Multicriteria decision analysis for fruits and vegetables routes based on the food miles concept

Análisis de decisiones multicriterio para rutas de frutas y verduras basado en el concepto de millas de alimentos

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ABSTRACT

The aim of this research is to propose a performance evaluation system to rank the efficiency of fruit and vegetables (FV) distribution routes based on selected criteria related to logistic, distribution practices and physical losses that are part of the attributes associated with the food miles concept. To achieve this end, the multicriteria Preference Ranking Method for Enrichment Evaluation (PROMETHEE) was adopted. The distance that a food item travels from the field to the table is an important logistical indicator and sooner it arrives in the hands of the consumer, the greater the degree of preservation of quality, *i.e.*, the integrity of the item's sensory and organoleptic characteristics. An analysis of the logistics involved should take into consideration issues such as distance, transportation time, pollutant emissions, conditioning, and all the other attributes pertinent to the food miles concept. Short routes were the most efficient, however the perishability of the product was not the main factor, this is because aspects related to a good ability to offer products, transport them safely and assertiveness in predicting demand contributed more to the high efficiency rates, thereby, it is the short routes that service the predilections of consumers who value locally produced food.

Keywords

logistical performance • food miles • PROMETHEE • wholesaling • food distribution • transport • MCDA • food supply chain

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Resumen

El objetivo de esta investigación es proponer un sistema de evaluación del desempeño para clasificar la eficiencia de las rutas de distribución de frutas y hortalizas (FV) con base en criterios seleccionados relacionados con la logística, las prácticas de distribución y las pérdidas físicas que forman parte de los atributos asociados al concepto de millas de alimentos. Para lograr este fin, se adoptó el Método de Clasificación de Preferencias multicriterio para la Evaluación del Enriquecimiento (PROMETHEE). La distancia que recorre un alimento desde el campo hasta la mesa es un indicador logístico importante y cuanto antes llegue a manos del consumidor, mayor es el grado de conservación de la calidad, es decir, la integridad de las características sensoriales y organolépticas del producto. Un análisis de la logística involucrada debe tomar en consideración aspectos como la distancia, el tiempo de transporte, las emisiones contaminantes, el acondicionamiento y todos los demás atributos pertinentes al concepto de millas de alimentos. Las rutas cortas fueron las más eficientes, sin embargo la perecibilidad del producto no fue el factor principal, esto se debe a que aspectos relacionados con una buena capacidad para ofrecer productos, transportarlos con seguridad y asertividad en la predicción de la demanda contribuyeron más a las altas tasas de eficiencia, por lo que, son las rutas cortas las que sirven a las preferencias de los consumidores que valoran los alimentos producidos localmente.

Palabras clave

rendimiento logístico • millas de alimentos • PROMETHEE • venta al por mayor • distribucion de comida • transporte • MCDA • cadena de suministro de alimentos

Introduction

Although substantial there is much research available addressing growth and the importance of local production and consumption to for the development of sustainable agriculture is now available, this research contributes in the analysis of the wholesalinge sector of fruits and vegetables (FV) role in this innovative new vision of production and consumption. Cities have come to rely heavily on large scale food sourcing (7), giving rise to new logistical issues, since the globalizing of food production systems requires long haul travel for its transportation (42).

In the USA, for example, the average distance traveled by fresh produce from the farm to the consumer market has increased in recent decades, currently ranging between 1,500 and 2,500 miles (22). In contrast, in the European Union, products travel an average of 865.5 miles (32).

In Brazil, the fruit and vegetable logistical supply chain (FV) makes little use of best distribution and supply practices. Among other factors, long distance transportation hampered by an inefficient logistics system with prolonged journey times, trucks with no refrigeration, and ineffective packaging, all contribute to the deterioration of product quality, loss and waste (45).

The hypothesis of this study is that food consumption based on economic logic is insufficient to promote the efficiency of agrifood chains, as the mitigation of losses is also emerging and the promotion of sustainable logistic systems.

The aim of this research is to propose a performance evaluation system to rank the efficiency of fruit and vegetables (FV) distribution routes based on selected criteria related to logistic, distribution practices and physical losses that are part of the attributes associated with the food miles concept. To achieve this end, the routes of FV marketed in a wholesale food market were evaluated using a multicriteria method the Preference Ranking Method for Enrichment Evaluation (PROMETHEE).

