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Comparison of the carbon footprint of the dietary patterns of the inhabitants of the city of Cali and the "Eat Lancet diet"

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ABSTRACT

The objective of this study is to compare, in nutritional and environmental terms, the dietary patterns of the inhabitants of Cali, Colombia, with a world reference diet based on environmental sustainability EAT-Lancet. The dietary patterns of the city were obtained through the dietary intake questionnaire of the National Survey of Nutritional Status - ENSIN in which information from 189 people between 18-64 years of age was used. By means of previous research and official sources, and considering the place of food production, the carbon footprint of the most representative foods (n=21) that are part of 8 food categories was calculated. Based on this, the daily carbon footprint of the current Cali diet and under the EAT-Lancet scenario was estimated. Under an EAT-Lancet scenario, the Cali diet would increase the grams and proportion of vegetables (247.12%) and fruit (181.95%), and would significantly reduce the intake of beef, lamb and pork (77.31%), tubers or starchy vegetables (71.80%) and eggs (70.26%). The carbon footprint of food in kg CO2eq/kg under de current diet, was estimated to be 1.27 for rice, 0.64 for corn, 0.40 for potato, 0.27 for plantain, 0.11 for citrus, 0.07 for tomato, 0.26 for onion, 0.99 for vetch, 0.69 for bean, 2.03 for milk, 8.13 for cheese, 5.00 for eggs, 2.32 for chicken, 17.63 for beef, 1.04 for palm oil, 0.47 for margarine, 3.99 for panela (unrefined sugar), and 4.60 for sugar cane. The main greenhouse gas emitting factor was manufacturing input, herd management and waste management or energy. It is estimated that the current daily Cali diet generates 1.64 kg CO2eq and under an EAT-Lancet scenario 1.51 CO2eq. In nutritional and environmental terms, the EAT-Lancet scenario diet is recommended.

Key words: sustainable diets, environmental impact, dietary patterns food systems, carbon footprint.

1. INTRODUCTION

Climate change is the greatest environmental threat facing humanity today. The impact of human activities on the environment is such that it has been posited that the world is moving to a new geological era, parallel to the Holocene, called the Anthropocene, which is characterized by the depletion of rivers, massive deforestation, accumulation of toxic waste in water and soils, degradation of landscapes and loss of biodiversity, among other factors (Haraway, 2015; Haraway et al., 2015).

Research suggests that one of the major drivers of environmental threats are the "new ways" of food production and consumption (Armstrong et al., 2020; Rose et al., 2019). Estimates show that food production causes 20-30% of the environmental impacts on the planet and that the agricultural sector is responsible for 10-12% of total greenhouse gas emissions (Behrens et al., 2017; Hartmann & Siegrist, 2017; Ridoutt et al., 2017; The Eat-Lancet Commission, 2019; van de Kamp et al., 2018). Likewise, the high intake of animal protein-based foods and dairy products puts increasing pressure on the environment (Hawkins, 2019; The Eat-Lancet Commission, 2019; Travassos et al., 2020).

At the environmental level, the impact is evidenced through the change on land use from natural ecosystems to farms, large-scale transformation of natural ecosystems for agricultural use, the use of agrochemicals harmful to the environment, illegal mining and climatic phenomena (drought and heavy rains) that result not only in economic losses and food insecurity, but also strong environmental impacts estimated in high emissions of various greenhouse gases, such as carbon dioxide (Acevedo Osorio et al., 2016; Hurtado-Bermúdez et al., 2020; Vélez Torres et al., 2011).

Colombia, like many countries in the world, is going through a food and nutrition transition (Herrán et al., 2020). The food choices made on a daily basis are highly influenced by the food environment, urbanization processes and economic, cultural, social and advertising aspects, which have various environmental and health impacts (Johnston et al., 2014; Rankin et al., 2021). However, these decisions are often not based on consumers' knowledge of the health and environmental implications of food choices (Armstrong et al., 2020; Camilleri et al., 2019).

Although there is a growing interest raised by issues related to the origins and contents of food and the production processes derived from this consumption (Martin & Brandão, 2017), analysis of the close relationship between eating behavior/food choices/food patterns of the city and its environmental outcomes in Colombia is still almost nonexistent and continues to be, for a large majority of the population, an association that is not entirely clear. The little research that has been produced on this topic in the region extends mainly to countries such as Brazil and Argentina (Arrieta & González, 2018; Blanco-Murcia & Ramos-Mejía, 2019; Travassos et al., 2020).

One way to determine how sustainable the dietary practices of a population are is to compare them with the recommendations of food-based dietary guidelines based on environmental sustainability. Although Colombia has Food-Based Dietary Guidelines (GABAS), which seek to prevent malnutrition in the population, to promote well-being and health and to contribute to reducing the risk of developing chronic non-communicable diseases, these have two important limitations. First, adaptation of the guidelines to local realities and then consumer adherence to these is rare and, on the other hand, as is case with the vast majority of dietary guidelines globally (See Behrens et al., 2017; van de Kamp et al., 2018), it does not consider elements of environmental sustainability (ICBF & FAO, 2020).

A dietary guideline based on environmental sustainability at a global level is recommended by The EAT-Lancet Commission (2019). The Commission focuses its dietary recommendations on two main points: the consumption of healthy diets and sustainable food production, two factors with major impact on human health and environmental conservation (The Eat-Lancet Commission, 2019). In general, the EAT-Lancet Commission proposes the inclusion of diets composed mostly of fruits, vegetables, legumes, and nuts, and emphasizes decreasing the consumption of foods such as red meat and sugars (The Eat-Lancet Commission, 2019). However, it is emphasized that it is necessary to analyze the particularities in a way that covers cultural, geographical, and economic aspects that fit local realities.

This research aims to compare, in nutritional and environmental terms, the current dietary patterns in Cali, Colombia, with the global reference diet based on EAT-Lancet. For this purpose, food intake was estimated according to eight categories under the current scenario and under the EAT-Lancet scenario. Additionally, the carbon footprint of the main foods that compose the current Cali diet was calculated, and the current Cali daily carbon footprint was estimated under the EAT-Lancet scenario.

This article is organized in five sections, including this introduction. Section 2 presents the methodology, including the Characterization of the study site, Dietary intake information, information for the estimation of the carbon footprint and estimation of the carbon footprint. Section 3 presents and discusses the main results, categorized into characterization of the study population, food categories consumed in Cali, carbon footprint of prioritized foods, current carbon footprint and under the EAT-Lancet scenario and the life cycle of production of the prioritized foods. Section 4 presents the limitations of the research, and Section 5 draws the conclusions together.

2. METHODOLOGY

2.1 Characterization of the study site

Cali is the third largest city in Colombia. It is part of the Pacific region which includes 4 states, including Valle del Cauca, of which Cali is the capital city.

Seventy percent of Cali's municipal territory (56,400 ha) is rural, made up essentially of hillsides located between 1,200 and 1,800 m above sea level. Most of these hillsides are part of the Farallones de Cali National Park and a forest reserve. In the last five years, the most frequent climatic hazards have been river floods, but also mass landslides due to soil instability and landslides on the slopes. Forest fires and illegal mining are the main cause of the deforestation of ecological corridors of vital importance for the water regulation of tributaries throughout the municipality (CVC et al., 2017; Rankin et al., 2021)

Like many Latin American cities, Cali is undergoing a transition in its demographic and food patterns (Arciniegas & Peña, 2017; DANE, 2018; Duque et al., 2019; Herrán et al., 2020). The city is characterized by a highly diverse, multi-ethnic, and multicultural population, the result of continuous internal migrations and a very high degree of social and environmental inequity (Rankin et al., 2021). Cali's food environment is influenced by a wide supply of ultra-processed foods, with high sugar content and a limited supply of fresh products, especially in low-income neighborhoods where the most vulnerable sectors of the population live and where ethnic groups of Afrocolombian and indigenous people, migrants and displaced persons are concentrated. The greatest supply of organic and fresh and healthy foods is concentrated in higher income neighborhoods where a privileged group of the population has access (Arciniegas & Peña, 2017).

