diets can lead to simultaneous reductions in health and environmental impacts globally (CLARK et al., 2019; SPRINGMANN et al., 2018).

The current Brazilian population food profile is based on a traditional diet of rice and beans, with foods that are low in nutrients and high in calories. In addition to the large number sugary drinks, added fat, and mostly industrialized foods, there is also a low consumption of fruits and vegetables, much lower than that recommended by the WHO and the Brazilian Guidelines (GABE; JAIME, 2020; GONZALEZ FISCHER; GARNETT, 2016; PHILIPPI, 2018).

From an ecological viewpoint, the environmental impacts related to the Brazilian adults' diet is also very high (GARZILLO et al., 2021; TRAVASSOS; CUNHA; COELHO, 2020). With the largest contributions coming from animal foods, mainly beef, the carbon footprint of the Brazilian diet exceeds that of the human diet by around 30%; it meets the nutritional needs of a healthy diet but also contributes to global warming (GARZILLO et al., 2021).

International organizations such as the Food and Agriculture Organization (FAO) have recommended for years that governments develop dietary guidelines to encourage people to choose healthier lifestyles. They are intended to provide "a basis for public food and nutrition, health and agricultural policies and nutrition education programmes to foster healthy eating habits and lifestyles". The most recent Brazilian edition is the 2014 *Guia Alimentar da População Brasileira* (Food Guide for the Brazilian Population) (GABE; JAIME, 2020). However, it is still unknown how these guidelines compare to popular healthy diets ant their impact on the environment and health.

Hence, two predictions can be evaluated from a nutritional-environmental standpoint: (1) imbalanced diets, and (2) increased consumption of animal products equates to greater environmental and health impacts in a diet pattern (BARONI et al., 2007; CLARK et al., 2019; LUKAS et al., 2016; VAN DOOREN et al., 2017). The NBFP is explicitly follows the Brazilian Dietary Guidelines (PHILIPPI, 2018), Thus, our goal was to determine the nutritional profile and estimate the NBFP diet's GHGE, and how it compares to five popular diets.

MATERIAL AND METHODS

Sample food lists

Our assessment was divided into three sections. Initially, sample food lists were constructed for six dietary patterns (hereon, diets). These dietary patterns were defined as: (1) Vegan (Vega) – no use of animal foods, with serving sizes suggested by (SLYWITCH, 2015) and adjusted by food groups (*sensu* GREGER; STONE, 2015); (2) Vegetarian (Vege) – mostly the vegan diet, plus cheese, replacing soy milk with bovine milk; (3) Mediterranean (Medi) – (*sensu* DAVIS et al., 2015); (4) New Brazilian Food Pyramid (PHILIPPI, 2018); (5) Ketogenic (Keto) – based on the "Atkins 100 Diet" diet (ATKINS NUTRITIONALS, 2022); and (6) Paleolithic (Paleo), *sensu* (CAMBESES-FRANCO et al., 2021). These popular diets were chosen because they represent an overall gradient from no use to a heavy use of animal foods.

Food lists were structured by servings of the following food items: whole grains, whole wheat bread, pulses, potatoes, leafy vegetables, non-leafy vegetables, pulses, citris fruits, other fruits, nuts, beef, pork, chicken, vegetable meat alternative, cheese, milk, vegetable milk), eggs, olive oil, fish, flaxseeds and added sugar. The food items used to construct the menu plans were compiled into a single list. Each list, therefore, was considered as a typical food consumption of that dietary pattern regarding setrvings. Energy and nutrients were reported according to the USDA National Nutrient Database for Diet Reference 26 (USDA, 2013). All diets were standardized to 2200 kcal/day for an adult male, according to the recommendations of the Dietary Reference Intakes (DRIs) of the US National Academy of Sciences (USHHS; USDA, 2015).

Greenhouse Gas Emissions

In parallel to the nutritional profiles, environmental impacts were weighed, allowing the sustainability level of each diet to be determined. To calculate the environmental impact factors of each pattern, we used information compiled from the meta-analysis by (POORE; NEMECEK, 2018). This study is global-scale and describes, among other impacts, the GHGE from various food groups. Each impact factor is expressed by its functional unit (FU): kilogram (solid foods) or liter (liquid foods). The GHGE was calculated per food by weight cosumed.

