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ORIGINAL PAPER

Food deserts and food swamps in a Brazilian metropolis: comparison of methods to evaluate the community food environment in Belo Horizonte

Olivia Souza Honório[1] · Paula Martins Horta[1] · Milene Cristine Pessoa[1] · Mariana Zogbi Jardim[1] · Ariene Silva do Carmo[2] · Larissa Loures Mendes[1]

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Abstract
The aim of this study was to evaluate the community food environment, food deserts and food swamps using several methods in Belo Horizonte City, Minas Gerais State, Brazil. Information on the community food environment was obtained from a comprehensive dataset collected from two secondary sources in the city. Analysis units comprised census tracts and buffers traced from the centroid of census tracts. *Per-capita* income was used as an explanatory variable. Five different methods, including one developed in Brazil, were used to identify and evaluate food deserts and food swamps throughout the city. The method from Brazil (which employs density of healthy establishments per 10,000 inhabitants) classified 37.7% of census tracts as food deserts. Food deserts were more frequent in the lowest-income tracts. Other methods gave food deserts lower values, and one method 2 (census tract) was similar to that found by the Brazilian method. The highest percentages of census tracts classified as food swamps were obtained using method 2 (mRFEI- percent healthy establishments, with 800 m buffer), with 66.6%, and using method 5 (density of outlets selling ultra-processed foods), with 58.5%. Food swamps were also found to be more frequent in the lowest-income tracts, especially when method 4 (count of unhealthy establishments) was applied. We conclude that most parts of Belo Horizonte provide easy physical access to retailers selling predominantly ultra-processed foods. Food deserts and food swamps were widely found, often in the same areas. The metric of food deserts and food swamps developed in Brazil was the most appropriate, because it considered specificities of the local food environment. In addition, it is necessary to improve existing food desert and wetland metrics. For example, include the income variable in these calculations.

Keywords Food deserts · Food swamps · Food environment · Socioeconomic vulnerability · Ecological studies · Food retailers

1 Introduction

A food environment comprises a group of physical, economic, political, and socio-cultural factors that influence food choices by individuals (Swinburn et al., 2013). The community food environment is a dimension of the food environment featured by the number and type of food outlets in neighborhoods (Glanz et al., 2005). It plays a key role in guiding the implementation of public policies to improve individuals' access to healthier food in these areas

✉ Larissa Loures Mendes
larissa.mendesloures@gmail.com

Olivia Souza Honório
oliviashonorio@gmail.com

Paula Martins Horta
paulamhorta@gmail.com

Milene Cristine Pessoa
milenecpessoa@gmail.com

Mariana Zogbi Jardim
zogbij@gmail.com

Ariene Silva do Carmo
arienecarmo@gmail.com

[1] Departamento de Nutrição, Universidade Federal de Minas Gerais, Belo Horizonte, Minas Gerais, Brazil

[2] Faculdade de Medicina, Universidade Federal de Minas Gerais, Belo Horizonte, Minas Gerais, Brazil

and to promote healthy eating patterns. Terms such as ´food deserts´ and ´food swamps´ have been used in the literature to describe the state of a community food environment (Beaulac et al., 2009; Walker et al., 2010; Bitler & Haider, 2011; Minaker et al., 2016). Food deserts are often characterized as socioeconomically vulnerable neighborhoods, where individuals have poor access to healthy food. It is important to emphasize that the component 'desert' in this term is inherently spatial and relates to physical lack of food outlets providing healthy food options in low-income neighborhoods (Cummins et al., 2002). In contrast, food swamps are neighborhoods that have large numbers of unhealthy food outlets (Mui et al., 2017), wherein strong marketing strategies constantly target and promote this food type (Yang et al., 2012).

Methods used to assess food deserts and food swamps are well established in studies conducted in North America. Two national studies aimed at suggesting metrics to assess food deserts were conducted in the USA (CDC, 2011; USDA, 2012), as well as a national study that proposed a method to assess food swamps (CDC, 2011). The assessments in these studies focused on investigating physical access to supermarkets, fast food restaurants, convenience stores and small grocery shops. Other studies in developed countries have associated features of the investigated neighborhood with health outcomes (Black & Macinko, 2008; Casagrande et al., 2009; Walker et al., 2010; Phillips & Rodriguez, 2019). However, the food environment in low- and middle-income countries, such as Brazil, includes other types of food establishment (CAISAN, 2018; Espinoza et al., 2017), such as butcher shop, fish market and mini-markets. These account for 30% of food establishments in the country (CAISAN, 2018) and are normally not included in most international studies.

Most studies conducted in Brazil have described community food environments in general (e.g., Duran et al., 2016; Junior, 2018), with just a few studies focused on assessing food deserts within Brazilian food environments (CAISAN, 2018; Davies et al., 2017). A major technical study developed by the Interministry Board of Food and Nutrition Security (CAISAN, in the Portuguese acronym created a method to evaluate access to food retailers that incorporates particularities of the food environments found in the country. That study mapped food deserts across the country based on secondary databases (CAISAN, 2018). Another study, by Davies et al. (2017), developed a method to identify food deserts in the Amazonian rainforest region. Their study took into consideration particularities of the region, such as local food types consumed in the locations and places where food was acquired. In this study, 41% of households were in areas with insufficient access to healthy food and in smaller cities this number was 60% (Davies et al., 2017). So far, no study has attempted to develop metrics specifically to identify food swamps in Brazil.

Thus the literature lacks studies comparing the methodologies used to identify and evaluate food deserts and food swamps in the context of Brazilian food environments. There are no studies for Belo Horizonte, which is a major conurbation in southeastern Brazil. Accordingly, the aim of the current study was to characterize community food environments and to compare different methods used to assess food deserts and food swamps in Belo Horizonte.