This leaves the city with one of the highest rates of overweight/obesity in the country (Instituto Colombiano de Bienestar Familiar et al., 2020), and although food production is low, mainly due to the high presence of sugarcane monocrop in the rural area, Cali presents unique characteristics: on the one hand, it is the main center of consumption and key point for the distribution and flow of food in the southwest of the country, and on the other, it maintains a close relationship with producing areas of various foods near the city.

2.2 Dietary intake data

To obtain information on the diet of individuals in the city, data from the 2015 National Nutritional Situation Survey ENSIN, conducted by the Colombian Institute of Family Welfare - ICBF, the National Institute of Health - INS and the Administrative Department for Social Prosperity (2020), were used. From this survey, data associated with the dietary intake subcomponent were taken, is part of one of the six components handled by the survey, called Food security, eating habits and dietary intake.

Food consumption was estimated using the 24-hour recall method (R24) , which consists of the individual application of a detailed interview to account for all foods and beverages consumed by the person during the last 24 hours of the day prior to the interview (Instituto Colombiano de Bienestar Familiar et al., 2020). The dietary intake questionnaire has a selection of 2,703 foods for the whole country and has two reminders, which are carried out on non-consecutive days between 48 and 72 hours apart. This second reminder was only made to a small subsample of individuals. For the purpose of knowing the current consumption, only the first reminder was used. The households that participated in the survey were selected through probability sampling, which allowed a more reliable approximation to identify the foods most consumed by the city's inhabitants and which are the most important in terms of people who reported consuming them.

Although the survey was applied to a representative sample of individuals from the Pacific region, this report takes data only from Cali. In addition, although the ENSIN considered the consumption data of persons older than 1 year, the sample frame of this research considered exclusively persons older than 18 years of age. In that sense, the study sample was composed of 189 subjects between 18 and 64 years of age.

The 593 foods consumed by the respondents were grouped into 22 categories defined according to the characteristics of presentation, nature, name, variety and cooking method of the food. For comparison purposes, alcoholic beverages, preparations and supplements were not considered. The conversion factors recorded in the survey were applied to convert the weight of cooked foods to raw foods, in order to obtain the real weight of the foods and to unify and standardize all foods under the same analysis criteria.

The EAT-Lancet Commission (2019) guide was chosen as the main input to compare the current dietary patterns in Cali in nutritional and environmental terms. The EAT-Lancet Commission guide (2019) proposes 8 food classification categories: whole grains (rice, wheat, corn and other), tubers or starchy vegetables (potatoes and cassava), vegetables (all vegetables), fruits (all fruits), dairy foods (whole milk or equivalents), added fats (saturated and unsaturated oils), added sugars (all sugars) and protein sources (beef, lamb and pork, chicken and other poultry, eggs, legumes, fish and nuts). Based on this, ENSIN foods were classified within the EAT-Lancet categories. Fish and nuts were excluded from this study because of the low specificity/diversity of the consumption of such foods in the ENSIN.

Due to the large number of foods registered in the ENSIN and given the technical complexity of calculating the carbon footprint of each one of them, we proceeded to select the most consumed foods measured by grams within each category and that were classified within the 8 groups of EAT-Lancet. Based on this, 21 foods were selected, which contribute approximately 78.50% of the total 915.76 grams consumed in the average daily diet of Cali.

2.3 Information for carbon footprint estimation

Once the current diet was constructed with the most representative foods of each EAT-Lancet category, detailed information was collected on the process and inputs used in the production of each food according to the place of origin. The places of origin of the 21 selected foods were taken into consideration, according to the information provided by the supply databases of the National Administrative Department of Statistics - DANE (2020).

The information regarding onion and tomato production was taken from the database of the preliminary study for calculating the carbon footprint of the Cali diet conducted by Gerbal (2019) and was complemented with a database from the Colombian Ministry of Agriculture and Rural Development . Similarly, to estimate the carbon footprint of rice, chicken, potato and plantain, the information provided by Gerbal (2019) was used as a basis. The data associated with the production of onions, citrus fruits, eggs, sugar cane, corn, oil, margarine and livestock (beef, milk and eggs) were supplied directly by units attached to the Colombian Ministry of Agriculture and Rural Development and companies producing these foods located in the respective places of origin.

Given the absence of carbon footprint information for beans and peas in Canada, the main origin of these foods for Cali, it was decided to extract the information from the agricultural production practices for beans and peas reported in the production costs provided by a Municipal Unit of Agricultural Technical Assistance -UMATA- of Valle del Cauca. Regarding wheat, which comes mainly from the United States, the carbon footprint of that food calculated by Sanders and Webber (2014) was taken directly.

2.4 Carbon footprint estimation

For the calculation of the carbon footprint, factors such as land use change impact (flooding methane and intermittent methane), machinery use (diesel and gasoline), energy (firewood, bagasse and tires), herd management (UGG, carrying capacity, dry matter consumed, enteric fermentation, urine and feces deposition), inorganic waste management (pesticide containers and sacks), organic waste management (wastewater and direct poultry manure, volatilization and leaching), fertilizers, insecticides, fungicides, herbicides, breeding and grow-out feeds, and use of other inputs (e.g. salt). Also included were the yield in the production of each feed, the cycles, the transport of inputs from the factories through the main town to the farms, and the movement of feed from the farm through the main town to the supply centers.

Subsequently, the direct and indirect emissions of CO_2, CH_4 and NO_2 generated by the inputs used in the production of 1kg, 1L or 1 unit of each food were estimated. Regarding direct emissions, for stationary combustion, the CO_2, CH_4 and CO_2 emission factors for gasoline (MINAM, 2012) and for ACPM and rubiales crude oil (Unidad de Planeación Minero-Energética, 2016) were considered for the use of fossil fuels. For emissions associated with the use of biomass as fuel, the calorific value of firewood, bagasse and tire residues were considered, as well as the respective emission factors (Unidad

de Planeación Minero-Energética, 2016). Regarding emissions from mobile combustion, gasoline emission factors were considered for motorcycles and light vehicles and ACPM for buses, heavy-rigid vehicles and agricultural machinery, respectively (World Resources Institute, 2015).

In addition, emissions in agricultural management were calculated. For direct N2O emissions, emission factors were taken into account for the application of: nitrogen fertilizers, ammonium sulfate, urea, ammonium nitrate, calcium ammonium nitrate, ammonium, nitrogen solution, ammonium phosphate, generic mineral N fertilizers and other NP-N, NK-N and NPK-N compounds (Bouwman et al., 2002). Indirect N2O emissions from volatilization were calculated from the emission factor corresponding to N2O emissions from atmospheric deposition and the fractions of N from synthetic fertilizers that volatilizes as NH3 and NOx and from organic fertilizers that volatilizes as NH3 and NOx (IPCC, 2006c). Also included were the fractions of N that volatilize as NH3 and NOx from ammonium sulfate, ammonium nitrate, calcium ammonium nitrate, ammonium anhydride, urea, mono-ammonium phosphate, nitrogen solutions (urea and ammonium nitrate), diammonium phosphate (DAP) and NK and NPK fertilizers (EEA, 2002), as well as the emission fraction of multi-nutrient fertilizers (Nemecek & Kägi, 2007). For indirect N2O emissions by leaching, the emission factor for N2O emissions by leaching and N runoff and the fraction of N in soils that leach/runoff (IPCC, 2006c) were considered. For direct CO2 emissions from liming, the emission factor for limestone application (CaCO3) and the emission factor for dolomite application (CaMg(CO3)2) were included (IPCC, 2006c). Finally, direct CO2 emissions from urea application were calculated from the emission factor for urea application (IPCC, 2006c).

