

# QUALITY OF HABANERO CHILI PEPPERS IN THE MARKETS OF MEXICO: A COMPARATIVE ANALYSIS

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## ABSTRACT

The high competitiveness of markets derives from the introduction of technology and the dynamics of consumer needs. It is necessary to improve the quality of products and, especially, in the agricultural sector. The objective of this research was to compare the characteristics of habanero chili peppers (*Capsicum chinense*) for export with those for sale in Mexico City markets through fuzzy logic, in order to determine their quality. Fuzzy logic is a qualitative method used to study social phenomena surrounded by uncertainty and subjectivity. Based on the standard “Denomination of Origin of habanero pepper from the Yucatan Peninsula”, the results show that the quality in shape and color of the habanero peppers sold in Mexico City is lower than that of those exported. Information on the quality of chili peppers distributed within the country and for export helps farmers and the government to generate specific policies and regulatory programs of differentiated support, according to the types of crops and the place where they are produced.

**Keywords:** fuzzy logic, quality characteristics, habanero chili pepper, competitiveness, export.

## INTRODUCTION

The world crisis of the 1980s opened the breach to intensify commercial relationships between countries and fostered the start of an international market where trading companies compete between one another (Estrella Ramón *et al.*, 2012). In addition, the economic globalization that began at the end of the 1980s and beginning of the 1990s drove the growth of international trade and brought with it a process of commercial revolution that in turn caused uneven global commercial exchange, formed by factors of growth and competitiveness that are perceived in different ways in each country (Zamora and Pedraza, 2013). Derived from this, industrialized nations that have better capital dictate the path to follow in global trade through the Washington consensus (Blanco Cruz *et al.*, 2015).

In 2010, Mexico had an important recovery in foreign trade that manifested its competitive advantage. This had positive implications for the Mexican economy because it fostered the economic investment of international companies and, as consequence, the acquisition of technological advantages; however, the Mexican agricultural sector lagged behind as a result of the negative effects of the global economy (Basurto and Escalante, 2012).

Since its discovery, chili pepper has been used in many ways, from traditional dishes to beauty products. Habanero chili pepper (*Capsicum chinense*) is one of the most popular, with international recognition due to its quality, and its export market needs qualitative control of product with technology (Corrales-García *et al.*, 2014). In Mexico City, there

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are no regulations of the norm “Denomination of origin” for habanero peppers sold and there is only quality control in shipping of merchandise towards the states of the country, although not regulation equal to that for exports (Pacheco-López *et al.*, 2017).

Despite the various programs implemented by different governments, the agricultural sector has not had the expected positive growth due to several factors, among them the absence of technology (Amaro-Rosales and de Gortari-Rabiela, 2016) which leads to a better quality in the products. The evaluation of quality indicators favors the comparison of the process with a standard, the identification of deficiencies, and the application of corrective actions (Giménez *et al.*, 2014).

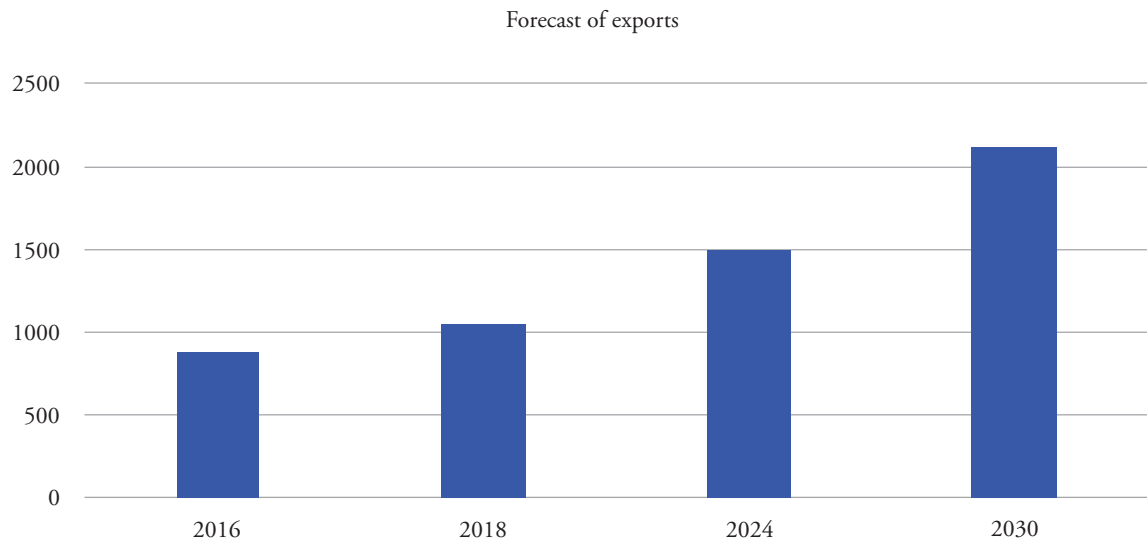
In international markets, competitiveness depends on the quality of the products. The constant search for high quality products is reflected in that it considers the essential element of competitiveness in the international market (Arellano-Díaz, 2017). Thus, quality is one of the most relevant decision variables of buyers to choose between competitive goods and services (Torres and Luna, 2017). It is important to reassess the quality standards through the use of indicators that respond to the needs and technology available, and also to define the limits of acceptance from national and international agreements (González Cantó *et al.*, 2017).