2 Methods

2.1 Study design

The study was carried out in Belo Horizonte City, which is the most populated city and capital of Minas Gerais State (Fig. 1). Belo Horizonte is the sixth most populated city in Brazil with 2,375,151 inhabitants, a demographic density of 7,167 inhabitants/km^2 and a Human Development Index (HDI) of 0.810. The territorial extension of Belo Horizonte City covers 331,401 km^2 (IBGE, 2018).

2.2 Analysis units

The units of analysis employed in this study complied with the original use of each evaluation method. Therefore, 400-m (Gordon et al., 2011; Hager et al., 2017; Luan et al., 2015) and 800-m (CDC, 2011) Euclidean buffers were drawn around the census center. Census tracts used for one of the methods (CAISAN, 2018) and the description of the community food environment were also considered as analysis units.

Census tracts are the smallest territorial units formed by a continuous area; they are used for data collection purposes. Census tracts are the administrative units used to conduct the Brazilian population census (IBGE, 2011). Of the 3,936 census tracts in Belo Horizonte city, 3,830 sectors were evaluated (97.3%). Non-residential census tracts (n = 106) were excluded from the study.

2.3 Community food environment-associated variables

Community food environments were featured based on a database comprising information derived from two secondary sources in 2015. These were the Superintendence of Revenue and Tax Information of the Treasury Department of Minas Gerais State and the Deputy Municipal Inspection Department. The database comprised the address, name and main activity carried out by the investigated

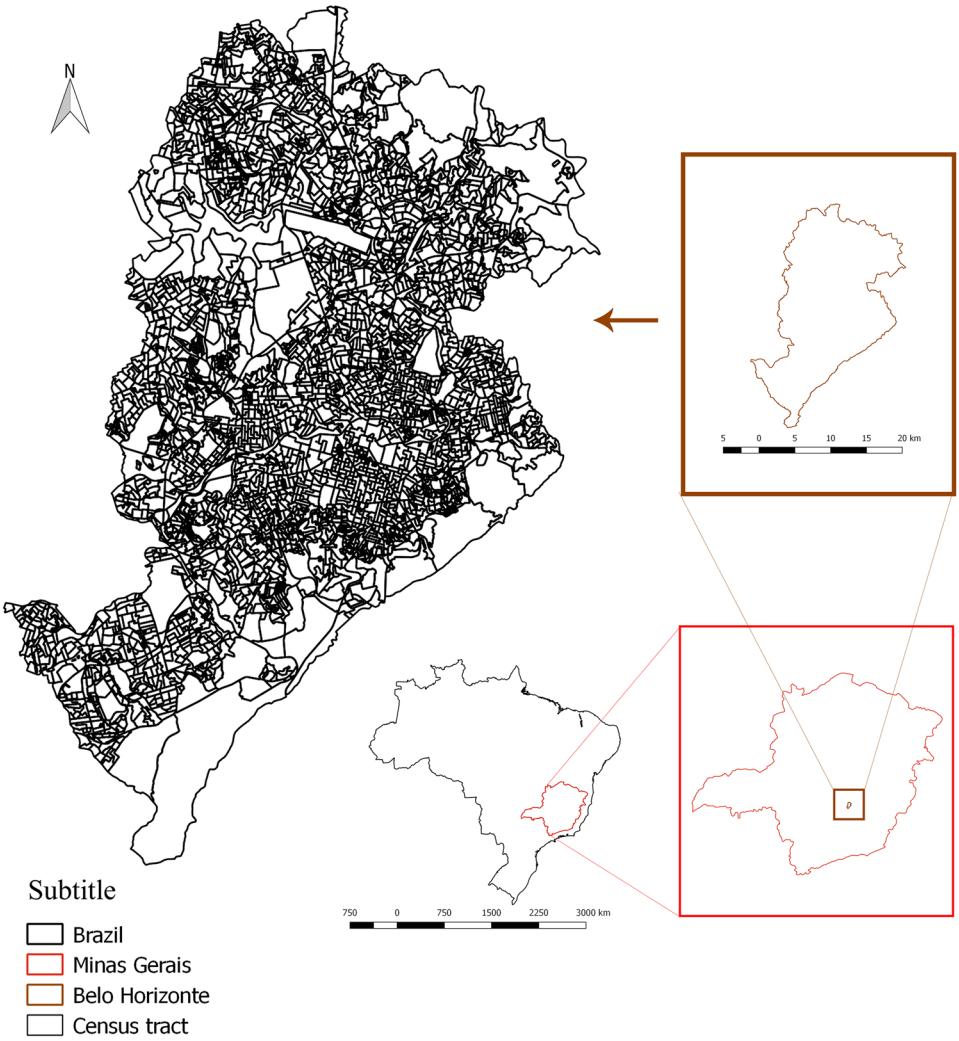

Fig. 1 Location of Belo Horizonte as place of study in Brazil

establishments (Leme & Rocha, 2018). Stores were defined based on information about food retailers provided by the National Classification of Economic Activities (CNAE, in the Portuguese acronym), which is the national instrument used to standardize both economic activity codes and categorization criteria used by different bodies of the National Tax Administration Office (IBGE, 2011). The database on establishments comprised information about 13 types of food retailer (S1) (Leme & Rocha, 2018).

The Public Facilities for Food and Nutritional Security (EPSAN, in Portuguese) of Belo Horizonte City: "Sacolões Abastecer" (fresh product retailers), "Programa Direto da Roça" (farmers' market), organic fair, and government-subsidized restaurants (https://prefeitura.pbh.gov.br)—which are physical structures and spaces used to supply, distribute and sell meals and food (Brasil, 2014)—were also included in the final database. The final database comprised 15,455 outlets in total in Belo Horizonte (Fig. 2) (Leme & Rocha, 2018).

2.3.1 Classifying features of community food environment

Food retailers were classified based on the Technical Study on Food Desert Mapping in Brazil in order to feature community food environments. Criteria adopted to perform such a categorization comprised the food purchase profile in the establishment, and a food processing classification (CAISAN, 2018).