To estimate the internal waste management (wastewater), the maximum CH4 production capacity (Bo), the CH4 emission factors in facultative lagoon and deep anaerobic lagoon (calculated from the CH4 correction factors in both scenarios) and the CH4 recovered (IPCC, 2006f) were included, in addition to the organic component separated as sludge in anaerobic and facultative conditions (Rodríguez, n.d.). On the other hand, emission factors for land use change (grassland-palm) were used (The British Standards Institution, 2011).

Regarding direct emissions, emissions from electric power were estimated considering the Colombian National Grid 2015 value, methane density, methane combustion efficiency and the fraction of methane that is not burned (IPCC, 2006d). Emissions from external solid waste management were also estimated. For municipal solid waste -landfills-, CH4 emission fractions from food waste and plastics, among others, were included (IPCC, 2006a), in addition to the fraction of degradable organic carbon that decomposes (DOCf), the CH4 correction factor (MFC), the fraction of anaerobic and semi-aerobic managed landfill, the fraction of deep (greater than 5m) and shallow (less than 5m) unmanaged landfill, the fraction of uncategorized landfill, the fraction of CH4 in landfill gas generated (F), the oxidation factor (OX) and the CO2eq emission factor (IPCC, 2006b). Emissions caused by waste incineration were also estimated and disaggregated into CO2, CH4 and N2O emissions (IPCC, 2006e).

Emissions associated with the manufacture of inputs were also estimated. To calculate emissions from fertilizer manufacturing, the marker for urea as N (GLO), potassium chloride as K2O (GLO), boric oxide, sulfur (GLO), magnesium oxide (GLO), phosphate fertilizer as P2O5 (GLO), ammonium nitrate as N (GLO), potassium fertilizer as K2O, phosphate roch as P2O5, dolomite, magnesium sulphate and ammonium sulfate as N were taken into account (Ecoinvent, 2016). For pesticide manufacturing, the marker for benzimidazole-compund, glyphosate (GLO), organophosphrus-compound and unspecified pesticides were included (Ecoinvent, 2016). For fuel manufacturing, marker by petroleum, diesel and petroleum 5%

ethanol by volume from biomass was included (Ecoinvent, 2016). Finally, emissions from the manufacture of other materials, such as palm oil esterification, among others, were estimated (Ecoinvent, 2016).

For emissions related to the transportation of inputs, market for transport, freight for lorry >32 metric ton -EURO3-, lorry 16-32 metric ton, -EURO3-; lorry 7.5-16 metric ton -EURO3-, lorry 3.5-7.5 metric ton -EURO3-, light commercial vehicle, and sea, transoceanic ship, as appropriate, were considered (Ecoinvent, 2016).

Finally, greenhouse gas emissions were unified in terms of CO_2eq. For the above, a global warming power of 1 was considered for CO_2, 21 for CH_4, 30 for fossil CH_4 and 310 for N_2O (Myhre et al., 2013).

3. RESULTS AND DISCUSSION

3.1 Characteristics of the study population

To describe the demographic, social, economic, and nutritional characteristics of the persons to whom the 24-hour recall questionnaire was applied, variables such as sex, age, educational level, occupation, wealth quartile, race/ethnicity, area and nutritional status were considered.

Table 1 shows the characterization for the 189 people surveyed. The sample consisted mostly of women (70.0%), more than half of the respondents (56%) had secondary education, 38.1% belonged to the lower wealth quartile, 35% reported informal employment/unemployment and 96.8% lived in the municipal capital. The average age was 37 years and 38.1% of the people were overweight and 20.1% obese.

Table 1. Sociodemographic characteristics of the respondents.

Variable	Sample (n = 189)	%
Sex/gender		
Male	57	30,0%
Female	132	70,0%
Race/Ethnicity		
Black	23	12,0%
Other	166	88,0%
Indigenous	0	0
Education		
Elementary school	31	16,4%
High school	106	56,1%
Technical	23	12,1%
College	20	10,6%
Other	9	4,8%
Activity		
Formal employee	64	33,8%
Informal employee	40	21,2%

Variable	Sample (n = 189)	%
Household	46	24,3%
Student	13	6,9%
Unemployment/Looking for a job	26	13,8%
Wealth status		
Under low	58	30,7%
Low	72	38,1%
Middle	56	29,6%
High	3	1,6%
Location		
Urban	183	97%
Rural	6	3%
Nutritional Status		
Normal	69	36,5%
Overweight	72	38,1%
Obesity	38	20,1%
Other	10	5,3%
Age		
Average	37 years	
Total	**189**	**100%**

Source: Calculations based on Instituto Colombiano de Bienestar Familiar et al. *(2020)*

3.2 Food categories consumed in Cali

Table 2 shows the food categories used in the study and the comparison of both under the current dietary scenario and under EAT-Lancet. In the current daily diet, an average of 915.76g of food is ingested per day, while the EAT-Lancet recommends ingesting around 1273.8 g. This indicates that in Cali 69.18% of grams of food are ingested with respect to the recommended consumption.

When observing the foods consumed by categories, the current diet shows that the intake of whole grains, tubers or starchy vegetables and whole milk or equivalents prevails, with lower consumption of fish, added sugars, added fats and legumes. When comparing the categories of foods consumed in Cali under the EAT-Lancet scenario, it is observed that the intake of vegetables (247.14%) and fruits (122.25%) would mainly increase. In addition to the above, it is recommended to decrease the consumption of beef, lamb and pork (77.31%), tubers or starchy vegetables (71.80%), eggs (70.26%) and chicken and other poultry (37.34%). It is worth mentioning that, although the consumption of dairy products and derivatives, added fats and all sugars are below the EAT-Lancet recommendations, the guidelines suggest that the consumption of these foods is optional and should be considered according to the culture of each place, therefore, if they were omitted in the EAT-Lancet scenario, the suggested consumption would decrease for the current diet.

The results suggest that, under an EAT-Lancet diet scenario, 48.9% of the consumption of added sugars would increase. However, this result should be analyzed with caution. As mentioned in the methodology, foods such as sugar-sweetened beverages, packaged foods, sweets and other industrialized foods, which hide sugar in different forms, were not considered in this study. Thus, the exclusion of these products

leads to a masking or underreporting of the real consumption of sugars by the population. A similar situation occurs with fats.

In fact, the consumption of sugars and fats in Colombia has had inequitable consequences for the health of the Colombian population, mainly for children and adolescents, as well as for people of low and medium socioeconomic resources. This is evidenced by the high prevalence of overweight/obesity and the increase in chronic noncommunicable diseases in recent years, which in turn have become the leading cause of morbidity and mortality at the national level (Herrán et al., 2020; Instituto Colombiano de Bienestar Familiar et al., 2020).

In nutritional terms, a balanced and nutritious diet should consider the consumption of foods high in nutrients and a limited consumption of high-calorie products (Minsalud, n.d.). A healthy diet does not necessarily imply an environmentally sustainable diet, just as a sustainable diet does not necessarily mean a healthy diet (The Eat-Lancet Commission, 2019), Thus, food consumption should balance both.