To integrate the impact of diets on health and the environment, the Sustainable Nutrient Rich Foods Index was used (SNRF; VAN DOOREN et al., 2017). The index groups the nutritional attributes of food groups in a single score, while also reflecting the environmental impacts. This index is given by the following equation:

$$SNRF = \frac{\left(\frac{EFA\ g}{12.4\ g} - \frac{SFA\ g}{20\ g}\right) + \left(\frac{VP\ g}{50\ g} - \frac{S\ g}{2.4\ g}\right) + \left(\frac{DF\ g}{25\ g} - \frac{AS\ g}{50\ g}\right)}{3 \times \frac{kcal\ energy}{2200\ kcal}}$$

Where:
EFA = essential fatty acids; SFA = saturated fatty acids, VP = vegetable protein; S = sodium; DF = dietary fiber; e AS = added sugars.

The SNRF represents seven fundamental nutritional characteristics (DREWNOWSKI, 2009; VAN KERNEBEEK et al., 2014). These include six distinct nutrients – three that should be encouraged (vegetable protein, essential fatty acids and dietary fiber) and three that should be limited (saturated fatty acids, sodium and added sugar) – plus energy density. The SNRF can be used to compare individual products as well as diets or food groups. The index values are positively correlated with a health score and negatively correlated with GHGE (VAN DOOREN et al., 2017).

The analyses and graphs were obtained using Minitab (MINITAB, 2021).

RESULTS

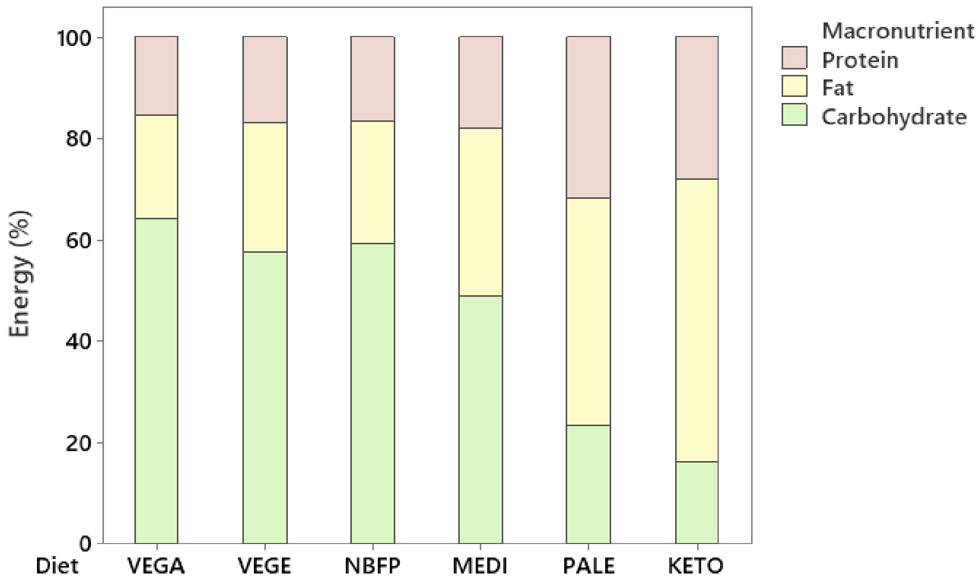
Energy intake

Typical food lists of each diet are shown in Table 1. More than 75% of the food (in grams) that made up the NBFP, Vege, and Medi diet was comprised of animal foods, while the Paleo diet was 68% and the Keto diet reached 58%. The Keto diet had greatest beef contribution when compared to the other diets. However, the Keto and Paleo diets both had a greater proportion of kilocalories from animal foods, 53% and 59%, respectively.

Nutrient profiles

The NBFP and VEGE diets had similar macronutrient ratios (Figure 1; Table 2). The diets consistent with the Acceptable Macronutrient Distribution Range (AMDR) for carbohydrates as the main energy source were only Vega (63.9%), NBFP (59.3%), Vege (57.6%), and Medi (48.9%). The Keto and Paleo diets provided fat as the main energy source (55.8% and 44.7%, respectively), and were below the AMDR for energy from carbohydrates. The Vega, Vege, Medi and NBFP diets provided energy from proteins (10 to 35%) and fats (20 to 35%) within the AMDR. Except for the Vega diet, all other had saturated fats above recommendations (≥10%). The Keto diet was deficient in fiber.

Figure 1 – Macronutrient intake of the NBFP diet and popular healthy diets for an adult man (2.200 kcal).