Artopoulos, Friel and Hallak (2014) mention that businesses in Asia stood out for being stable exporters of differentiated products to industrialized countries. Their main strength, in contrast with local producers, lies in adapting to the needs of consumers of these countries, because the quality standards and commercial practices of developed countries have systematic differences from those of developing countries (Brambilla *et al.*, 2012).

At the national level, innovation and new technologies in the habanero pepper crop generated for Mexico to become global leader in exports: 986.5 thousand tons (t) are exported (SAGARPA, 2017a). SAGARPA (2017b) indicated that 845 thousand t of this product were traded in 2014, which generated currency in the amount of US\$ 560 million. Most of the funds for improvement of habanero pepper production are directed towards producers in Sinaloa (Fundación Produce Sinaloa A. C., 2011). In 2016, Mexico exported chili peppers and peppers in the amount of US\$ 880.4 million and it is expected that in 2030, Mexico will export chili peppers and peppers in the amount of US\$ 2.1 billion (Figure 1).

However, regarding the evaluation of quality indicators, it should be mentioned that production, distribution and international trade methods had notable changes as consequence of globalization, which implied a structural change in commercial interaction (Coppelli Ortiz, 2018). The creation of new cultures, traditions, customs and habits comes from their mixture caused by the elimination of borders between countries and continents (Valencia Sandoval *et al.*, 2017). The preferences and tastes of consumers are complex, which is why businesses must modify their structure to improve their competitiveness in international markets.

Mexico has an important participation in the international agrifood market. In 2020, the most exported agrifood products from Mexico were beer, avocado and berries (Figure 2). And chili peppers and peppers are part of the exports of this type of products (Ministry of Agriculture and Rural Development (Mexico), 2021).

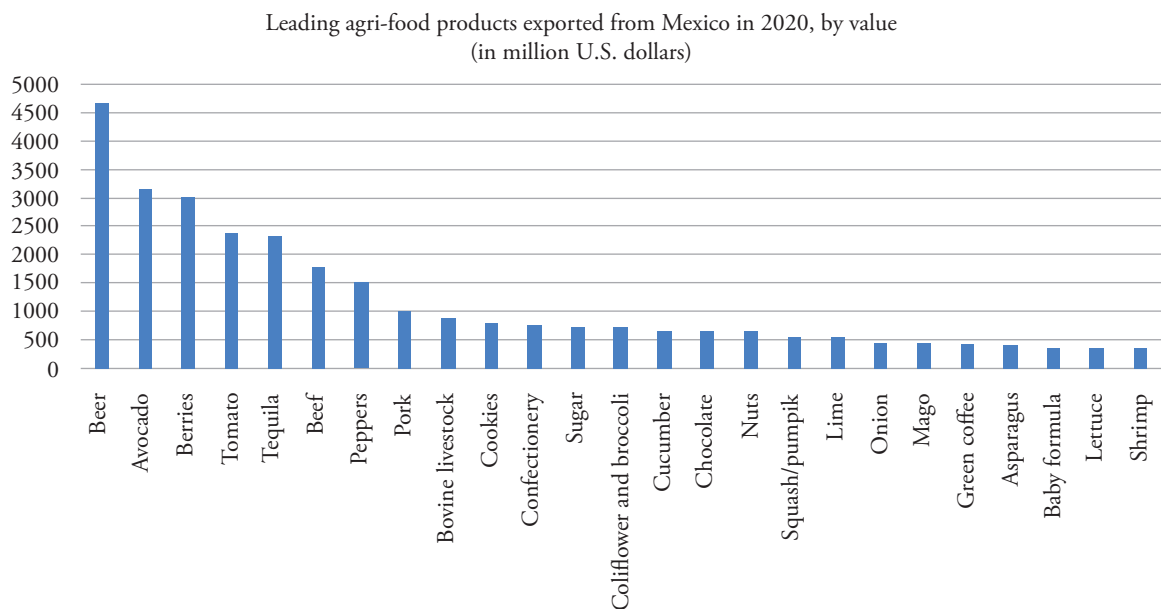


Values predicted with data until 2030.