Table 2. Daily current diet food intake and EAT-Lancet diet by category.

Category	Current average intake (g)	EAT-Lancet recommended intake (g)	Percent change from current intake to EAT-Lancet
Whole grains	196,40	232,00	18,13%
Tubers or starchy vegetables	177,32	50,00	-71,80%
Fruits	89,99	200,00	122,25%
Vegetables	86,42	300,00	247,14%
Legumes	26,60	75,00	181,95%
Whole milk or equivalents	113,90	250,00	119,49%
Eggs	43,71	13,00	-70,26%
Chicken and other poultry	46,28	29,00	-37,34%
Beef, lamb and pork	61,70	14,00	-77,31%
Added fats*	41,09	51,80	26,06%
Added sugars	20,82	31,00	48,90%
Nuts	7,42	50,00	573,85%
Fish	11,50	28,00	48,89%
Total	923,15	1323,80	39,10%

Source: Calculations based on Instituto Colombiano de Bienestar Familiar et al., (2020) and The Eat-Lancet Commission (2019).

*EAT-Lancet classifies added fats into saturated and unsaturated fats. However, in this study they were lumped together in one category. EAT-Lancet recommends consuming 11.8g and 40g of saturated and unsaturated fats, respectively

Figures 1 and 2, show the graphical representation of the composition of dishes according to their percentages in the current scenario and the EAT-Lancet scenario. The differences are notable in both scenarios, especially in fruits, vegetables and red meat.

Under the EAT-Lancet scenario, fruits and vegetables represent 40% of the plate, while this is only 19% in the current diet. That is, less than half of the ideal. A healthy diet should include fruits and vegetables of all colors on a daily basis, because they are a primary source of minerals, antioxidants, fiber and phytochemicals that can reduce the risk of chronic heart disease, diabetes, obesity and some types of cancer, as well as micronutrient deficiencies (Subdirección de Salud Nutricional Alimentos y Bebidas et al., 2013). According to data from the Colombian Ministry of Health, 35% of people do not consume fruits daily, and 70% do not consume vegetables daily (Minagricultura, 2015).

The above becomes especially relevant when considering that in Cali faces a severe public health challenge, expressed in anemia in women of childbearing age and deficiencies of zinc, vitamin B12 and vitamin D for adolescents, boys and girls in the city (Rankin et al., 2021). Also considering that in Colombia about 37.7% of people between 18 and 64 years of age are overweight and 18.7% obese (Instituto Colombiano de Bienestar Familiar et al., 2020), it is evident that the sample of people reported here was very similar to the national reports, although it tended to be above these values, especially in terms of obesity.

Another difference in dietary composition is determined by animal products. While under the current scenario meat consumption reaches 18% of the plate, under the EAT-Lancet scenario it is equivalent to 6%. In other words, it would need to decline by one third. In the case of red meat, there is no definitive consensus as to how much red meat should be consumed. Red meat consumption varies from country to country and depends largely on cultural elements. For example, countries such as India have a very low consumption of red meat, while in Latin American countries such as Argentina y Brazil have the highest consumption. Colombia, ranks 4th in terms of meat consumption (OECD 2021).

According to the latest nutritional situation survey (Instituto Colombiano de Bienestar Familiar et al., 2020), 94.3% of people in the country reported consuming red meat, with a frequency between 3 to 4 times per week. In general terms, the WHO recommends avoiding a high and sustained consumption of red meat, sausages and processed meat, due to the risk of developing type 2 diabetes mellitus and colon, pancreatic and prostate cancer (Organización Mundial de la Salud, 2015; Organización Panamericana de la Salud, 2015). However, public health actions are aimed at reducing meat consumption and not at eliminating it completely from the diet, since, in the absence of other foods, meat has a high nutritional value, especially in B vitamins, iron and zinc (Alzate Yepes, 2019).

Another food group with a great difference in the consumption is tubers, while in the current diet it is equivalent to 19% of the plate, in the EAT-Lancet scenario it is equivalent to only 4%, that is, almost 5 times less than the recommended consumption. In the city there is a high intake of mainly potato and plantain.

Figure 1. Composition of the current daily diet.

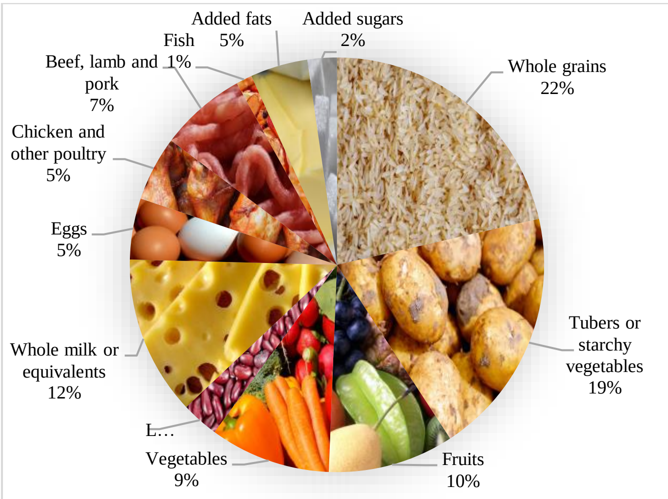
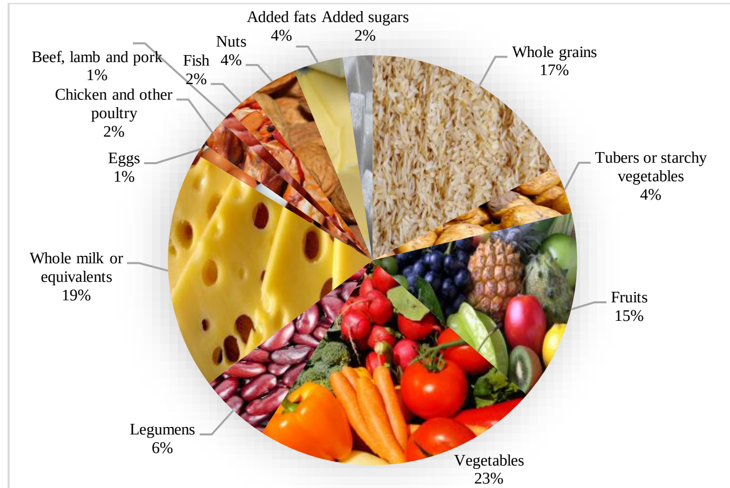


Figure 2. Composition of the current daily diet under EAT-Lancet scenario.



Source: Calculations based on Instituto Colombiano de Bienestar Familiar et al., (2020) and The Eat-Lancet Commission (2019).

3.3 Most consumed foods in Cali

Table 3 presents the 21 foods prioritized in daily consumption in Cali according to their respective categories, the percentage of intake of each food with respect to its category group and the percentage of intake of each of the selected foods compared to the total food consumed in the daily diet.

The results indicate that the selected foods make up 78.48% of the total grams consumed daily in the Cali/current diet. In this sense, although the amount of foods chosen was relatively low, they represent the great majority of the composition of the daily diet.

The representation in grams of the prioritized foods with respect to each category shows that the foods chosen covered 97.96% of the grams ingested daily in the category of whole grains, 94.11% of tubers or starchy vegetables, 26.00% of fruits, 26.00% of vegetables and 26.00% of vegetables, 26.00% of fruits, 39.65% of vegetables, 80.17% of legumes, 90.96% of whole milk or equivalents, 99.69% of eggs, 100% of chicken and other poultry, 50.80% of beef, lamb and pork, 87.35% of added fats and 96.39% of added sugars. Considering the above, the foods chosen represent more than half of the grams consumed within each category. An exception to this is the case of fruits and vegetables.