The application of decision-making methods to complex problems characterized by multiple criteriais on the increase (17). Several Multi-Criteria Decision Analysis (MCDA) methods can now be found in the literature, for example: Analytic Hierarchy Process (AHP), Data Envelopment Analysis (DEA), Elimination and Choice Translating Reality (ELECTRE), Multi-attribute Utility Theory (MAUT), Preference Ranking Method for Enrichment Evaluation (PROMETHEE), Technique for the Order of Prioritisation by Similarity to Ideal Solution (TOPSIS), among many others (55).

MCDA methods can be classified into three categories according to their preference modeling principles: 1- synthesis of single criterion approach, 2- interactive judgment approach and 3- outranking approach (35). In the case of outranking methods, there is a construction of an overclassification/supremacy relationship, which in-corporates the preferences established by the decision maker (28, 57). It was within this infrastructure of outranking methods that PROMETHEE was developed (28).

The application of PROMETHEE and hybrid methods that include you, were used to assess the performance of supply chains, in particular regarding the strategies for locating distribution centers by (2, 24, 27, 47, 51). The multicriteria method has also been used to identification of strengths and weaknesses of attributes related to food security (46), selection of green suppliers in the field of the food supply chain (21) and organizational performance management applied to fruit exporters (48).

The food miles concept fits this perspective as it addresses the importance of production close to the place of consumption, the concept has ramifications that go far beyond local food in its consideration of environmental, economic and social sustainability issues. The importance of food miles is such that they can be considered an indicator of sustainable development (40). Research discussing the importance of the food miles concept is now extensive in the literature (37, 42).

Food distribution connects consumption to production in different ways (20). This is especially so in the fresh produce wholesaling sector (6). In Brazil, two companies, CEASA Campinas and CEAGESP, are considered references in the Wholesale Food Market, in addition to being important players in the supply of several Brazilian municipalities. CEASA Campinas sells robust volumes of horticultural products despite being located in the same state as the largest centralized supplier in the country (54).

To this end, the fruit and vegetable routes marketed by the wholesaling center, CEASA Campinas, were evaluated using PROMETHEE. The FVs were chosen accordingly from the most commercialized lines in terms of volume and/or number of financial transactions.

Materials and methods

PROMETHEE is one of the most recent MCDA methods developed by Brans in 1982 and in the years following several modules were created and applied to the most diverse of areas (4, 11, 25, 28, 31, 37, 57). The method is based on the comparison of pairs of alternatives ac-cording to each criterion, and in relation to the weightings. The result is a ranking of the options from the best to the worst, *i.e.*, based on the construction of an overclassification relationship (10, 57). The main difference that separates PROMETHEE from other methods is that it considers the internal relationships of each item in the assessment during the decision-making process (1, 10, 37) and advantage stems from its mathematical properties and easy interaction with the user (1, 35).

The steps necessary to apply the method are. First, define a decision matrix containing a set of alternatives and criteria: The Multicriteria problems solved with PROMETHEE consist of a finite set A, of n alternatives where f1 to fk are k criteria. The fj (a) function is the evaluation of the alternative "a" in the fj criterion (9). The data is expressed in a preference matrix format. Each row corresponds to an alternative and each column to a criterion. Whenever not declared, it is assumed that all criteria fell into the earned value category (21, 37). Set preferences for each of the criteria: First, the decision maker must assign weightings "w" to each criterion, according to their relative importance. The higher the value of the weighting, the greater the importance of the criterion (4, 29).

$$\sum_{j=i}^{k} wj = 1$$

Next, the decision maker can decide whether the weighting will be maximized or minimized so as to achieve optimization (10, 11). When a criterion is maximized, this function gives preference to "a" over "b" for deviations observed between criteria evaluations (10).