According to the aforementioned criteria, food outlets were classified as predominantly fresh product retailers when more than 50% of the sold food was freshly produced or minimally processed (i.e., healthy food). Food outlets categorized as predominantly ultra-processed food retailers were establishments where more than 50% of the sold food is ultra-processed (i.e., unhealthy food). Other, mixed retailers were identified that did not show prevalence of one sold food type (CAISAN, 2018).

Food outlets classified as predominantly fresh food retailers comprised the EPSAN outlets, fresh product stores, butchers and fish markets. Food retailers of

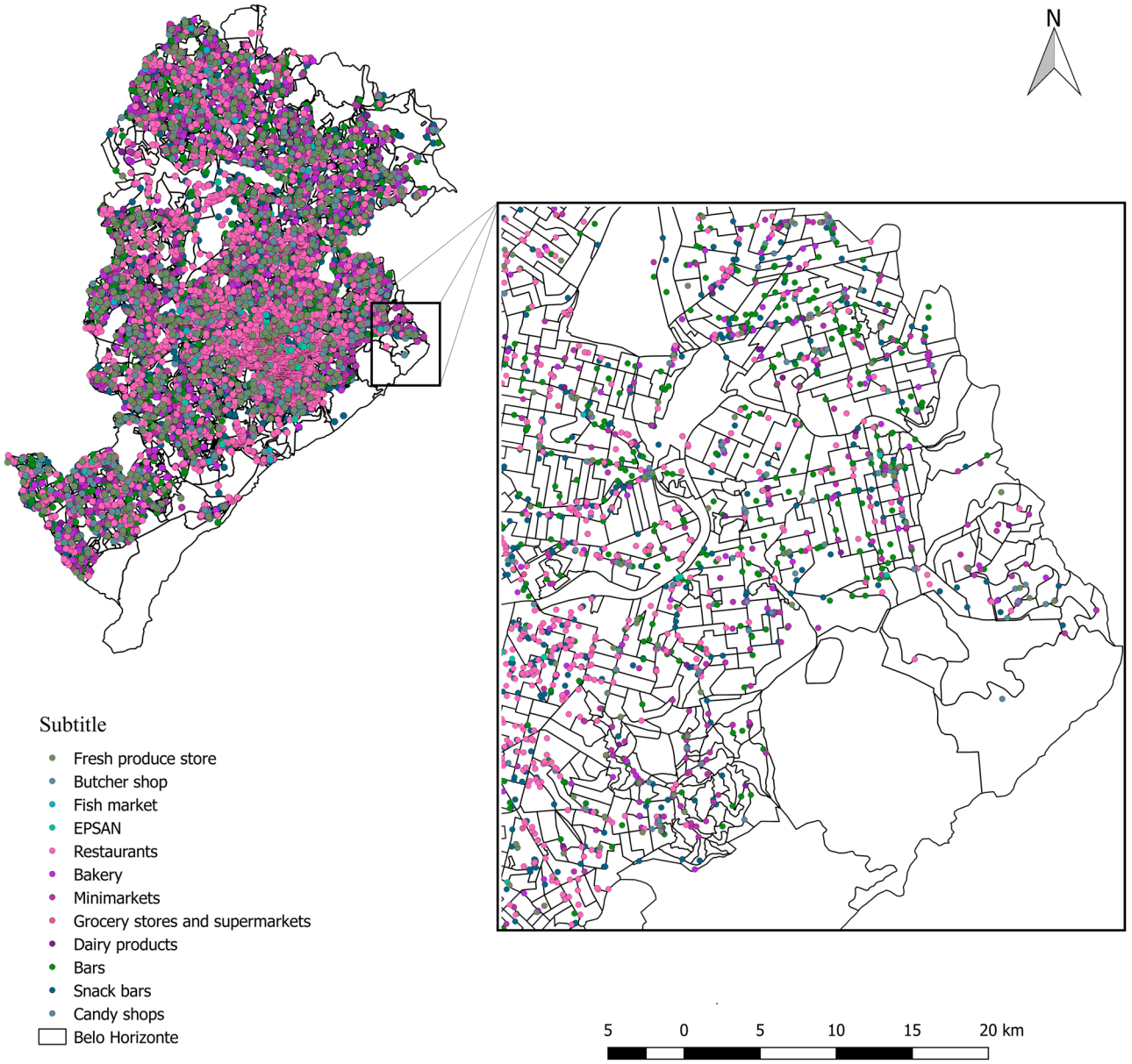

Fig. 2 Distribution of the food retailers in Belo Horizonte. Belo Horizonte, 2015

predominantly ultra-processed food included snack bars, candy shops and bars. Mixed retailers included restaurants, bakeries, dairy stores, mini-markets, supermarkets and hypermarkets (CAISAN, 2018).

2.4 Socioeconomic variables

Per-capita income was used as an explanatory variable in the current study. This variable was calculated as the ratio of total income of the census tract/total population of that specific census tract. The information used for the calculation was extracted from the Population Census conducted in 2010 (IBGE, 2011). The *Per-capita* income variable was created by following the formula below:

per capita income= Total income from the census tract /Total population of that census tract

The *Per-capita* income was divided into distribution quartiles – 1st quartile: from US$ 46.83 to US$ 158.61; 2nd quartile: from US$ 158.62 to $ 250.24; 3rd quartile: from US$ 250.25 to US$ 562.85; and 4th quartile: values higher than US$ 562.85, according to the US dollar exchange rate on December 30th, 2010, the year the census was conducted.

2.5 Food desert and food swamp analysis

International articles on this topic were searched for in the PubMed database during May to August 2018, using keywords such as *"food desert", "food deserts", "food swamp" and "food swamps"*. These articles were used to select the methods for this study to assess the incidence of food deserts and food swamps in Brazil. At the same time a review of governmental documents about food deserts and food swamps was also conducted to identify local documents to support the present study.