VEGA = vegan, VEGE = vegetarian, MEDI = mediterranean, NBFP – New Brazilian Food Pyramid; KETO = ketogenic and PALEO = paleolithic. Source: The authors

Mineral levels were adequate in all diets (Table 2), with one exception: levels of Ca, Mg and K were low in the Keto diet, according to RDAs. The Vega and Medi diets had an ideal Ca:Mg ratio (DURLACH, 1989); the Vege diet had a lower ratio and the other diets had higher ratios.

All diets had the appropriate levels for most vitamins examined. Nonetheless, the Vega diet provided a slightly higher level of vitamin B-12; the Medi, NBFP and Paleo diets had low choline levels; the Paleo diet had high, potentially toxic levels of vitamin A. The NBFP had low vitamin E levels. All diets had low vitamin D levels.

Environmental impacts

In general, animal foods are associated with significantly higher emissions of kg CO_2eq/kg than those of plant origin (Figure 2). Beef had the greatest environmental impact among all the food products analysed (60.4 kg of CO_2eq/kg). To produce 100 g of beef protein, approximately five times more carbon is released into the atmosphere than pork (6.5 kg CO_2eq/100 g), about seven times more than chicken (4.3 kg CO_2eq/100 g), and nine times more than fish (3.46 kg CO_2eq/100 g). However, there may also be a large variation between animal products from the same source. For example, three food products from cattle: milk, cheese and meat, had very different carbon impacts. Milk has the lowest GHGE among animal foods (2.65 kg of CO_2eq/L).

Table 1 – Composition of food categories and representative food items of individual diets for an adult man (2.200 kcal). Solid foods are expressed in grams and liquid foods in mililiters.

Category	**Food Item**	**Diets**					
		Vega	**Vege**	**Medi**	**NBFP**	**Keto**	**Paleo**
Whole grains	Brown rice [c]	375	338	272	314	43	0
Whole bread	Whole bread	0	0	268	112	0	0
Pulses	Lentils [c]	488	440	31	28	57	0
Potato	Potato [b]	63	56	112	448	0	79
Vegetables (leafy)	Broccoli [c]	563	507	167	101	135	397
Vegetables (non-leafy)	Carrot	125	113	168	135	135	397
Fruit (excluding berries)	Orange	540	487	103	242	225	198
Fruit (berries)	Cherry	75	68	98	272	87	194
Nuts	Almond	38	34	4	6	43	38
Beef	Top sirloin [c]	0	0	19	26	23	32
Pork	Pork loin [c]	0	0	0	18	57	132
Chicken	Chicken Breast [c]	0	0	75	22	199	87
Veggie meat alternative	Tofu	125	0	0	0	0	0
Dairy (cheese)	Mozzarella	0	62	19	76	100	0
Dairy (milk)	Whole milk	0	219	186	326	0	0
Plant-based milk	Unsweetened soymilk	243	0	0	0	0	0
Eggs	Egg [sb]	0	51	21	10	128	42
Oil	Olive oil	10	9	39	9	44	12
Fish	Salmon [d]	0	0	45	22	57	329
Flaxseed	Flaxseed	13	11	0	0	0	0
Added sugar	Sugar	13	11	0	14	0	0

Vega = Vegan, Vege = Vegetarian, Medi = Mediterranean, NBFP – New Brazilian Food Pyramid; Keto = Ketogenic and Paleo = Paleolithic. [c]cooked; [b]boiled; [sb]soft boiled; [d]cooked, dry heat. Source: The authors