The prioritized foods are consistent with what has been reported in research on consumption patterns in the city and in Colombia in general (Instituto Colombiano de Bienestar Familiar et al., 2020). These foods are highly consumed in the city mainly for cultural and economic reasons.

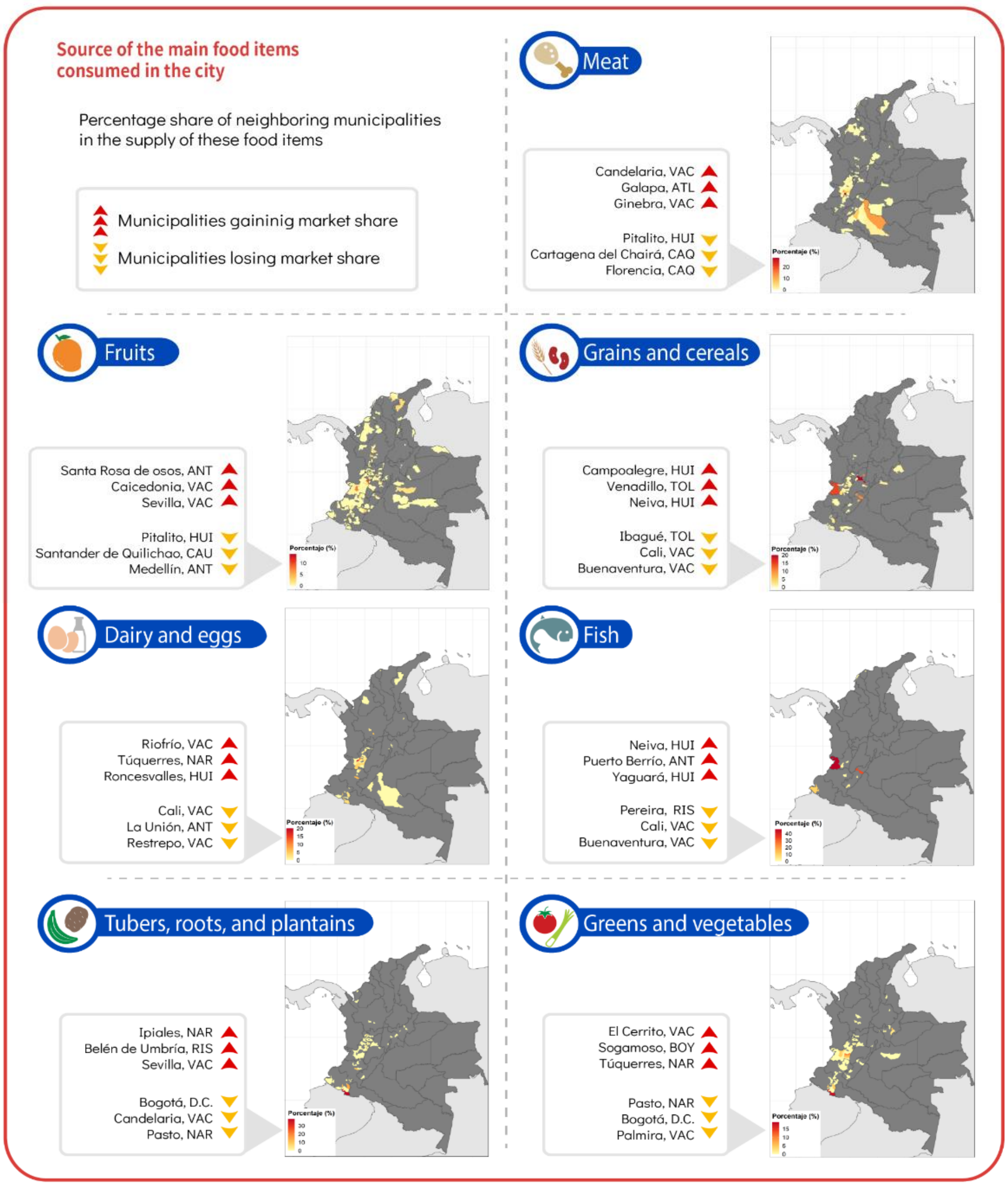
Table 3. Prioritized foods in the current diet

Category	Food*	Average intake (g)	Percentage of intake with respect to category	Percentage of intake with respect to total diet
Whole grains	Rice	86,37	43,98%	9,43%
	Wheat	56,46	28,75%	6,17%
	Corn	49,54	25,23%	5,41%
Tubers or starchy vegetables	Potato	138,59	78,16%	15,13%
	Plantain	28,28	15,95%	3,09%
Fruits	Citrus**	23,40	26,00%	2,56%
Vegetables	Tomato	19,50	22,56%	2,13%
	Onion	14,43	17,09%	1,58%
Legumes	Peas	13,96	52,47%	1,52%
	Bean	7,37	27,70%	0,80%
Whole milk or equivalents	Milk	79,52	69,81%	8,68%
	Cheese	24,09	21,15%	2,63%
Eggs	Eggs	43,57	99,69%	4,76%
Chicken and other poultry	Chicken	46,28	100,00%	5,05%
Beef, lamb and pork	Beef	31,36	50,80%	3,42%
Added fats	Palm oil	22,77	55,42%	2,49%
	Margarine	13,12	31,93%	1,43%
Added sugars	Panela***	11,22	53,87%	1,23%
	Sugar cane	8,85	42,52%	0,97%
Total		**718,68**	**78,48%**	**78,48%**

*Fish and nuts were excluded from the selection of the 21 prioritized foods due to the low specificity of the type of these foods consumed in the ENSIN. **Citrus fruits included orange, tangerine and lemon.
*** Unrefined sugar. *Source: Calculations based on Instituto Colombiano de Bienestar Familiar et al., (2020) and The Eat-Lancet Commission (2019).*

Figure 3 shows the main sources of food consumed in Cali. In the food systems of south-west Colombia, Cali is mainly a focus of consumption rather than primary production. However, most of the food consumed here comes from nearby domestic production in the department of Valle del Cauca, as in the case of chicken, poultry, pork, eggs and sugar cane. Other foods, such as potatoes, plantain, tomatoes, oranges and tangerines come from nearby departments, such as Cauca and Nariño, located within the same Pacific region. It is worth mentioning that, although the country could be self-sufficient in certain products such as fish, rice, grains and milk, these are imported, mainly due to macroeconomic policies such as free trade agreements (FTAs) (El País, 2015). In fact, some of the foods prioritized here are imported, as in the case of wheat and corn from the United States, and peas and beans from Canada.