Articles comprising information about delimited methods were initially selected. The most often adopted methods were selected based on these references. Then methods that could be replicated or adapted to be applied to the database developed in the current study were assessed. Five methods capable of classifying food deserts and food swamps were selected (see Panel 1).

2.5.1 Method 1

Method 1 refers to the proposition by Gordon et al. (2011). This method investigated food deserts based on the Food Desert Index, which takes into consideration three food outlet types, namely: supermarkets, healthy grocery stores and fast-food restaurants. Each establishment type is assigned a score ranging from 1 to 3. The score assigned to the block accounting for evaluating supermarkets takes into consideration the number of these outlets within a pre-established radius. The evaluation of healthy grocery stores and fast-food restaurants takes into consideration their proportion in comparison to the total number of grocery stores and restaurants, respectively. The final index value is calculated by summing the scores attributed to all three types of food outlet. Census tracts presenting an index equal to 3 are classified as food deserts (Gordon et al., 2011).

Proportion of healthy stores:

$$\frac{Fresh\ product^{1}}{Freshproduct\ +\ ultra\ -\ processedfood^{2}} * 100$$

[1]Food retailers mainly selling fresh products
[2]Food retailers mainly selling ultra-processed food

Proportion of fast-food restaurants:

$$\frac{Snack\ bars}{Snackbars\ +\ Restaurants} * 100$$

The analysis unit was a 400-m radius buffer traced from the centroid of the census tract. Healthy grocery stores were replaced by food retailers mainly selling fresh products, whereas fast-food restaurants were replaced by snack bars, for adaptation purposes.

2.5.2 Method 2

Method 2—which proposes a metric to assess food deserts and food swamps—was developed by CDC (2011). It suggests using the Modified Food Retail Environment Index (mRFEI), which considers supermarkets, hypermarkets and fruit stores as healthy food outlets; fast-food restaurants and convenience stores are considered unhealthy food outlets. The index is calculated as the ratio of healthy to unhealthy outlets multiplied by 100 (CDC, 2011).

$$mRFEI = \frac{Grocery\ stores\ +\ Supermarket\ +\ Freshproductstore}{Snack\ bars\ +\ Minimarkets} * 100$$

Two different analysis units were used in this method. The census tract was the first unit, while the 800-m radius buffer traced from the centroid of the census tract was the second one. Fast food restaurants were replaced by snack bars, for adaptation purposes. Convenience stores were not included in the present study.

A food desert classification was attributed to neighborhoods presenting mRFEI equals to 0, whereas a food swamp classification was assigned by low, positive values (CDC, 2011). Furthermore, the CDC (2011) method did not specify the cut-off value used to classify a given neighborhood as a food swamp. Therefore, a literature review was conducted to find studies that used this method to identify food swamps. The cut-off value suggested by Li et al. (2014) was the one we adopted. This cut-off value takes into consideration mRFEI values (*modified Retail Food Environment Index*) ranging from 0.01 to 20 to classify neighborhoods as food swamps.

2.5.3 Method 3

The third method evaluated in the current study was used by Luan et al. (2015), which evaluates both food deserts and food swamps. Similarly to the previous method, it also adopts the mRFEI. However, only supermarkets and hypermarkets were considered to be healthy food retailers. Convenience stores and fast-food restaurants were categorized as unhealthy food retailers.

$$mRFEI = \frac{Grocery\ stores\ +\ Supermarket}{Snack\ bars}$$

In addition, Luan et al. (2015) used the 400-m buffer network as the analysis unit. In this case, the necessary adaptation comprised replacing fast-food restaurants by snack bars. Convenience stores were not included in this method. Moreover, buffers were traced by using Euclidean distance. The adopted classification was the same as the one adopted for method 2.

2.5.4 Method 4

Method 4 was only used to identify food swamps. This method was proposed by Hager et al. (2017). The calculation was done by summing the number of convenience stores, corner stores and minimarkets within a 0.4-km (0.25 miles) radius.

Corner stores were replaced by "Retailers of sweets, candies, candy bars, and similar products", for adaptation to local conditions. Convenience stores were not included in this method. The buffer was plotted from the centroid of the census tract. Census tracts were classified as food swamps when the sum of stores in them was ≥ 4.

2.5.5 Method 5

Method 5 was set up to evaluate food deserts by taking into consideration features of Brazilian food environments (CAISAN, 2018). In the current study we adapted the metrics used to evaluate food deserts in order to also evaluate food swamps.

Healthy food outlet density per 10,000 inhabitants was taken into consideration to determine food deserts. Establishments mainly selling fresh products, as well as mixed food retailers, were considered healthy food outlets (CAISAN, 2018). The census tract was the adopted analysis unit.

Food deserts:

$$\frac{Food\ retailers\ mainly\ selling\ fresh\ products\ +\ Mixed\ retailers}{Census\ tract\ population} * 10000$$

Food swamps:

$$\frac{Food\ retailers\ mainly\ selling\ ultra\ -\ processed\ food}{Census\ tract\ population} * 10000$$

The method was adapted to identify food swamps by calculating the density of food outlets mainly selling ultra-processed food (unhealthy food outlets) per 10,000 inhabitants. Census tracts below the 25th percentile were classified as food deserts. The cut-off value used to classify census tracts as food swamps was a density of food outlets mainly selling ultra-processed food above the 25th percentile.

2.6 Statistical analysis

Community food environment data of the city and the evaluation of food deserts and food swamps were described through frequency distribution and stratified based on income quartiles. Descriptive analyses were carried out in SPSS (Statistical Package for the Social Sciences) version 19.0.