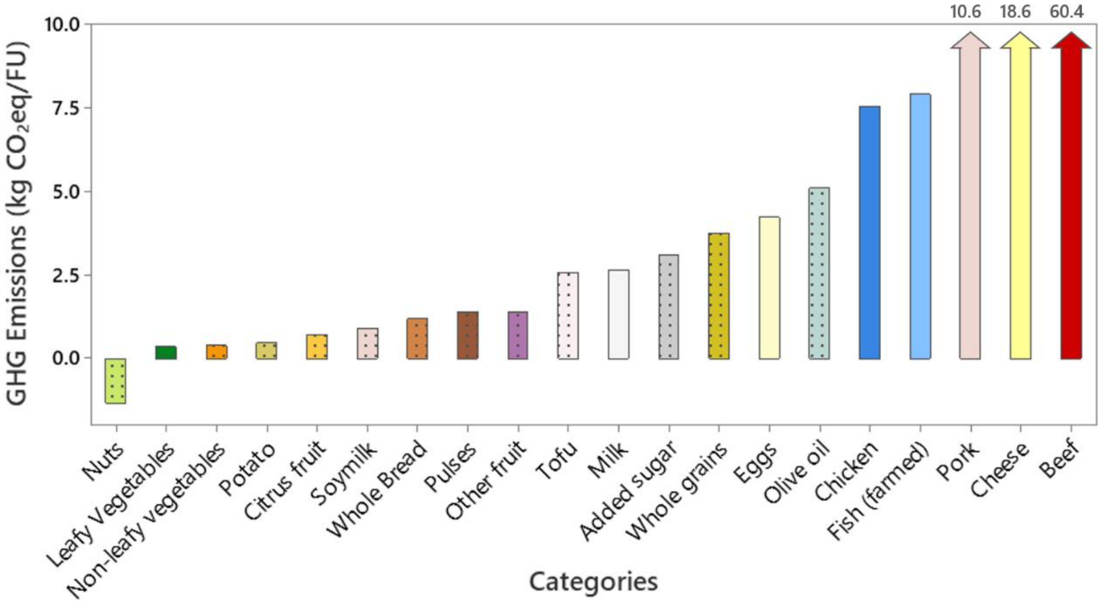
Table 2 – Dietary Reference Intakes[1] and nutritional composition of individual diets for an adult man (2.200 kcal).

Nutrients	Reference	Vega	Vege	Medi	NBFP	Keto	Paleo
Macronutrients							
Protein (% kcal)	10-35	15.3	16.8	18.1	16.4	28.1	31.9
Carboidrate (% kcal)	45-65	64.0	57.6	48.9	59.3	16.1	23.4
Total Fats (% kcal)	20-35	20.5	25.7	33.0	24.3	55.8	44.7
Saturated Fatty Acids (% kcal)	<10	6.3	18.4	23.0	23.2	35.4	23.9
Linoleic acid (ω-6) (g)	17.0	13.4	9.5	12.0	6.7	17.2	16.6
α-Linoleic acid (ω-3) (g)	1.6	4.5	4.0	2.7	1.8	2.6	8.3
Fiber (g)	34	91.0	81.3	51.1	40.5	25.0	37.6
Added sugar (% kcal)	<10	0.0	0.0	0.0	0.0	0.0	0.0
Minerals							
Calcium (mg)	1000.0	1507.6	1283.7	1005.0	1273.3	958.9	621.5
Iron (mg)	8.0	32.9	23.9	13.2	10.7	11.0	11.1
Magnesium (mg)	400.0	772.1	669.5	499.2	494.4	358.1	459.1
Phosphorus (mg)	700.0	2207.8	2293.2	1727.0	1730.7	1969.8	2198.6
Potassium (mg)	3400.0	6148.6	5547.1	3441.0	4504.3	3284.8	5884.4
Sodium (mg)	2300.0	482.5	957.7	1993.0	1466.2	1943.8	1182.1
Zinc (mg)	11.0	15.5	15.7	12.9	13.9	13.9	13.6
Vitamins							
Vitamin C (mg)	90.0	679.6	612.7	193.2	264.0	227.5	424.4
Thiamine (mg)	1.2	2.6	2.3	2.1	2.2	1.6	3.4
Riboflavin (mg)	1.3	2.5	2.5	1.7	1.9	2.3	2.6
Niacin (mg)	16	20.9	18.0	32.8	26.1	33.5	53.1
Vitamin B-6 (mg)	1.3	3.5	3.2	2.7	3.2	2.4	5.1
Folate (mcg DFE)	400.0	1775.8	1597.2	485.6	421.1	472.6	752.6
Choline (mg)	550.0	577.3	627.9	346.1	334.1	627.2	527.6
Vitamin B-12 (mcg)	2.4	2.1	2.8	3.5	4.9	6.5	11.6
Vitamin A (mcg RAE)	900.0	1727.5	1725.0	1769.9	1713.3	1725.2	3845.9
Vitamin E (mg AT)	15.0	21.4	19.8	18.2	9.3	22.2	20.5
Vitamin D (IU)	600.0	107.6	56.0	25.0	36.5	146.6	92.0
Vitamin K (mcg)	120.0	838.0	751.1	310.9	195.0	242.3	625.3