Source: prepared by the authors with data from SAGARPA (2017b).

**Figure 1.** Export value of chili peppers and peppers in Mexico between 2016 and 2030 (in US millions of dollars).

The evaluation of the quality standards allows quantifying the factors related to the growth of production of agrifood products such as surface, yield and structure of soil



Source: Ministry of Agriculture and Rural Development (Mexico) (2021).

**Figure 2.** Main agrifood products exported from Mexico in 2020, per value (in US\$ millions).

uses according to Cruz-Delgado *et al.* (2013). In 2009, Mexico covered 62.4% of the total value of imports of all the products, even non-agrifood, of the US market (Valencia Sandoval, *et al.*, 2017).

In this context, the objective of this study was to compare the characteristics of habanero chili peppers for export and for sale in markets of Mexico City, through fuzzy logic, with the aim of determining their quality. The central hypothesis assumes that the tools to measure the quality of products support producers and the Mexican government in decision making in matters of cultivation and foreign trade.

## MATERIALS AND METHODS

The study was retrospective and descriptive, and the years 2008 and 2018 were taken as study points to analyze the change in food consumption. The research was based on a qualitative and quantitative analysis; this allowed deducing the phenomena that are object of observation based on a theory, using the deductive method (Dávila Newman, 2006). Concerning the secondary sources, the bibliography review implied giving more accuracy to the study, which began with themes related to the crisis of the habanero pepper, climate variability and food.

In the study, field visits were performed in the municipality, carried out during the months of May to July, 2018. To gather the information, a questionnaire was used as instrument, which was applied through a translator from totonaco and náhuatl to spanish. The questionnaire covered technological aspects of habanero pepper, emphasizing the diet of producers.

The advantage of using statistics is management of quantitative data, although the main inconveniences are the need to verify *a priori* the relevant conditions for their application (normality, statistical independence, etc.) and the necessary experience to process results. An alternative approach to formulate ambiguous concepts could be beneficial to measure qualitative attributes.