3 Results

The community food environment of Belo Horizonte City (Table 1) features a high incidence of food retailers, which mainly sell ultra-processed food (46.9%) and mixed food (42.9%). Snack bars were the most frequent outlet type (25.4%); they were followed by restaurants (24.5%) and bars (18.8%).

Interestingly, 25% of the census tracts analyzed in the current study did not have food retailers, 77.5% of them did not have a retailer mainly selling fresh products, and 12.7% of these tracts showed a prevalence of ultra-processed food retailers (Fig. 3). The census tract classified as (1) lacking food retailers, (2) not having any retailer mainly selling fresh products, and (3) prevalence of ultra-processed food retailers, was the most frequent profile in the lowest income quartile (Fig. 3).

The assessment of retailer types based on *per-capita* income quartiles of the census tract showed that low-income census tracts have poorer access to all food retailer types, whereas high-income census tracts recorded higher mean mixed (2.7 ± 4.2) and ultra-processed food (2.7 ± 5.3) retailers.

Regarding the evaluation of food deserts according to the selected concepts and methods, it was verified that 39.1% of census tracts were classified as food deserts based on the method comprising the number of food retailers within census tracts from Method 2. In contrast, 2.5% were classified as food deserts when the 800-m *buffer* method was used. Furthermore, 13.8% and 37.7% of the census tracts were classified as food deserts according the methods proposed by Method 2 and Method 5, correspondingly. No food desert was observed when the methodology elaborated by Method 3 was applied (Table 2).

Food deserts were more frequent in the highest *per capita* income census tracts for the selected international methods: 28.1% for Method 2 in the number of food retailers within census tract, 43.6% for Method 2 in the number of food retailers within 800-m *buffer*, and 43.6% for the method proposed by Method 1 (32.3%). Only the Method 5 methodology identified food deserts as more frequent in census tracts with lowest *per capita* income (37.4%) (Table 2).

It was found that 2.5% of the census tracts were classified as food swamps according to the Method 2, which evaluated the number of food retailers within census tract, 66.6% were classified as swamps when the number of food retailers within 800 m' *buffer* was used, 34.9% according to the Method 4, and 58.5% when the adapted Method 5 was applied. According to the method proposed by Method 3 all census sectors are food swamps (Table 2).

Table 1 Description of food retailers according to National Classification of Economic Activities (CNAE) of Belo Horizonte. Belo Horizonte, Brazil, 2015

Food retailers	N	Proportion (%)
Food retailers of predominantly fresh produce	**1573**	**10.2**
Fresh produce store	754	4.9
Butcher shop	700	4.5
Fish market	65	0.4
EPSAN*	54	0.4
Mixed retailers	**6631**	**42.9**
Restaurants	3789	24.5
Bakery	911	5.9
Minimarkets	1368	8.9
Grocery stores and supermarkets	185	1.2
Dairy products	378	2.4
Food retailers of predominantly ultra-processed food	**7251**	**46.9**
Bars	2904	18.8
Snack bars	3919	25.4
Candy shops	428	2.7
Total	**15,455**	**100**

*Equipamentos Públicos de Segurança Alimentar e Nutricional (Public Equipments of Food Security)

The results of the analysis of the food swamps distribution according *per capita* income denoted that food swamps, by the Method 2 and Method 5 methodologies, were less frequent in lower-income census tracts. Conversely, the methodology of Method 4 suggested that the lower income census tracts were those with the highest frequency of food swamps (Table 2).

4 Discussion

The community food environment in Belo Horizonte was mainly formed by retailers mostly selling ultra-processed food; snack bars and restaurants were the most frequent food retailers. One fourth of census tracts lacked any food outlets, and most census tracts did not have retailers of fresh food products. In the evaluation of food deserts, Method 2 (which analyzed the number of food retailers within census tracts) and Method 5 (which analyzed the number of food retailers within census tracts.) were the methods that classified most census tracts to be food deserts. Method 2 (which also analyzed the number of food retailers within the buffer), Method 3 (which analyzed the number of food retailers within buffer) and the adapted Method 5 were the ones that identified the largest number of census tracts fitting the food swamp classification.

Previous studies performed in Brazil have shown similar patterns in the community food environment, with a high frequency of food retailers mainly selling ultra-processed food, such as minimarkets (25%) and snack bars (19%), in this country (CAISAN, 2018). In addition, 60% of food outlets in Rio de Janeiro City were previously classified as mixed retailers, whereas 32% mainly sold ultra-processed food (Junior, 2018). Recent studies conducted in other Brazilian medium-sized and large-sized cities such as Viçosa (MG) and Juiz de Fora (MG) have also found this pattern (Leite et al., 2021; Novaes, 2018).

Furthermore, we found census tracts lacking food outlets and the ones lacking food retailers that mainly sold fresh products were more frequent among the lowest *per-capita* income tracts. The association between socioeconomic aspects of neighborhoods and physical access to food stores is well established (especially from work in the USA), since the most vulnerable neighborhoods have poor access to food, especially to healthy items, as well as high physical access to unhealthy food (USDA, 2009; Walker et al., 2010; Larson et al., 2009; Hilmers et al., 2012; Li et al., 2019).