[1]All reference values are expressed as RDA (Recommended Daily Allowances), except for fiber (14g/1.000 kcal), added sugar and saturated fatty acids, expressed as DGA (Dietary Guidelines for Americans); Linoleic acid, α-Linoleic acid, potassium, and choline, expressed as AI (Adequate Intake); and sodium, expressed as CDRR (Chronic Disease Risk Reduction Level). Reference Value Source: USHHS; USDA (2015)

As mentioned above, plant foods had lower GHGE, in general, when compared to corresponding animal foods. For example, producing 100 g of tofu is equivalent to approximately 63% less GHGE than chicken. Likewise, plant foods may also have a wide range of GHGE. Olive oil (5.09 CO_2eq/L), brown rice (5.09 CO_2eq/L), tofu (3.73 CO_2eq/kg) and sugar (2.58 CO_2eq/kg) had the highest GHGE among plant foods. There is an exception for a processed plant food product: bread made with wheat or rye, which have an intermediate emission (1.18 kg CO_2eq/kg). Fruits (excluding berries) and cruciferous vegetables have the lowest levels of GHGE (< 1 kg CO_2eq/kg). Nuts, on the other hand, had negative GHGE values, because this product can temporarily sequester carbon if grown on agricultural land or pastures (POORE; NEMECEK, 2018).

Figure 2 – Individual contribution of food groups to GHGE. Functional Units (FU) are kilograms for solid foods and liters for liquid foods.



Source: The authors

Fish and beef were responsible for the largest contribution to the GHGE of the Paleo diet (Figure 3); in the Keto diet, cheese and beef; in the NBFP diet, beef, cheese and whole grains; in the Medi diet, beef and whole grains; in the Vege diet, whole grains and cheese; and in the Vega diet, whole grains and pulses. Compared to the most GHGE efficient diet, the Vega diet, the Vege and Medi diets were 45% and 34% less carbon efficient. The NBFP diet was 72% less efficient and the Keto and Paleo were ≈ 80% less.

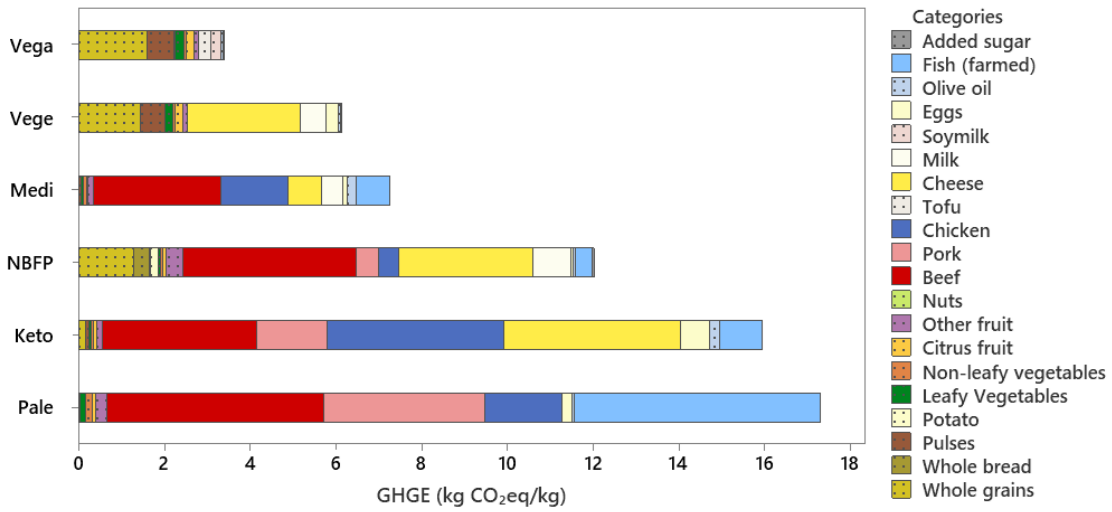
The Vega diet had the highest SNRF score (2.1), followed by the vegetarian diet (SNRF = 1.4). The Paleo diet scored much lower but very closely (SNRF = 0.7) to the Medi (SNRF = 0.6) and NBFP diet (SNRF = 0.5). The Keto diet had the lowest SNRF score (SNRF = 0.1) compared to the other diets.