Finally, the decision maker selects the preference function that is to be associated with each criterion. Rj (a, b) represents the function of the difference between the evaluations of alternative "a" compared to alternative "b" in each criterion in a degree ranging between 0 and 1. The dj (a, b) refers to the assessments of "a" and "b" in each criterion (1).

$$Rj\,(a, b) = Fj\,[dj\,(a, b)]$$

The selection method is enriched by six possible forms of preference function: 1- usual criterion (no parameters are defined); 2- U-shape (parameter q is defined); 3- V-shaped criterion (parameter p is defined); 4- level criterion (parameters q and p are defined); 5- V shape with in-difference criterion (q, e, p parameters are defined) and 6- Gaussian criterion (standard deviation must be fixed) (37). Once the preferences have been set (weightings, maximizing/minimizing and the preference function), the next step in PROMETHEE modeling is to compare each action against each other. This is done by calculating a multicriteria preference index (9).

$$\{\pi(a, b) = \sum_{j=1}^{k} Qj(a, b)wj \quad \pi(b, a) = \sum_{j=1}^{k} Qj(a, b)wj$$

The degree of exceeding $\pi\,(a, b)$ expresses to what degree "a" is preferable to "b" over all criteria; and, $\pi\,(b, a)$ as "b" is preferable to "a". Both $\pi\,(a, b)$ and $\pi\,(b, a)$ are normally positive values. The following properties are valid:

$$\{\pi(a, a) = 0, 0 \leq \pi(a, b) \leq 1, 0 \leq \pi(b, a) \leq 1, 0 \leq \pi(a, b) + \pi(b, a) \leq 1$$

$\pi\,(a, b) \approx 0$ indicates that a is WEAKLY preferable to b
$\pi\,(a, b) \approx 1$ indicates that a is STRONGLY preferable to b

Calculate the important flows: Each alternative competes with (n-1) and other alternatives. The balance of these competitions can be expressed through two flows, positive and negative. It should be emphasized that the greater the net flow, the better the performance of the alternative.

The net preference flow is the balance between positive and negative preference flows:

Positive flow (Phi +) (ø⁺) of overshoot: $\quad \emptyset^{+}(a) = \frac{1}{n-1}\sum_{x \in A} \pi(a, x)$
Negative flow (Phi-) (ø-) of overshoot:

$$\emptyset^{-}(a) = \frac{1}{n-1}\sum_{x \in A} \pi(x, a)$$

From the information on net flows (Phi-) (ø-), the rankings of the alternatives are obtained in decreasing order of their respective flows.

The alternatives are first compared in pairs with each criterion according to the preferences of the decision maker, resulting in local scores which are then added to the global scores through the application of the PROMETHEE I and PROMETHEE II modules (31). The basic principle of PROMETHEE II (full ranking) is based on the net preference flow (Phi), which can be interpreted as a score attributed to the alternative according to its performance. It includes preferences and indifference: <P, I> (9). An alternative "a" can outperform an alternative "b" if the net flow of "a" is greater than the net flow of "b". The alternative "a" may be in-different to "b" if its net flows are the same. Thus, the ranking of alternatives is based on the decreasing order of their respective net flows (9). The GAIA module is an extension of the PROMETHEE results through a visual procedure, which helps in the interpretation of the results (10).

Description of the data
Five FVs were selected, which are among the most commercialized in terms of volume and/or number of financial transactions, sources of regular supply throughout the year in their respective categories and different perishables such as lettuce (*Lactuca sativa* L.) (leaf, flower and stem), tomato (*Lycopersicon esculentum* Mill.) (fruit),

potato (*Solanum tuberosum* L.) (root, bulb, tuber and rhizome), orange (*Citrus sinensis* L. Osbeck) (fruit) and papaya (*Carica papaya* L.) (fruit) (14). Whatsmore, those produce is among those most commonly consumed by the Brazilian population, according to the latest Household Budget Survey - POF 2017-2018. In the group of fruits, orange ranks 3rd, followed by papaya in 4th, in the group of vegetables, tomatoes lead the ranking in 1st, potatoes in 2nd and lettuce in 8th (12).

The data were collected from the Brazilian Horticulture Market Modernization Program (Prohort) of CONAB (2019) and considered the following: road transport routes (from the city of production to CEASA Campinas), in addition to their respective volumes (in kg) and average annual value. Distances (in km) and time (in minutes) were also calculated. Field research was carried out in which wholesale traders were interviewed via a questionnaire. This questionnaire was applied on the spot between October 2019 and January 2020.