We found the highest rate of food deserts when the CDC method was applied. A possible explanation for this is because that framework takes into consideration the ratio between the sum of supermarkets and horticulture retail stores divided by the sum of snack bars and small grocery stores (CDC, 2011). Snack bars and small grocery stores were common in our study area, recording more than five times the number of supermarkets and horticulture retail stores in the community food environment of Belo

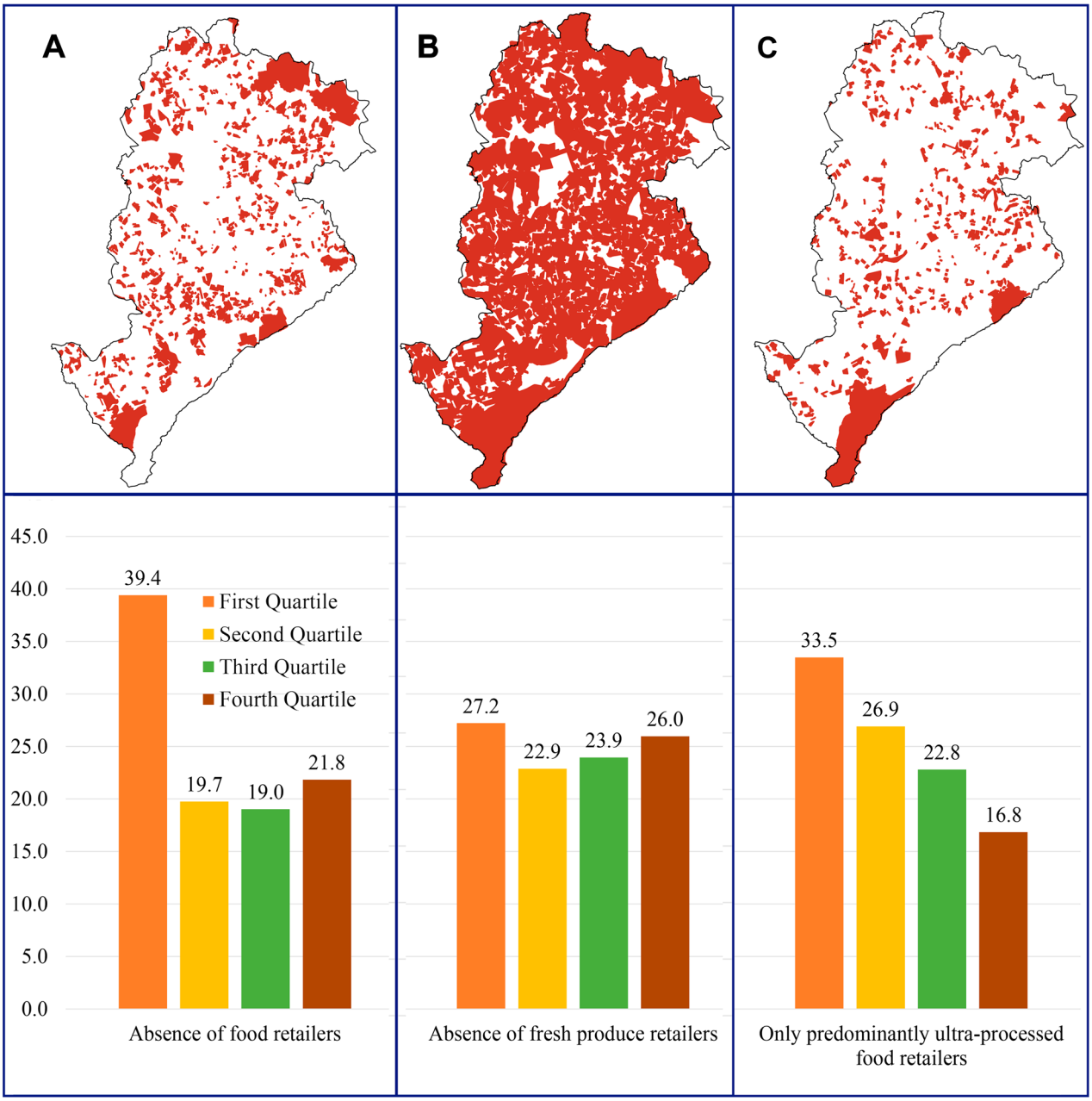

Fig. 3 Characterization of the census tracts according to type of food retailer. Belo Horizonte, 2015

Horizonte City. Thus, snack bars and small grocery stores significantly contributed to this finding and they represent a limitation for application of the CDC method in Brazil.

A significant limitation of the CDC method is that it considers just two outlet types to be healthy food retailers. Moreover, the suggestion by the CDC method to consider supermarkets as healthy food retailers is controversial, since consumers in these establishments are often induced to purchase ultra-processed food due to shelf layout, sales or attractive packaging, and persuasive marketing strategies adopted by large food companies (Stanton, 2015; Taillie et al., 2016).

These shortcomings are minimized by the CAISAN method, which takes into account food purchasing profiles in 13 different types of establishment (CAISAN, 2018) and is more suited to the situation in Brazil. However, the non-inclusion of the income variable to classify food deserts was a limitation observed in both methods (i.e., methods 2 and

Table 2 Evaluation of the food deserts and food swamps in the city of Belo Horizonte by different methods. Belo Horizonte, Brazil 2015

		1° Quartile (US$46.830 – $158.61)	2° Quartile (US$158.62 – $250.24)	3° Quartile (US$250.25 – $562.85)	4° Quartile (> US$562.85)
	n (%)	n (%)	n (%)	n (%)	n (%)
Food deserts					
Method 1	530 (13.8)	120 (22.6)	112 (21.1)	127 (24.0)	171 (32.3)
Method 2 – within census tract	1498 (39.1)	296 (19.8)	372 (24.8)	409 (27.3)	421(28.1)
Method 2—800 m buffer	94 (2.5)	30 (31.9)	12 (12.8)	11 (11.7)	41 (43.6)
Method 3	0	0	0	0	0
Method 5	1444 (37.7)	540 (37.4)	320 (22.2)	293 (20.3)	291 (20.1)
Food swamps					
Method 2 – within census tract	97 (2.5)	2 (2.1)	27 (27.8)	33 (34)	35 (36.1)
Method 2—800 m buffer	2550 (66.6)	543 (21.3)	538 (21.1)	705 (27.6)	764 (30.0)
Method 3	3830 (100)	957 (100)	958 (100)	958 (100)	957 (100)
Method 4	1338 (34.9)	408 (30.5)	340 (25.4)	301 (22.5)	289 (21.6)
Method 5	2240 (58.5)	399 (17.8)	621 (27.7)	625 (27.9)	595 (26.6)

5). We suggest using an income cut-off point in order to improve the CAISAN methodology by enhancing its specificity. Including a socioeconomic vulnerability variable, such as income, is fundamental to increase the method's reliability. Since evidence from the literature shows that food deserts are associated with low-income locations (USDA, 2009; Walker et al., 2010; Gordon et al., 2011; Crush et al., 2018).