DISCUSSION

The aim of this study was to compare the environmental impacts and nutritional quality of five popular diets compared to the New Brazilian Food Pyramid. To the best of our knowledge, this is the first study to evaluate the environmental impacts and diet quality of the "New Brazilian Food Pyramid". Our research indicates that diets with more plant protein, prioritizing whole foods, tend to be more nutritious and sustainable. Several studies have corroborated these findings (CHAI et al., 2019; FRESÁN et al., 2020; RABÈS et al., 2020; SCARBOROUGH et al., 2014; SPRINGMANN et al., 2018; TILMAN; CLARK, 2014). Although containing minimally processed foods, such as soy milk and tofu, the vegan diet still had the highest SNRF score. Compared to the other diets, the SNRF index ranked the NBFP diet as the second least sustainable diet, only surpassed by the Keto diet. But we find this very small difference to be irrelevant, as the NBFP it ranks closely to the Paleo and Medi diets.

A similar dietary study comparing the national Turkish Dietary Guidelines to popular diet models reported that a vegan and mediterranean diet had also a lower GHGE than the national guidelines (KEMALOGLU; ÖNER; SOYLU, 2023). Another equivalent study contrasting the Argentinian National Guidelines against a gradient of more plant-based modelled diets also found that the national guidelines was the least sustainable and a vegan diet scored the highest (ARRIETA; GONZÁLEZ, 2018).

FIGURE 3 - Contribution of food groups to the Greenhouse Gas Emissions (GHGE) of individual diets for a brazilian adult man (2.200 kcal).



[1]As there was no available information for flaxseeds' GHGE, the total kilocalories were recalculated to 2200 kcal without its energy contribution. Source: The authors

Nutritional quality of diets

Diets with a high proportion of fats (Paleo and Keto) were more nutritionally unbalanced and had a high overall GHGE. These "low-carb" diets also tend to have more nutrient deficiencies (CAMBESES-FRANCO et al., 2021; DE SOUZA et al., 2008), such as excess saturated fat, trans fat and cholesterol. Apart from the Vega diet, all other diets also had high levels of saturated fat.

Maintaining a high lipid content in a diet can lead to lipotoxicity due to the accumulation of free fatty acids in the body (Petersen & Shulman, 2018). This eventually promotes exhaustion of the pancreas β cells (GRUBELNIK et al., 2022), as well as mitochondrial dysfunction and can lead to insulin resistance (SERGI et al., 2019). If this diet is high in meat and – hence – in saturated and trans-fat, there may be a negative impact on the healthy intestinal microbiota, which is directly related to gastrointestinal diseases, obesity, and metabolic syndrome (ZHANG; YANG, 2016). These risk factors increase the risk of cancer and mortality (KIM; JE; GIOVANNUCCI, 2021).

However, not all fat increase health risks. Essential Fatty Acids (EFA) in the diet may have a protective effect on health (KIM; JE; GIOVANNUCCI, 2021). For example, ω-3 EFA are strongly associated with the prevention of atherosclerosis and may improve the lipid profile by reducing the inflammatory response and oxidative stress (DINICOLANTONIO; O'KEEFE, 2020). Some nuts and plant oilseeds, such as flaxseed, are rich in ω-3 EFA, beneficial for reducing the risk of CVD mortality (AUNE et al., 2016). On the other hand, high ω-6 EFA dietary intake has been linked to inflammation.

Yet, many plant foods contain both ω-6 and ω-3 EFA. They are metabolized by the same biochemical pathway and consumption of both results in enzymatic competition (BURNS-WHITMORE et al., 2019). Therefore, the favorable ω-3:ω-6 ratio is 2-4:1 (SIMOPOULOS; DINICOLANTONIO, 2016). The keto diet had the highest ratio (≈ 7:1), which would indicate a tendency for a systemic pro-inflammatory response when adopting this diet.

Additionally, a way to promote a healthy intestinal microbiota is to eat more fruits, vegetables, low fat content, low sugar intake, in addition to the consumption of fermented dairy products (ZHANG; YANG, 2016). But despite these general guidelines, the best available literature suggests that a diet with more emphasis on plant-based foods is much more effective in promoting a diverse beneficial gut microbiota to support overall health (TOMOVA et al., 2019). The |Keto diet was very poor in fiber, as there is a reduction in carbohydrates, notably from fruits and vegetables, corroborating a deficiency which is typical of this diet pattern. Fibers and polyphenols, also abundant in plant foods, promote anti-pathogenic and anti-inflammatory effects and cardiovascular health.