This methodological approach is known as rapid appraisal and has been applied (5, 18) and, with a focus on strategies for supply chain management, Alidrisi (2021) and Sukati *et al.* (2012). This method uses data from secondary sources together with interviews based on semi-structured questionnaires, in which detailed data and/or information are needed for understanding the dynamics of the sector evaluated. The development of the questionnaire was adapted from the work of Gustavsson *et al.* (2013) and Mendonça Lima; Ramos de Oliveira (2021) and reflects the logistical practices already established for each product category with a view to monitoring a sampling so as to ensure the representation would be appropriate (33). The number of wholesalers that sell exclusively lettuce, potatoes, oranges, papaya and tomatoes totals 81 wholesalers. CEASA Campinas wholesalers agreed to participate in the survey (87.6% response rate).

CEASA Campinas is an important Wholesale Food Market of fruits and vegetables and other fresh products for the state of São Paulo, being responsible for supplying more than 500 municipalities. There are more than 580 wholesalers, distributed in about 940 stores (15). The study limit is the Wholesale Food Market de Campinas and was chosen because of: (i) easy access and collection of merchant information; (ii) in the 2017-2019 triennium, 1.8 million tons of food were sold, of these, 560 thousand tons of fruits and vegetables, ranking as the eighth largest wholesaler in the country (16).

Selection of routes by distance range

The distances for all the routes analyzed were surveyed. Next, the routes were grouped into three distance ranges for each selected FV, classified as short, medium or long (table 1). For this division, the data was separated into a cluster using the SPSS software program (19).

Table 1. Categories of routes.

Tabla 1. Categorías de rutas.

	Lettuce	Potato	Orange	Papaya	Tomato
Categories of routes	**Distances (km)**				
Short	< 80	<350	< 210	< 610	< 400
Medium	80 - 200	350 - 1,200	210 - 1,100	610 - 1,800	400 - 1,550
Long	> 200	> 1,200	> 1,100	> 1,800	> 1,550

Criteria selected for evaluation

The criteria were established based on research that addressed the concept of food miles (44, 53). The concept also contributed to establishing the criteria, and identifying road transport practices, obtained from an interview with CEASA Campinas' FV marketing managers, as well as certain players in the wholesaling sector and transportation operators (15). In addition, the criteria were defined by their association with the quality of the product, or rather, attributes that should be configured to ensure the integrity of the food (maintenance of the physical and nutritional quality of food). Altogether, 12 criteria were defined as follows: 1- Distance, 2- Time, 3- Volume, 4- CO_2, 5- Price, 6- Losses, 7- Truck, 8- Packaging, 9- Own transport, 10- Traceability, 11- Change in packaging and 12- Handling. The calculation used for each criterion is described in supplementary material.

Weightings assigned to the criteria

The weighting assigned to each criterion was determined by a questionnaire applied to specialists in the sector (decision makers), who had to rank them in order of importance taking into account their perceptions of the food miles concept. Each specialist evaluated the criteria individually, and assigned percentages (again individually) whereby the sum of all of them totalled 100%. Immediately after, the arithmetic mean of the weighting of each criterion was calculated, as well as work developed (1). The definition of weightings by consultation with a specialist is a very common practice (1, 21). The usual criterion preference function was selected as being the most appropriate approach to the problem.

RESULTS AND DISCUSSION

The importance of measuring the logistical performance of distribution channels of different lengths (km) based on criteria supported by the concept of food miles and in the main logistical practices of distribution of fruits and vegetables, contribute to the definition of strategies to mitigate food losses and the promotion of more sustainable supply chains. This is one of the main contributions of this research, which also points out the vulnerable points of each distribution channel and proposes measures to be implemented to overcome these obstacles.

It can be seen that the short lettuce route alternative scored as being the most efficient within the established parameters (table 2). This result corroborates the tendency of consumers to value locally produced food, as has been shown firstly, by the work of Grebitus *et al.* (2013) in which the products analyzed with the shortest distance covered had the highest preference score with consumers and secondly, by the work carried out by Pektaş *et al.* (2017) who showed the extent to which degree of loyalty of people rose when valuing organizations that sell locally produced food. The alternative long papaya route, characterized by long journey and travel time, was the most efficient in the lower stratum compared to the long tomato, long potato and long orange routes, which covered much shorter distances. This is due to the fact that long papaya is transported in refrigerated trucks, as shown by Liu *et al.* (2020) where temperature can be a more effective factor in the preservation of fresh fruit and vegetables. What stands out is the significant difference between the short lettuce and medium lettuce scores, which produced a result of 57.47.