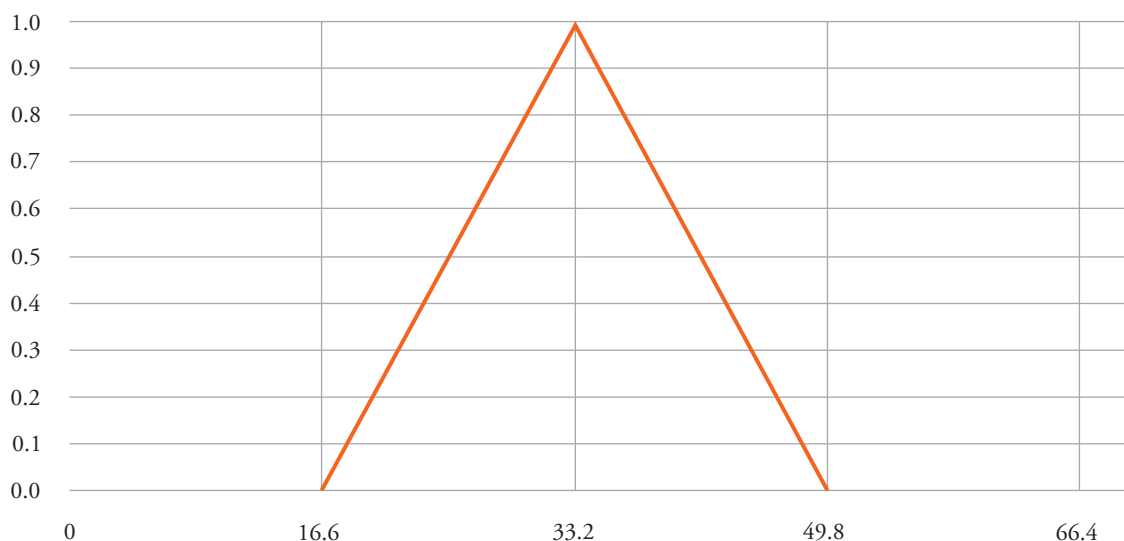
### Fuzzy logic

Fuzzy logic (Zadeh, 1965) stems from artificial intelligence and mixes mathematical concepts with degrees of belonging; mathematics is combined with human language through linguistic expressions within a quantitative framework (Sugeno and Yasukawa, 1993). Fuzzy logic is a qualitative method and a useful tool while making decisions that are surrounded by ambiguity and uncertainty (Metzger and Spengler, 2019).

Fuzzy logic assigns degrees of belonging to linguistic etiquettes through fuzzy sets (Zadeh, 1965), which are determined by a function  $\mu_A: X \rightarrow [0, 1]$ , indicating the degree of belonging of an element  $x$  to the set  $A$ , i.e.,  $\mu_A(x) = r$  means that  $r$  is the degree to which  $x$  belongs to  $A$ . If  $\mu_A(x) = 0$ , the element  $x$  does not belong to the set  $A$  and if  $\mu_A(x) = 1$ , the element belongs totally to the set  $A$  (Saad *et al.*, 2014), (Figure 3).

For the case of a function of belonging defined on a discrete set, there is a simple expression to represent a fuzzy set. In this case, the fuzzy set  $\tilde{A}$  given by the function of belonging  $\mu_A$  which is given by the following expression:

$$\tilde{A} = \left\{ (x_1, \mu_A(x_1)), (x_2, \mu_A(x_2)), (x_3, \mu_A(x_3)), \dots, (x_n, \mu_A(x_n)) \right\}$$



Graphic representation of a fuzzy set given by the function of belonging  $\mu_A$  whose graph is a triangle.  
 Source: prepared by the authors.

**Figure 3.** Function of belonging  $\mu_A$ .

There are different functions that are distances between elements and sets. For this study, the Hamming  $d$  distance was used (Saad *et al.*, 2014), which allows comparing two subjects through fuzzy sets. The Hamming distance emerged in 1950 and it is a tool that offers a practical alternative by analyzing data and taking advantage of them to solve problems in decision making.

Through the Hamming distance, these characteristics are evaluated. The closer to zero that this distance is, the more similar the products will be; and the closer to one that this distance is, the products will have a greater difference. The distance between two sets  $A$  and  $I$  is given by:

$$d(A, I) = \frac{|x_1 - i_1| + |x_2 - i_2| + \dots + |x_n - i_n|}{n} \quad (1)$$

where  $x_1, x_2, \dots, x_n$  are attributes of the subject  $A$ , and  $i_1, i_2, \dots, i_n$  are the attributes of the subject  $I$  with which it is compared (for example, an ideal subject) and  $n$  the number of attributes.

The Hamming distance will be used to contrast the quality of habanero peppers with “Denomination of origin of habanero chili pepper from the Yucatan Peninsula” (Table 1) and of those that are consumed in the locality.

The products analyzed in this qualitative study were 28 habanero peppers, of which 14 chili peppers ( $y_1, y_2, y_3, y_4, y_5, y_6, y_7, y_8, \dots, y_{1,14}$ ) are for export, and they were acquired at the business “Chiles San Juan”, with address: Calle las Palmas S/N BO, San Juan Zitlaltepec, Zumpango C.P. 55628, Estado de México. The 14 habanero peppers sold in Mexico City were obtained in the market at address: Calle Xochiquétzal, Col. Santa Isabel Tola, Delegación Gustavo A. Madero.

**Table 1.** Ideal characteristics for the habanero chili from the Yucatan Peninsula.

Notation	Characteristic
$x_1$	Hollow bell-shaped berry, with a pointed end.
$x_2$	The gynoecium is made up of two or four carpels.
$x_3$	Little fleshy and the walls that divide the interior are incomplete (they do not have the locules)
$x_4$	Thin skin that covers the chili
$x_5$	They have the same characteristic smell and taste, regardless of the color of maturation.
$x_6$	Average length of 4.5 to 6.0 cm.
$x_7$	An average width of 2.5 to 3.0 cm
$x_8$	The shape of the fruit at the junction with the pedicel is cordate and the neck at the base is absent.
$x_9$	The shape of the apex of the fruit is pointed.
$x_{10}$	The color of the ripe habanero is determined by two pigments: carotenoids (yellow, orange, and red) and anthocyanins (red, purple, or blue).
$x_{11}$	Free of rot, stains, diseases and pests.
$x_{12}$	Clean and free of any foreign matter.