Regarding mineral intake, the Paleo and Keto diets were deficient in Ca. This mineral regulates important physiological events that reduce the risk of metabolic disorders and cardiovascular disease (DAS; CHOUDHURI, 2021). The Keto diet was also deficient in other minerals crucia for electrolyte balance: Mg and K. Adequate Mg levels are inversely associated with chronic diseases, such as hypertension, ischemic heart disease, stroke, metabolic syndrome, diabetes and colorectal cancer (NIELSEN, 2018).

Besides the minimum and/or adequate intake, a balance between some of these minerals promotes a synergistic effect. For example, the optimal Ca:Mg ratio of 2:1 is associated with cardiovascular health (DURLACH, 1989). Only the Vega, Vege and Medi diets showed an adequate ratio. It is possible that the phenomenon of cellular calcium activation is part of the pathology caused by the high Ca:Mg ratio in the diet. This may also contribute to the development of diabetes, cardiobvascular disease and inflammation (ROSANOFF; WEAVER; RUDE, 2012).

All diets were deficient in vitamin D, which would be expected, as it is not a nutrient that generally has food as a relevant source (GREGER; STONE, 2015). The low RDA of vitamin B-12 in the Vega diet was also expected, as widely reported in the literature; this vitamin has a low concentration in plant foods and supplementation is generally necessary when following this diet (GREGER; STONE, 2015).

The low concentration of vitamin E in the NBFP diet was considered unexpected, since this diet is based on a national recommendation for Brazil (PHILIPPI, 2018). Vitamin E has a central role as an antioxidant, reducing systemic inflammation and carcinogenesis; some of the main symptoms of its deficiency include neuromuscular and cardiovascular disorders (RIZVI et al., 2014)).

Another nutrient low in the NBFP diet, as well as in the Medi and Paleo diets, was choline. This essential dietary amine found in plant and animal sources is associated with several important functions such as neurotransmitter synthesis, cell membrane signalling, lipid transport and metabolism of methyl groups (GOH; CHEAM; WANG, 2021).

Environmental impacts

Animal foods exhibit higher GHGE in general, therefore it would be expected that diets with less emphasis on animal foods would also have the lowest impacts overall, as corroborated in our research (CLARK et al., 2019; POORE; NEMECEK, 2018; SPRINGMANN et al., 2018; VAN DOOREN et al., 2014).

When compared to the production of foods of plant origin, animal production is not efficient in terms of GHGE. According to BARONI et al. (2007), animal metabolism, notably of ruminants, require a large amount of water and energy to convert animal feed and in the maintenance of facilities. On the other hand, fish production has significantly lower impacts than red meat and/or processed meat. Environmentally, this variation may also result from differences in production (CLARK et al., 2019).

Regarding the SNRF index, our analyses demonstrate that the Vega diet is the most sustainable. These results corroborate several studies (CHAI et al., 2019; RABÈS et al., 2020; SCARBOROUGH et al., 2014). The Vege diet is a second option that is comparable to this diets' nutritional quality and lower GHEG. The main differences between the former and the latter are the higher SFAs present in the latter, and this is probably what determines the difference between the SNRF index.

Diets with all meat and dairy replaced by plant-based foods can reduce environmental impacts by more than 40% (SEVES et al., 2017). Based on our current knowledge, proteins from plant sources are fully suitable for protein nutrition in healthy adults, even with the exception of animal protein, as long as the diet is diversified and of high nutritional quality (MARIOTTI, 2019). Furthermore, plant protein intake is associated with lower risk of all-cause and cardiovascular disease mortality (NAGHSHI et al., 2020). However, it must be noted that diets associated with less environmental impacts may also contain more added sugars and lower levels of vitamin B-12, Zn and Ca (FRESÁN et al., 2020).

The Paleo diet, despite the large GHGE, obtained a SRNF score just behind, the Vege diet, possibly boosted by the large contribution of fish in this diet pattern. Also, its slightly higher inclusion of vegetables makes the difference for greater sustainability. But the Paleo diet is still rich in fats, proteins and unsaturated fatty acids, restricting more carbohydrates. This can lead to better body weight and improved muscle development (PITT, 2016). Nonetheless, in addition to being costly, the high levels of cholesterol and SFA in the Paleo diet may potentially cause long-term negative health effects, increasing the risk of cancer and cardiovascular diseases (CAMBESES-FRANCO et al., 2021). The Keto had the worst nutritional profile. Because carbohydrates are mostly removed from this diet, an overproduction of ketones bodies results in metabolic acidosis and an increase in a plethora of health risks (SCHUTZ; MONTANI; DULLOO, 2021).