Table 2. Ranking of FV routes.

Tabla 2. Clasificación de rutas FV.

Routes	Score	Phi	Phi+	Phi-
LettuceS	100.0	0.5592	0.5902	0.0310
OrangeS	55.2	0.3226	0.4716	0.1490
PotatoS	46.3	0.2416	0.4445	0.2029
LettuceA	42.5	0.2014	0.4395	0.2381
PapayaS	41.6	0.1904	0.4157	0.2252
TomatoS	35.6	0.1152	0.4137	0.2986
OrangeA	30.7	0.0411	0.3502	0.3090
LettuceL	26.0	- 0.0419	0.2033	0.2452
PotatoA	22.4	-0.1165	0.2654	0.3819
PapayaA	21.2	-0.1440	0.2443	0.3883
PapayaL	19.6	-0.1808	0.2326	0.4135
TomatoL	18.6	-0.2075	0.1205	0.3280
PotatoL	15.5	-0.2933	0.0776	0.3709
TomatoA	13.9	-0.3400	0.1862	0.5262
OrangeL	13.7	-0.3475	0.0505	0.3980

The criteria of volume, packaging and traceability were the criteria that most penalized the alternative route. It is also important to note the influence of the criteria on each alternative (figure 1).

Phi+ means how much one alternative is dominating the others and Phi- means how much one alternative is dominating the others. The difference between these flows generates the Phi that shows the ordering of the alternatives, from the largest net flow to the smallest.
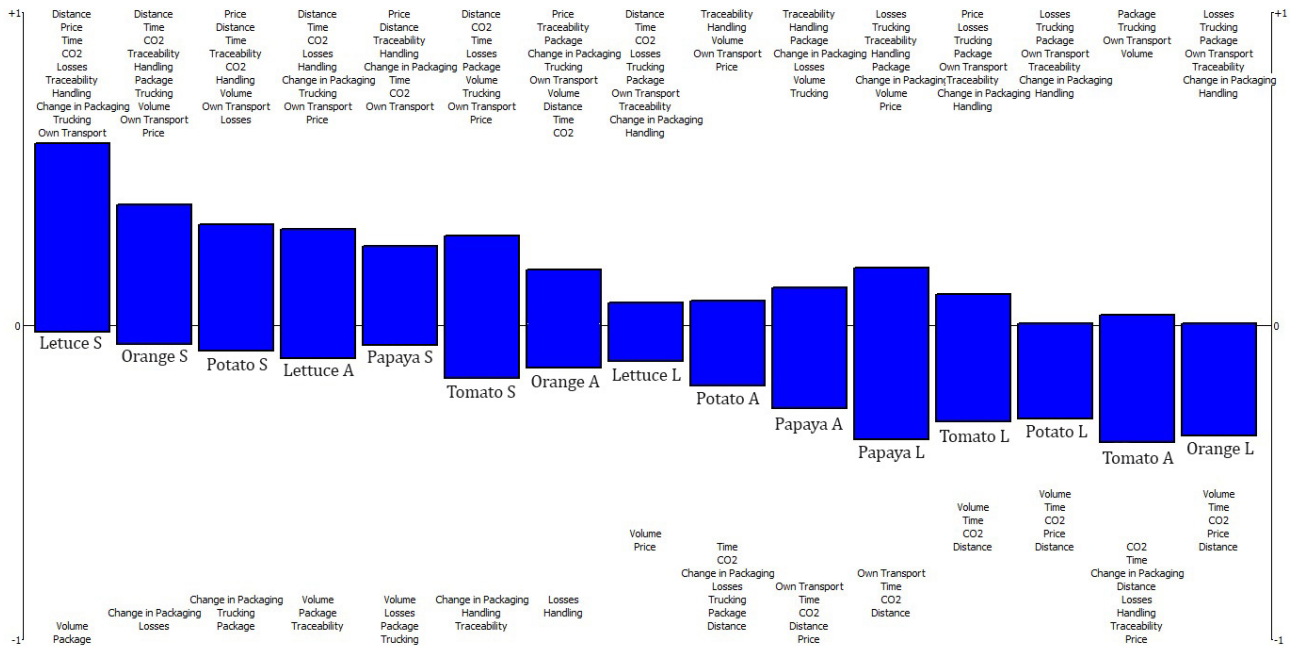

Figure 1. Participation of the criteria in the FV routes.
Figura 1. Participación de los criterios en las rutas FV.