Although income was not initially considered a variable by the methods, in the current study we evaluated the distribution of tracts classified as food deserts and food swamps based on income. The CAISAN method was the only one capable of identifying that most of the census tracts classified as food deserts were located in the lowest income tracts. This finding reinforces outcomes available elsewhere in the literature demonstrating that food deserts are more often observed in lower-income neighborhoods (Gordon et al., 2011; Slater et al., 2017; Walker et al., 2010).

Both the CDC and CAISAN methods highlighted that those tracts classified as food swamps in Belo Horizonte were more often observed to be higher-income. Conflicting results about food swamps can be found when data are stratified based on income. Some authors have also shown that food swamps were more often observed in lower-income neighborhoods (Gordon et al., 2011; Slater et al., 2017), while elsewhere there are results indicating that food swamps were more often observed in higher-income neighborhoods (Cooksey-Stowers et al., 2017).

In our study we observed that a single census tract could be concomitantly classified as a food desert and a food swamp (where neighborhood with limited availability of establishments selling healthy foods and with high availability of establishments selling unhealthy foods), similar to the study by Hager et al. (2017) conducted with adolescents living in low-income neighborhoods in the city of Baltimore, USA. Based on their study, 16.1% of adolescents lived in neighborhoods simultaneously classified as food deserts and food swamps (Hager et al., 2017).

Method 3 (by Luan et al., 2015) classified all census tracts as food swamps, with no census tract classified as a food desert. This result is explained by the fact that this method adopted a buffer size of 4,000 m. That was used by Luan et al. (2015) because it represents the distance corresponding to 5-min travel by car, which is the main means of transport used in their study region (Region of Waterloo, Ontario, Canada). This finding reinforces the importance of using methods appropriate to the whole environment of the investigated neighborhood, rather than just to features of the food environment.

In addition, the choice of the unit of analysis influences the results because the definition of neighborhoods employs different criteria (Health Canada, 2013). For example, buffers are geographic areas with fixed distances (Health Canada, 2013), and census tracts are geographic areas defined by the number of households (IBGE, 2016).

Finally, our results underscore that methodologies used to classify food deserts and food swamps should take into consideration particularities of local food environments. Of the methods used, method 5 was the most adequate to identify food deserts and food swamps in Belo Horizonte and probably elsewhere in Brazil. Nevertheless, this methodology needs to be improved. In particular, we feel it is necessary to include a variable "income" at the time of the study to calculate food deserts.

Limitations in our study are associated with the use of secondary databases. It was not feasible to collect primary

data, because Belo Horizonte is a major metropolis. Another limitation involved the need to adapt the methods applied to identify food deserts and food swamps, since it was not possible to collect all necessary data, such as addresses of individuals, use of public transport and car ownership required in some of the methods. Additionally, studies carried out in middle- and low-income countries have pointed out that food deserts are more often associated with food purchasing power than with physical access to food outlets (Davies et al., 2017; Crush et al., 2018). This factor was also a limitation of our study, since we did not evaluate purchasing power. Nevertheless, the present study has contributed to knowledge about the community food environment since it was the first Brazilian study aimed at testing different methods to evaluate food deserts and food swamps, as well as encompassed the entire urban extension of the investigated city.

5 Conclusions

We conclude that in general in Belo Horizonte city, there is easier physical access to the many food retailers mainly selling ultra-processed food, and poor physical access to fresh product retailers. Thus, many parts of the city have features associated with food swamps. Moreover, the distribution of food outlets is overall uneven and it is influenced by neighborhood income, with many of the poorer areas having features of food deserts.

Regardless of the method used to investigate food deserts and food swamps, it is possible to find many neighborhoods with such characteristics in the city of Belo Horizonte. Furthermore, this study demonstrates that those methods more specific to the characteristics of the local food environment are more appropriate for the evaluation of food deserts and food swamps. Accordingly, further work is needed to adapt and use methods more appropriate to the food environment in Brazil.

Panel 1 Concepts, methods and adaptations for the assessment of food deserts and food swamps

Method	Evaluated construct	Concept	Method	Analysis unit	Classification
Method 1 (GORDON et al., 2011)	Food deserts	Socioeconomically vulnerable neighborhoods where individuals have poor access to healthy and affordable food, mostly with fast food restaurants	Food Desert Index, which considers three types of food outlets: supermarkets, healthy grocery stores and fastfood restaurants. Each type of establishment receives a score ranging from 1 to 3. The score assignment to the block that evaluates supermarkets considers the number of these outlets within a pre-established radius. The evaluation of healthy grocery stores and fast food restaurants considers their proportion relative to the total of grocery stores and restaurants, respectively	400 m radius buffer traced from the centroid of census tract	Final index value is obtained by the sum of the scores of the three types of food outlets. Census tracts that have an index equal to three are classified as food deserts
Method 2 (CDC, 2011)	Food deserts and food swamps	Food deserts are neighborhoods that do not have access to fruits, vegetables, whole grains, low-fat milk and dairy products and other foods that make up a healthy diet. Food swamps are neighborhoods with more options of high energy density food than healthy food	It proposed the use of the Modified Food Retail Environment Index (mRFEI), an index that considers supermarkets, hypermarkets and fruit stores as healthy food outlets, and fast food restaurants and convenience stores as unhealthy food outlets. The index is calculated as the ratio of healthy to unhealthy outlets multiplied by 100	Census tract and 800 m radius buffer traced from the centroid of the census tract	Food desert classification is assigned when mRFEI equals 0, and food swamps classification is assigned by low, positive values