Figure 3: Origin of the main foods consumed in Cali

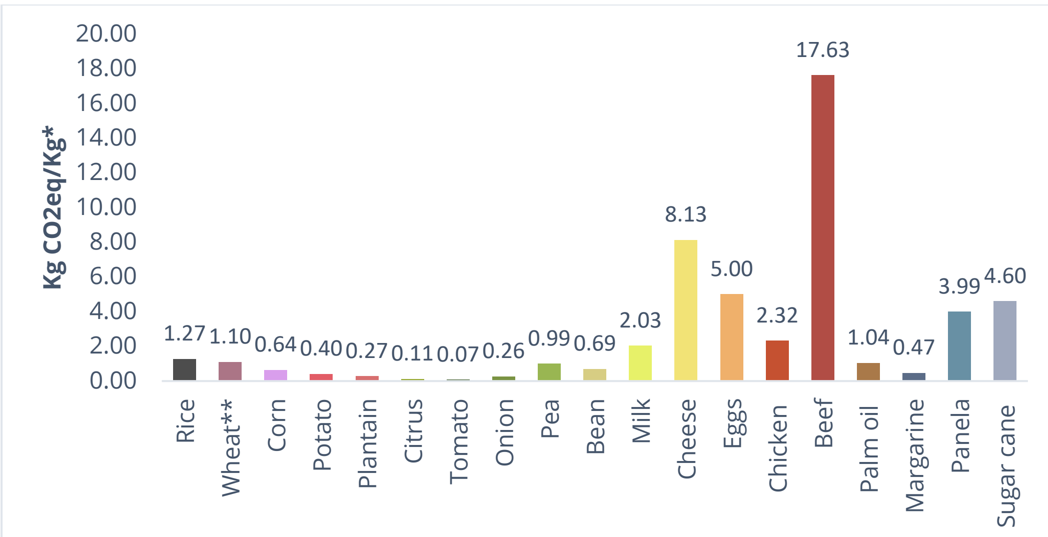


Source: Rankin et al. (2021).

3.4 Carbon footprint of prioritized foods

Figure 4 shows the results obtained for the calculation of the carbon footprint of 1 kg of each prioritized food. The foods that generate the largest carbon footprint are beef (17,63 kg CO2/kg) and cheese (8,13 kg CO2/kg), although other foods, such as eggs (5,00 kg CO2/dozen), sugar cane (4,60 kg CO2/kg) and panela (3,99 kg CO2/kg) also generate considerable impacts, followed by chicken (2,32 kg CO2/kg) y milk (2,03 kgCO2/L). The remaining foods generated a lower environmental impact: rice (1,27 kg CO2/kg), wheat (1,10 kg CO2/kg), palm oil (1,04 kg CO2/kg), peas (0,99 kg CO2/kg), bean (0,69 kg CO2/kg), corn (0,64 kg CO2/kg), margarine (0,47 kg CO2/kg), potato (0,40 kg CO2/kg), plantain (0,27 kg CO2/kg), onion (0,26 kg CO2/kg), citrus (0,11 kg CO2/kg) and tomato (0,07 kg CO2/kg).

Figure 4. Carbon footprint of prioritized foods



**Wheat carbon footprint was taken directly from Sanders and Webber (2014).
Source: Author´s calculation

The carbon footprints estimated here are comparable with the footprints determined by other national and international research. Pathak et al. (2010) estimated the carbon footprint of rice in India at 1.22 and 1.52 kgCO2eq/kg, depending on its production system. However, the carbon footprint of rice estimated here differs from that found in Colombia by authors such as González Meneses et al. (2014), in the department of Huila, and by Andrade et al. (2015), in the department of Tolima, who estimate the carbon footprint of that food at 0.42 kg CO2eq/kg and 0.163 kg CO2eq/kg, respectively. Regarding corn, a value similar to the one found here is estimated by Nguyen et al. (2012) in France, which is 0.50 kg CO2eq/kg. Meul et al. (2012) found a lower value in France of 0.398 kg CO2eq/kg. As mentioned, the carbon footprint used in this study was taken directly from the study conducted by Sanders & Webber (2014) in the USA. Other studies have determined the footprint of wheat, with different results. Such is the case of Pathak et al. (2010), in India, who estimated it around 0.12 kg CO2eq/kg, and Nguyen et al. (2012), in France, who obtained a value of 0.54 kg CO2eq/kg. For potato, carbon footprints of 0.52 kg CO2eq/kg and 0.48 kg CO2eq/kg, resonant with the findings here, were estimated by Williams et al. (as cited in Cembalo et al., 2013) in Israel. Different values were found by Pathak et al. (2010) in India, by O'Halloran et al. (2008) in Australia, and by Wilson et al. (2008) with values of 0.25 kg CO2eq/kg, 0.13 kg CO2eq/kg, and 0.337 kg CO2eq/kg, respectively. Pathak et al. (2010) estimated the carbon footprint of banana at 0.07 in India, a value not far from that found here for plantain.

As for citrus fruits, from the fruit category, the values found are different from other studies. Sanjuán et al. (2005) estimated the carbon footprint of oranges at 0.28 kg CO2eq/kg in Spain, and Brovia Cortel (2015) calculated that of mandarins at 0.4 kg CO2eq/kg, also in Spain.

Regarding vegetables, the CO2eq emissions calculated here are similar to those found by Wilson et al. (2016), who estimated it at 0.25 kg CO2eq/kg in Spain. However, these results differ markedly from other studies. For example, Saunders et al. (2006) estimated their footprint at 0.17 kg CO2eq/kg in the UK. Lagerberg-Fogelberg & Carlsson-Kanyama (2006) calculated a carbon footprint of onion at 0.15 kg CO2eq/kg in Denmark and 0.07 kg CO2eq/kg in Sweden. Finally, O'Halloran et al. (2008) estimated the carbon footprint for this food in Australia and obtained values of 0.12 kg CO2eq/kg. Regarding tomatoes, the carbon footprint estimated here, although similar to that found by O'Halloran et al. (2008) of 0.17 kg CO2eq/kg in Australia, differs from several studies. For example, Williams et al. (2006) calculated the tomato footprint at 9.14 kg CO2eq/kg for the UK case. Similarly, Williams et al. (as cited in Cembalo, Del Giudice, and Caracciolo 2013), calculated the footprint of tomato at 0.74 kg CO2eq/kg, 1.04 kg CO2eq/kg and 3.11 kg CO2eq/kg in Spain, and at 2.24 kg CO2eq/kg, 5.12 kg CO2eq/kg and 5.86 kg CO2eq/kg in UK.

On the other hand, for legumes, some studies have calculated similar results, although lower, than those determined here for peas. Nemecek et al. (2011) estimated it at 0.75 kg CO2eq/kg in Spain, Meul et al. (2012) at 0.48 kg CO2eq/kg in France and Nguyen et al. (2012) at 0.37 kg CO2eq/kg in France. For bean, Nguyen et al. (2012) estimated a carbon footprint of 0.29 kg CO2eq/kg in France.

Regarding whole milk or equivalents, Pathak et al. (2010) calculated the carbon footprint of milk in India at 0.73 kg CO2eq/kg. In another study, Cederberg & Mattsson (1999) determined this footprint to be 1.00 kg CO2eq/kg for Sweden. As can be seen, the footprint found here is double those found at these sites. However, it is similar to that estimated by Dyer et al. (2010) in Canada of 2.15 kg CO2eq/kg. As for eggs, Pathak et al. (2010) estimated the footprint of that food at 0.59 kg CO2eq/kg for India. Higher values have been recorded by Taylor et al. (2014) in the UK, who estimate it at 2.2 kg CO2eq/dozen eggs, or 1.6 kg CO2eq/kg (assuming average egg weight of 60 g). Finally, Estrada-González et al. (2020) calculated emissions of 5.58 kg CO2eq/kg of eggs produced in Mexico. The latter value resonates more with the findings of this study.

Regarding beef, a similar emission to the one presented here was estimated by Cederberg (2002), which is 17 kg CO2eq/kg for cattle in USA produced by home feed growing and mixing. Another close footprint is estimated by Subak (1999), which is 14.5 kg CO2eq/kg. A very different footprint from these is that calculated by Sanders and Webber (2014), who estimated the carbon footprint at 31 kg CO2eq/kg for beef production in USA. On the other hand, Williams et al. (2006) determined the carbon footprint of poultry in UK at around 8.99 kg CO2eq/kg, and Dyer et al. (2010) at 0.87 kg CO2eq/kg in Canada.