Source: prepared by the authors.

### Linguistic variables

A linguistic variable is differentiated from a numerical variable by considering words instead of numbers. A linguistic variable is a concept with a higher order than the fuzzy variable, and in this sense a linguistic variable takes fuzzy variables as values (Zadeh, 1965). In this study a linguistic variable was defined when using the set of characteristics of the products to be evaluated. The values that each variable takes are determined by the following set: {Fulfills completely, Fulfills nearly completely, Fulfills moderately, Fulfills slightly more, and Doesn't fulfill}.

The numerical values assigned to each linguistic label belong to the interval [0,1]. As consequence, the universe of the discourse is the interval [0,1]. The linguistic labels and the values of belonging are shown in Table 2.

Habanero chili pepper, according to the Denomination of Origin from the Yucatan Peninsula, is considered as the ideal subject according to the General Declaration of Protection of the Denomination of Origin of Habanero Chili Pepper from the Yucatan Peninsula. And each of its characteristics have the value 1.0 (Table 3).

Finally, the one with the lowest interval or the one closest to zero is selected. As the difference is closer, the businesses subject to analysis in compliance share more characteristics; and the further the difference, less.

The qualitative comparative analysis based on fuzzy sets is a method of recent application in the social sciences. Although this approach is considered to be in development, it has already been discussed as a useful methodology in the social sciences, especially when they imply judgement of experts and subjective uncertainty (Lee, 2014).

**Table 2.** Values corresponding to linguistic labels.

Linguistic label	Value
Fully compliant	1.0
Almost fully compliant	0.8
Fairly compliant	0.6
Fulfill a little more	0.2
Non-compliance	0

Source: prepared by the authors.

**Table 3.** Ideal profile on the characteristics of the habanero chili.

Characteristic	Ideal profile
$I_{1-14}$	1.0
$I_{1,1-1,14}$	1.0

Source: prepared by the authors.

## RESULTS AND DISCUSSION

To evaluate the quality of each of the products (habanero chili peppers for export and habanero peppers for sale in Mexico City), a fuzzy set was constructed based on the characteristics of each. As mentioned, fuzzy logic allows contrasting the characteristics of products with those of the ideal product (denomination of origin).

For each of the products to be evaluated (habanero peppers for export and habanero peppers for sale in Mexico City), a fuzzy set was constructed that has the characteristics described in the previous section (Equation 1).

The results of these evaluations are summarized in Table 4 and 5, which shows that the products  $y_4$  and  $y_5$  acquired in markets of Mexico City have better quality, because the value of their function of belonging is close to 1.

The products  $y_{12}$  and  $y_{13}$  have in their majority values that are close to 0 because their quality is lower. The characteristics  $x_1$ ,  $x_8$  and  $x_9$  obtained low marks: 0, 0.2 and 0.6, while  $x_2$ ,  $x_3$ ,  $x_4$ ,  $x_5$ ,  $x_6$ ,  $x_{11}$  and  $x_{12}$  obtained evaluations higher than 0.8.

The products  $y_{10}$  and  $y_{12}$  had evaluations close to one and the products  $y_{14}$  and  $y_{18}$  obtained values close to zero. The characteristics  $x_1$ ,  $x_8$  and  $x_{10}$  obtained the values 0, 0.2 and 0.6, respectively; while  $x_4$ ,  $x_5$ ,  $x_6$ ,  $x_7$ ,  $x_{11}$  and  $x_{12}$  had values higher than 0.8. The characteristics  $x_1$ ,  $x_8$ ,  $x_9$ ,  $x_{10}$  are the ones that are least fulfilled, and their compliance should be observed. Tables 6 and 7 show the products with export quality.

Again, it shows that the form (characteristic  $x_9$ ) is the one that has lower values. In contrast, the characteristics  $x_{11}$  and  $x_{12}$  are fulfilled in nearly 100%.