The short lettuce route, which was the most efficient, presented the shortest distance from the field to the wholesaling center. However, the criteria of volume and type of packaging used showed negative results in the analysis (figure 1). Although the short lettuce route was the most efficient among the other routes, it did not meet 100% efficiency for all the criteria. This shows that even though it was the best route, it is still possible to find vulnerable points where improvements could be implemented.

Lettuce covers an average radius of 168 km as it is a very perishable food production that takes place closer to the wholesale center. Transport is more frequent and volumes are smaller, making the offer more assertive to meet demand, avoiding losses. On the other hand, papaya travels on average a radius of 1,517 km added with negative performance operational criteria contributed to greater losses. This result is proven by the work of Mendonça Lima and Ramos de Oliveira (2021) who disclosed that practices such as transshipment operation, transport of an open truck (often covered with canvas) and the use of "K" type packaging (wood) were associated with higher levels of residues for papaya.

In Slovenia, a survey of tomatoes showed that regional production around 250 km could reduce the ecological footprint left by transportation by up to 83.33%, compared to the 1,500 km transcontinental transportation journey (49). In Canada, a study analyzed the distances that imported foods travel and CO_2 emissions in 2006 showed that 30% of agricultural commodities consumed in the country were imported and that food miles exceeded 61 billion tons of km generating approximately 3.3 million tons of CO_2. Fruit and vegetables were, in fact, the foods responsible for emitting the most CO_2 (25).

In the case of tomato routes, the average route proved to be less efficient compared to the long route. The criteria of changes in packaging, losses, handling, traceability and price penalized the performance of the alternative medium route compared to the long route (figure 1, page 103). While short routes are more efficient, principally as a function of the distance involved, there are weak aspects to be overcome by better planning such as the type of packaging used and handling in relation to changes in packaging.

Weightings have a significant influence on performance analysis and the multicriteria model was associated with this problematic model, in the same way as the work carried out by Wu *et al.* (2020) in which the application of PROMETHEE proved it presented the best method for comparing alternatives.

The influence of the criteria, especially qualitative ones, on the analysis is significant. Research involving qualitative issues almost always raises doubts as to what constitutes best decision-making, and the use of multicriteria analysis in these cases is an efficient tool (21).

Overall analysis (figure 2) is based on the Phi flow (PROMETHEE II), which facilitates an ordering of the alternatives. When applying the module, an overall assessment is presented by overrun, whereby the short lettuce route is highlighted, followed by the second best alternative, which is the short orange route. The upper half of the scale (in green) corresponds to Phi + scores and the lower half (in red) to Phi- scores.
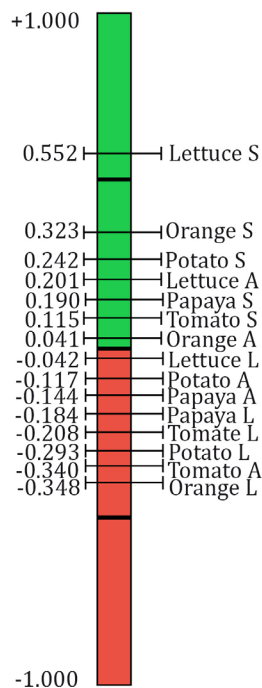

Figure 2. Overall ranking.

Figura 2. Clasificación general.