For the added fats, the carbon footprint of the oil palm described here is found to be at a midpoint of other studies conducted in Colombia. For their part, Gmünder & Rubio (2016) determined such carbon footprint in the department of Meta at -0.96 kgCO2/kg. Geraldes Castanheira et al. (2014) calculated the carbon footprint of oil palm in four scenarios, and the footprint fluctuated from -3.0 to 5.3 96 kgCO2/kg. Finally, Nguyen et al. (2012) estimated the carbon footprint of this product at 2.79 kgCO2/kg in Malaysia. On the other hand, Campos et al. (2019) determined the carbon footprint of soybean-based margarine at 1.32 kgCO2/kg, and that of butter at 2.91 kgCO2/kg in Brazil. Finally, and regarding added sugars, Reinosa-Valladares et al. (2018) determined the carbon footprint of sugar in Mexico at 0.27kgCO2/kg, a value notoriously lower than the one found here.

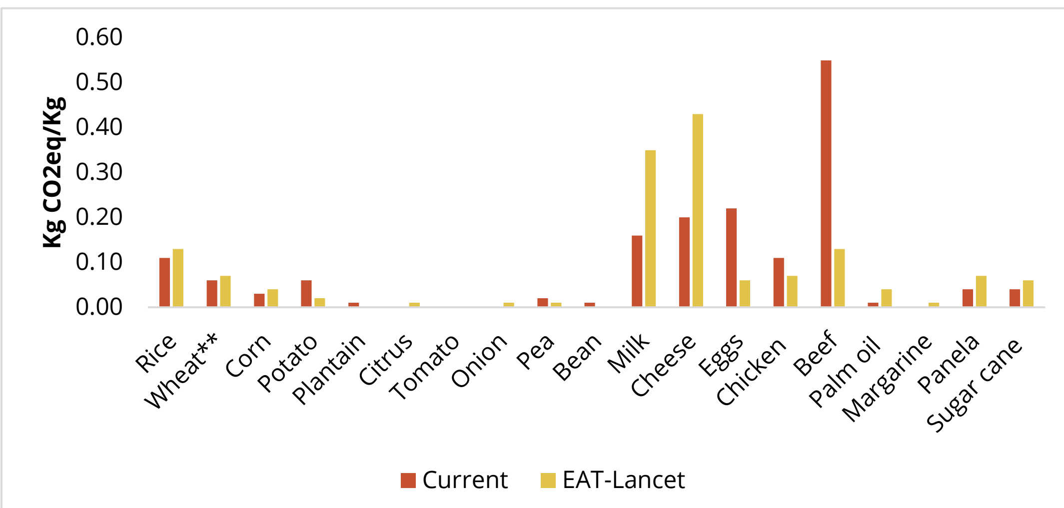
Although the carbon footprint of fish was not determined in this study, studies such as Pathak et al. (2010) in India estimate it at around 0.72kgCO2eq/kg, and Ghosh et al. (2014) at 1.40kgCO2eq/kg, also in India. On the other hand, regarding peanuts, a nut widely consumed in Colombia, Bongiovanni et al. (2016) calculated the carbon footprint of fried and roasted peanuts at 0.40 kg CO2eq/kg in Argentina. In addition, they noted that the more split peanuts are sold, the higher their carbon footprint.

3.5 Carbon footprint of the current Cali diet and the EAT-Lancet scenario

Figure 5 shows the estimated carbon footprint of each food in the current daily diet and under the EAT-Lancet scenario, considering the percentage of intake with respect to category presented in Table 2. From the calculations performed, it is estimated that the carbon footprint of the average daily Cali diet of a person is 1.64 kg CO2eq.

Since EAT-Lancet only specifies the number of grams recommended to be ingested within each category, without taking into account the type of food consumed, the guide was adapted to the food consumed in Cali. For this purpose, the information in Table 3 was considered and the same procedure applied to calculate the carbon footprint of the current diet was used. From this, the carbon footprint of the EAT-Lancet scenario was estimated to be 1.51 kg CO2eq. Therefore, these results suggest that the Cali carbon footprint is higher than the one that would be generated in an EAT-Lancet scenario.

Figure 5. Comparison of the daily carbon footprint of the current Cali diet and the EAT-Lancet scenario.



Source: Calculations based on Instituto Colombiano de Bienestar Familiar et al., (2020) and The Eat-Lancet Commission (2019).

Although the difference seems minimal, they become more relevant at the population scale. In a hypothetical scenario, assuming that the population of Cali (estimated at 2'227,642 people) follows the current diet, they would generate 3'653,332 kg COeq/day, and if they follow, in its entirety, the diet recommended by EAT-Lancet, they would generate 3'363,739 kgCO2eq/day. In this sense, by making the dietary change, there would be a mitigation of greenhouse gas emissions equivalent to 289,592 kg CO2eq/day, or 104,832,666 kg CO2eq/year. It is here, precisely, where lies the importance of nutritious diets that contribute positively on human health and sustainable, contributing to environmental conservation proposed by EAT-Lancet. This is precisely where the importance of nutritious and sustainable diets lies.

Following this conceptualization, the results show that the differences between the carbon footprint of the current diet and that of the EAT-Lancet scenario lie mainly in the above-recommended consumption of animal protein-based foods (meat, chicken and eggs) and tubers (plantain) in the current diet. Specifically, the intake of beef is the main driver of environmental impact in the current Cali diet. In this sense, and as mentioned above, reducing the consumption and therefore the frequency of meat consumption would help to mitigate the environmental impact.

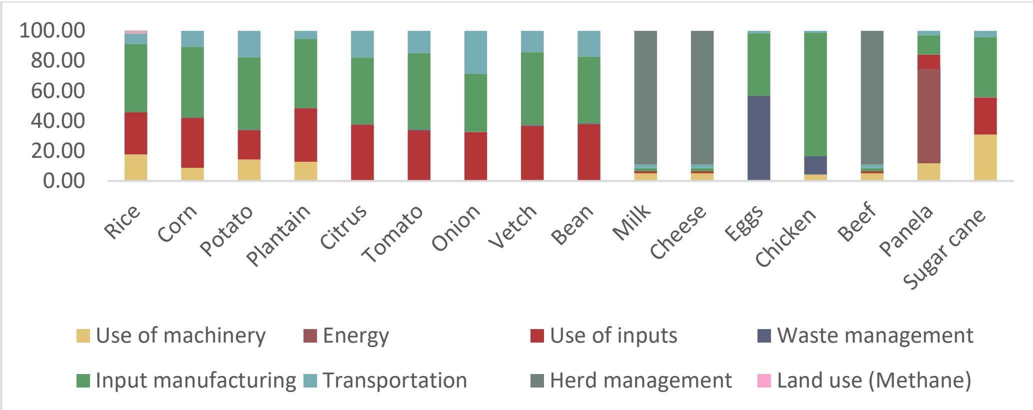
Nutritionally speaking, the high consumption of carbohydrates, processed foods and sugars is not consistent and balanced with the low consumption of fruits and vegetables. This situation has had an impact on the nutritional status of the population, as essential micro and macronutrient deficiencies are evidenced, several of which could be addressed through the consumption of vegetables. The current health problems in the country and the city, such as morbidity and mortality due to chronic non-communicable diseases, which are currently the main cause of medical consultation and mortality, and the statistic that 1 out of every two people in the country is overweight and/or obese, reflect this reality. Added to this, a higher consumption of fruits and vegetables, nuts and legumes generate a smaller environmental footprint.