The Medi diet, a popular and widely admired health-focused diet, in Brazil and around the world, usually ranks high in sustainability scores (DAVIS et al., 2015; ELLIOT, 2019; VAN DOOREN et al., 2014). This diet traditionally makes use of many plant foods that are beneficial to health, placing an emphasis on nuts and olive oil. Its low environmental impact profile is the closest to Vega and Vege diets. Even so, environmental impacts can vary greatly depending on their regionalization (ELLIOT, 2019). In our study, it ranked very closely and between the Paleo and NBFP diets.

The Keto diet had, by far, the worst SNRF score, and has also significant impact on the metabolism (NOTO et al., 2013). Hence, as it can be considered a choice with the greatest negative impact on GHGE, it is the least sustainable and healthy.

Is the NBFP diet nutritional and environmentally sustainable?

It's worth noting that the NBFP diet has a lower environmental impact than both the Keto and Paleo diets. This is because it emphasizes consuming plenty amounts of nutrient-rich vegetables and whole fruits (OLIVEIRA; SILVA-AMPARO, 2018; PHILIPPI, 2018). The downside is a low recommendation of pulses, as they are placed within a portion of “beans and nuts” in the pyramid (PHILIPPI, 2018). In fact, the pyramid suggests less than a portion of pulses by merging these two groups. It may appear to be a paradox, as beans are a staple food in Brazil. A higher contribution of beans could both lower the environmental impact and enhance the nutritional value of in this diet. But increasing the category “beans and nuts” may also increase fat because of nuts. Unfortunately, trend analyses in Brazil showed a decrease in the intake of beans in the last decades (RODRIGUES et al., 2021), but excessive meat consumption (CARVALHO; FISBERG; MARCHIONI, 2012).

The Brazilian Dietary Guidelines is considered one of the best worldwide, and includes important sustainability principles, but has does not provide specific, quantifiable recommendations that apply to consumers at the individual level (JAMES-MARTIN et al., 2022). Here is the pratical significance of the NBFP and strategic adjustments on food groups classification, portion size and recommendations that could lead to healthier and environmentally friendly diet.

Lastly, understanding the effects of food choices, not only on public health, but on the environment, in a large country like Brazil will serve as evidence to promote changes in the food system, suggesting that diet-related diseases, climate change and effects on key natural resources must be addressed simultaneously (TRAVASSOS; CUNHA; COELHO, 2020). The result of this more holistic vision brings profound changes in public management and health, including the discussion on climate change, food insecurity and changing food consumption patterns (AIKING, 2019; SABATÉ; HARWATT; SORET, 2016).

Study limitations

Methods for integrated analysis of the nutritional and environmental impact of foods, although imperative, are still a recent and relevant area of research (FANZO et al., 2021). This study has several limitations. Firstly, our analyses are based on food lists that prove to be very efficient for comparing different diets in combination, macro and micronutrients, as well as their sustainability (HALLSTRÖM et al., 2018). Howevever, food lists have a possible shortcoming, which is the choice of representative items.

Secondly, carbon-footprint data for each food are not available for Brazil, and thus we applied a multi-indicator global database that includes life-cycle information for combined food groups representing approximately 90% of protein/calorie global consumption. This approach has been used in the literature on estimating the environmental impact of diets in developing countries (TRAVASSOS; CUNHA; COELHO, 2020).

Finally, there is still an important debate about whether a healthy diet is always a sustainable diet (CLARK et al., 2019; MACDIARMID, 2013). Different databases of foods' environmental impacts may lead to diverse estimates for common indicators when linked to the same food consumption data. Analyses based on averages of daily and/or weekly menus, considering different regions in Brazil can add additional information to analytical methods on this topic.

CONCLUSIONS

Brazil has one of the best Dietary Guidelines in the world. They are based on foods and meals, address eating patterns as a whole and are therefore different from nutrient-based guidelines, even those with some recommendations on specific foods or food groups. Nevertheless, we present evidence that the guidelines-based NBFP pyramid may contribute to an increased risk of chronic diseases and GHGE, due to the low emphasis on plant-based protein. Diets with higher ratio of vegetable/animal protein are not only more nutritious, but more environmentally sustainable. This suggests that updating the recommendations by proportionally reducing animal foods and increasing plant foods would make the New Brazilian Food Pyramid healthier and more sustainable.

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