Once the product is harvested, it is no longer possible to improve its quality just be preserve, the use of refrigerated transportation is an important attribute because under conditions of monitored temperatures it is possible to travel a greater distance without materially penalizing product quality. However, from the perspective of sustainability, is not always the best, since ultimately, kilometers driven translate into greater emission of pollutants and higher economic costs. The use of more appropriate packaging for each type of FV and less handling should contribute to improvements in this configuration. The packaging's beneficial effects in maintaining produce quality during transportation and retail marketing have been demonstrated for many types of FV, such as mangoes, strawberries and kale (13). Edible coatings and waxes, based on proteins, lipids, polysaccharides and their composites, are also protecting and preventing food losses and waste (52). Cardboard

packaging, for example, is sustainable, and post-first time use is then recycled. Furthermore, the fact that this packaging model supports lower volumes reduces the need to switch to lesser options, as with potatoes that arrive in 50 kg bags and in some cases when unloading, are transferred to 25 kg bags, or in the case of tomatoes, which are in plastic boxes and sometimes transferred to plastic bags. According to Müller and Schmid (2019), depending on the packaging, biological, chemical or physical processes can occur, leading to deterioration in the product.

The use of the best logistical models can be found on both long and short routes. Thus, distance and time become paramount when choosing the best routes. This contributes to meeting the expectations of new consumption trends whereby sustainability is prioritized.

In Brazil, logistics for FV products is still under development, since many of the operations are in deficit. As can be seen in the results of this research, certain medium and long routes may be more efficient as appropriate means of transport, packaging and refrigeration are deployed.

Relocating producing regions close to large consumer centers is not simple. This is because in Brazil the northeast region has proved to be quite suitable for the production of various FV, due to good climate and soil conditions. In addition, the northeast region is closer to the EUA and Europe, which contributes to shorter distances for export. The improvement of some practices can bring substantial gains to the sector before heavy investments in infrastructure.

A number of local marketing practices connecting producers and consumers have been adopted worldwide which, increasingly, are appearing in the Brazilian scenario; for example, the Community Supported Agriculture (CSA), known as the CSA (37). Although this model has proven to be quite well-structured and developed, there are others in the making gaining adherents. Such is the case for urban agriculture, where a community comes together to produce food in idle urban spaces, such as squares, backyards, balconies, vacant lots, public or private green areas, building slabs and shopping malls (38).

Although CEASAs has been gradually losing market share to large retail chains, the system remains crucial to the Brazilian model. However, the growth of populations looking for locally produced food calls for modernization of this system to meet the demands of the new consumer market. Considering the continental dimensions of Brazil, wholesaling centers should continue to maintain the interface between producers and consumers, since there are regions with potential for greater production of certain products the results can contribute to direct public policies on the promotion of sustainable foods and loss and waste reduction.

Porat *et al.* (2018) argue that measures, such as the public awareness campaigns and information platforms to publish and advertise adequate professionally recommended storage instructions are important policies soft. But it is also necessary that governments and municipalities can adopt more rigorous approaches in terms of public policy regulating the type and conditions of transport, more adequate storage and ways to avoid losses and waste, failure to comply with these measures can result in fines and fees. Such propositions have already been suggested in the studies by Bloom (2010) and Priefer *et al.* (2016), as pointed out Porat *et al.* (2018).

Conclusion

Short routes were the most efficient, however the perishability of the product was not the main factor this is because aspects related to a good ability to offer products, transport them safely and assertiveness in predicting demand contributed more to the high efficiency rates, thereby, it is the short routes that service the predilections of consumers who value locally produced food.

The food miles concept, as a starting point for evaluating routes, showed that the distance attribute is important, however, it is not the only one for defining the most efficient route, since the evaluation of the performance of the routes is multidimensional, considering operational aspects and also sales management, such as environmental impact, packaging, prices, distances and losses.

It is noteworthy that the adoption of short routes is not always the best alternative, as there are scenarios in which the reallocation of agricultural production would not be

possible, due to land and climate. However, the adoption of good logistical practices associated with the concept is a positive tool for better performance on long routes.

One of the advances of this research was to show the contribution of the food miles concept to propose a performance evaluation system to classify the efficiency of fruit and vegetable distribution routes based on logistical criteria that go beyond distance.

This work may serve as a resource for future studies which seek points of improvement for less efficient routes. Once the attributes that need improvement are met, it is expected that the result will be greater preservation of sensory and organoleptic quality and less losses and waste, thus improving the supply of FV.

Supplementary material

https://drive.google.com/file/d/1wql_1-ECKoJXkrxO6_pjwlTzGxzCbjVP/view?usp=sharing

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