Panel 1 Concepts, methods and adaptations for the assessment of food deserts and food swamps

Method	Evaluated construct	Concept	Method	Analysis unit	Classification
Method 3 (Luan et al., 2015)	Food deserts and food swamps	Uses the same definition as in CDC (2011) to describe food deserts and food swamps	Uses mRFEI, but considers only supermarkets and hypermarkets as healthy food retailers. Convenience stores and fast food restaurants are categorized as unhealthy food retailers	400 m buffer network (geographical unit used to calculation the distance by street network)	Uses the same classification system as CDC (2011)
Method 4 (Hager et al., 2017)	Food swamps	Food swamps are neighborhoods with limited access to supermarkets and healthy food retailers and an excess of high energy density food retailers	Summation of all convenience stores, corner stores, and minimarkets within a 0.4 km (0.25 miles) radius	400 m radius buffer traced from the centroid of the census tract	A census tract is considered as a food swamp when the summation of stores is ≥ 4
Method 5 (CAISAN, 2018)	Food deserts and food swamps	Food deserts are neighborhoods where access to healthy food is limited. There is no defined concept for food swamps	Healthy food outlet density per 10,000 inhabitants. Establishments were considered healthy food outlets when they predominantly retail fresh produce and when they were mixed food retailers	Census tracts	Census tracts that are below the 25th percentile are classified as food deserts. The cut-off to classify tracts as food swamps was density of food outlets of predominantly ultra-processed food above the 25th percentile

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Olivia Souza Honório Nutritionist graduated from the Federal University of Juiz de Fora in 2016. Master's degree in Nutrition and Health from the Federal University of Minas Gerais (UFMG), in the Nutrition and Public Health research line. PhD student in Health and Nutrition at the FederalUniversity of Ouro Preto (UFOP). Member of the Group of Studies, Research and Practices in Food Environment and Health (GEPPAAS).

Paula Martins Horta Adjunct Professor, Department of Nutrition, Federal University of Minas Gerais (UFMG). Nutritionist (2010) and Master (2013) in Nursing from UFMG. PhD in Health Sciences (2016), area of concentration Child and Adolescent Health, from UFMG. Member of teams involved in the implementation of research and innovation projects in cooperation with national and international institutions. Has experience in the area of food information environment,

food advertising, regulatory policies in food and nutrition,food and nutrition education and assessment of food consumption. Member of theResearch Group on Nutrition Interventions - UFMG and the Group of Studies, Research and Practices in Food Environment and Health (GEPPAAS) - UFMG. Permanent advisor of the Graduate Program in Nutrition and Health - UFMG.

Milene Cristine Pessoa She has a degree in Nutrition from the Federal University of Ouro Preto (2006), a master's degree in Health and Nursing from the Federal University of Minas Gerais (UFMG) (2009) and a PhD in Nursing from the same University (2013). She is currently an adjunct professor and subcoordinator of the Undergraduate College of Nutrition at the Federal University of Minas Gerais (UFMG). Researcher and leader of the Study Group Research and Practices in Food Environment and Health (GEPPAAS). Advisor in the Post-Graduation Programs in Nutrition and Health (UFMG) and Health and Nutrition (UFOP). She has experience in Nutrition Epidemiology and Nutrition, with emphasis on Food Environment and Nutritional Analysis of Population.

Mariana Zogbi Jardim Master in Nutrition and Health from the Postgraduate Program in Nutrition and Health at the FederalUniversity of Minas Gerais with research focused on Food Environment, Food andNutrition Security and Public Equipment for Food and Nutrition Security. Memberof the group of Studies, Research and Practices in Food Environment and Health(GEPPAAS). She has a degree in Nutrition from Universidade Federal Fluminense,was a Scientific Initiation student and member of the research group withchronic renal patients, with scholarship funded by the Institutional Programfor Scientific Initiation Scholarship (PIBIC). She was part of the FunctionalNutrition Research Group (GPeNF) and of the Scientific Initiation program,being a scholarship holder through the Carlos Chagas Filho Foundation forResearch Support of the State of Rio de Janeiro (FAPERJ).

Ariene Carmo da Silva PhD in Health Sciences-Child and Adolescent Health from the Medical School of the Federal University of Minas Gerais (UFMG). Nutritionist and Master in Health and Nursing (UFMG). She has experience in the area of Public Health, working on the following themes: maternal and child health, health promotion, prevention and control of diseases and non-communicable diseases, nutritional epidemiology, and food environment. Member of the following groups recognized by the National Council for Scientific and Technological Development (CNPq): Group of Interventions in Nutrition (GIN); Group of Study, Research and Practice in Education, Food and Nutrition (GEAN) ; and Center for Studies in Food and Nutrition in Life Cycles (NEANC). She is also a member of the Group for the Study of Nutritional Epidemiology (GREEN) and the Group for Study, Research and Practice in Food Environment and Health (GEPPAAS).

Larissa Loures Mendes She has a degree in Nutrition from the Federal University of Ouro Preto (2005). Master's degree (2008) and PhD (2012) in Nursing from the School of Nursing, Federal University of Minas Gerais. She is currently an adjunct professor at the Department of Nutrition at the Federal University of Minas Gerais, the Graduate Program in Health Nutrition at the Federal University of Minas Gerais, the Graduate Program in Child and Adolescent Health at the Federal University of Minas Gerais and collaborating professor in the Graduate Program in Public Health at the Federal University of Minas Gerais. She leads the Group of Studies, Research and Practices in Food Environment and Health (GEPPAAS) and has experience in the area of Nutrition in Public Health, working mainly on the following topics: nutrition, chronic noncommunicable diseases, nutritional epidemiology and analysis of the food environment.