In the case of the EAT-Lancet diet, the main driver of environmental impact would be the consumption of milk and cheese. The mitigation of the environmental impact of the EAT-Lancet diet adapted to the context of Cali could be greater because, although EAT-Lancet recommends the consumption of 250g of whole milk or equivalents daily and in the EAT-Lancet scenario they generate the greatest environmental impact in terms of carbon footprint, it is proposed that the consumption of such foods could be maintained according to the levels currently reported in Cali, or could even decrease, and thus be more environmentally sustainable.

3.5 Life cycle of prioritized foods

Figure 6 shows the relative contribution to carbon footprint of different phases of the life cycle of production of the prioritized foods. In the case of rice, corn, potato, plantain, citrus, tomato, onion, peas, bean, chicken and sugar cane, the carbon footprint was generated mainly by “input manufacturing” and the “use of inputs”, such as herbicides, insecticides, fertilizers, among others. Transportation, which includes the transportation of inputs and harvest, also generated a contribution among these foods, although this was more noticeable in the case of onions. Regarding land use (methane), the generation of methane was minimal. The “use of machinery” also generated a significant contribution of CO2eq, to a greater extent for sugar cane, and to a lesser extent for rice, corn, potato and plantain.

Figure 6. Relative contribution to carbon footprint of different phases of the life cycle of production of the prioritized foods.



Source: Author´s calculation

On the other hand, the CO2eq generated in the production of milk, cheese and beef comes mainly from "herd management". A similar case is found for eggs, where "waste management" is the main factor generating CO2eq, although "input manufacturing" also plays an important role. In the case of chicken, it is evident that "input manufacturing", related to the production of feed for fattening, has the greatest impact on the carbon footprint. Regarding panela, it is shown that "the energy" used in the process is the main generator of CO2eq, and to a lesser extent the "input manufacturing", "use of machinery", "use of inputs" and "transportation". Sanders and Webber (2014) report that the carbon footprint of wheat comes from agriculture production (36.10%), food manufacturing (26.47%), food packaging (20.46%), food service facilities (6.50%), food retail facilities (5.29%) and residential food preparation (5.17%).

4. LIMITATIONS OF THIS STUDY

First, the sample surveyed by the ENSIN was significant at the regional level, but not at the city level, so the conclusions derived here should be taken with caution. However, it is important to recognize the absence of more data like this for Cali and the difficulties of conducting the survey, and to highlight the level of detail of the information presented by the ENSIN.

Although the ENSIN survey included indigenous population (4%) and Afrocolombian population (8.2%), the subsample used in this study for Cali, even though it had a higher percentage of Afrocolombian population compared to the region (26%), was not proportional to the composition found in Cali, so that their dietary patterns are underrepresented in the survey. On the other hand, there was no presence of indigenous population in the subsample for Cali. Therefore, the information derived from this study cannot be extrapolated to Afrocolombian or indigenous populations, who are also part of the city.

Only 21 foods were prioritized in the estimation of the carbon footprint, which represent 78.48% of the daily diet. Although significant, there is still a remainder of the diet whose carbon footprint was not estimated in this study, and it is in this percentage where the greatest variety of foods resides, such as fruits and vegetables. In addition, fish and nuts were not included in the carbon footprint estimation, which is important when considering that the intake of such foods increases in the EAT-Lancet scenario. On the other hand, not including the intake of foods such as sweets, prepared beverages and fried foods leads to an underreporting of information regarding the current consumption of sugars and fats.

Finally, it is worth mentioning that the information used to estimate the carbon footprint of each food was conditioned by the information provided by the organizations consulted. In this sense, not all carbon footprints have the same level of detail of their processes. On the other hand, no other environmental impact was evaluated so that a joint effect of environmental impacts could be determined, such as water footprint and other impact processes related to food waste.

5. CONCLUSIONS

This study was able to determine the carbon footprint of the current daily diet in Cali and under an EAT-Lancet scenario. We consider that the findings of this research can be useful at national and international level to better understand the environmental impact of the production and consumption of the 21 foods addressed here.

The carbon footprint of prioritized foods in kg CO2eq/kg, was estimated to be 1.27 for rice, 0.64 for corn, 0.40 for potato, 0.27 for plantain, 0.11 for citrus, 0.07 for tomato, 0.26 for onion, 0.99 for vetch, 0.69 for bean, 2.03 for milk, 8.13 for cheese, 5.00 for eggs, 2.32 for chicken, 17.63 for beef, 1.04 for palm oil, 0.47 for margarine, 3.99 for panela, and 4.60 for sugar cane. The current daily Cali diet generates 1.64 kg CO2eq and under an EAT-Lancet scenario 1.51 CO2eq. In nutritional and environmental terms, the EAT-Lancet scenario diet is recommended.

The results show that Cali consumes fewer grams of food than recommended by EAT-Lancet but generates a larger carbon footprint. This indicates that if the consumption were the same, the environmental impact would be even greater in the current diet.

The results presented suggest including in the city's dietary patterns a higher consumption of fruits and vegetables, nuts and legumes, decreasing the consumption of red meat and moderating the intake of dairy products. The transition to greener diets brings nutritional and environmental benefits.

Although the inclusion of foods such as milk and dairy products, animal protein, sugar, tubers and saturated fats is optional in the EAT-Lancet scenario, for the purposes of this study they were included due to the high representation of all these foods in the Cali diet. This generated a larger footprint in both scenarios. Thus, the elimination of these foods would result in a lower environmental impact and in emphasizing and encouraging the consumption of fruits, vegetables, grains, fish and nuts would generate not only environmental but also nutritional gains.

This study is one of the first of its kind conducted on dietary patterns and the environmental impact caused in Cali through the carbon footprint. A significant number of foods were considered, and the comparison was made considering how what we are consuming affects the environment through an environmentally sustainable diet such as the EAT-Lancet.

There is a need for more dissemination of all the possible effects of not consuming food in a responsible and sustainable way. In this sense, it is recommended that public policy makers in Cali consider the results presented in this study to promote healthier, more balanced and environmentally sustainable diets among the city's inhabitants.

Although the perception of the inhabitants was not explored to determine how consumption affects the environment, in the local context, the knowledge of the relationship between diet and environment is

still almost nonexistent. Little has been gained in knowing the relationship between diet and health. In this sense, it is necessary to adapt and use national dietary guidelines that consider both scenarios.

Although national dietary recommendations were not considered in this study, it is considered that adherence to these guidelines by the general population is not reflected in the dietary patterns evidenced in the Cali diet. These recommendations include ¼ part of the diet in fruits and vegetables, ¼ part of the diet in foods based on animal protein and another quarter of the diet in dairy products and derivatives, this would be an indication that the national diets of Colombia could generate a considerable environmental impact due to the foods and portions considered. Further research should be aimed at evaluating the impact caused by the national recommendations so that elements of analysis can be considered to re-evaluate the dietary patterns of the population in order to mitigate both the impact on health and the environment.

It is recommended to conduct a nutritional status survey stratified by variables such as gender, wealth quartile and race/ethnicity for the city of Cali. A specific analysis of the dietary patterns of Afrocolombian and indigenous populations is encouraged, since, due to cultural differences, dietary composition may differ from the rest of the population. It is essential to consider the dietary patterns of these populations in order to generate recommendations and public policies that are more contextualized to the scenarios experienced by them. As Colombia is a multiethnic and multicultural country, knowing the dietary patterns of these populations is a way of recognition and inclusion of these ethnic groups.

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