Next, the Hamming distance between each product object of evaluation and the one that fulfills at 100% each characteristic (ideal) were obtained. The Hamming distance provides

**Table 4.** Evaluations of chili peppers purchased in the Mexico City open-air market.

Characteristic	Chili	Chili	Chili	Chili	Chili	Chili	Chili
	$y_1$	$y_2$	$y_3$	$y_4$	$y_5$	$y_6$	$y_7$
$x_1$ -Hollow flared berry, with a pointed end.	0.6	0.6	0.2	0.6	0.8	0.6	0.8
$x_2$ -The gynoecium is made up of two or four carpels.	1.0	1.0	0.8	1.0	1.0	0.8	1.0
$x_3$ -Little fleshy and the walls that divide the interior are incomplete (they do not have the locules).	1.0	0.8	0.8	0.8	1.0	0.8	0.6
$x_4$ -Thin skin that covers the chili.	1.0	1.0	1.0	1.0	1.0	1.0	1.0
$x_5$ -They have the same characteristic smell and taste, regardless of the color of maturation.	1.0	1.0	1.0	1.0	1.0	1.0	1.0
$x_6$ -Average length from 4.5 to 6.0 cm.	1.0	1.0	1.0	1.0	1.0	1.0	0.8
$x_7$ -An average width of 2.5 to 3.0 cm.	0.6	0.8	0.8	1.0	1.0	1.0	0.8
$x_8$ -The shape of the fruit at the junction with the pedicel is cordate and the neck at the base is absent.	0.2	0.2	0	0.8	1.0	0.2	0.6
$x_9$ -The shape of the apex of the fruit is pointed.	1.0	0.6	0.2	0.6	1.0	0.8	0.6
$x_{10}$ -The color of the ripe habanero is determined by two pigments: carotenoids (yellow, orange and red) and anthocyanins (red, purple or blue).	0.4	0.6	1.0	1.0	0.2	0.6	0.8
$x_{11}$ -Free of rot, stains, diseases and pests.	1.0	1.0	1.0	1.0	1.0	1.0	1.0
$x_{12}$ -Clean and exempt of any foreign matter	1.0	1.0	0.8	1.0	0.8	1.0	1.0

Source: prepared by the authors.

a proportion of the mean deviation of the differences. To obtain this distance, the values obtained for the evaluation products and the ideal are substituted in Equation 1, for example, the Hamming distance between product  $y_1$  and ideal product  $I$  is:

$$\begin{aligned}
 d(y_1, I) &= \frac{1}{12} (|1 - 0.6| + |1 - 1| + |1 - 1| + |1 - 1| + |1 - 1| + |1 - 1| \\
 &+ |1 - 0.6| + |1 - 0.2| + |1 - 1| + |1 - 0.4| + |1 - 1| + |1 - 1|) \\
 &= \frac{2.2}{12} = 0.18
 \end{aligned}$$

The results of the Hamming distance between each product and the ideal are summarized in Table 8. The exported chili peppers ( $y_{1.1} - y_{1.14}$ ) have better quality because they have a lower number of imperfections, contrary to those acquired in the Mexico City markets ( $y_1 - y_{14}$ ). The Hamming distance between habanero pepper  $y_1$  and the ideal  $I$  was calculated with Equation 1 and the values in Table 3. The quality of the habanero peppers sold in Mexico

**Table 5.** Evaluations of chili peppers purchased in the Mexico City open-air market

Characteristic	Chili $\mathcal{Y}_8$	Chili $\mathcal{Y}_9$	Chili $\mathcal{Y}_{10}$	Chili $\mathcal{Y}_{11}$	Chili $\mathcal{Y}_{12}$	Chili $\mathcal{Y}_{13}$	Chili $\mathcal{Y}_{13}?$
$x_1$ -Hollow flared berry, with a pointed end.	1.0	0.6	0.8	0.2	0	0.2	0.6
$x_2$ -The gynoecium is made up of two or four carpels.	0.8	0.6	0.8	1.0	0.2	1.0	0.8
$x_3$ -Little fleshy and the walls that divide the interior are incomplete (they do not have the locules).	0.8	0.8	0.8	0.8	0.6	1.0	0.8
$x_4$ -Thin skin that covers the chili.	1.0	1.0	1.0	1.0	1.0	1.0	1.0
$x_5$ -They have the same characteristic smell and taste, regardless of the color of maturation.	1.0	1.0	1.0	1.0	1.0	0.8	1.0
$x_6$ -Average length from 4.5 to 6.0 cm.	0.6	1.0	0.6	0.6	0.8	0.2	0.8
$x_7$ -An average width of 2.5 to 3.0 cm.	0.8	0.8	0.8	0.8	1.0	0.8	0.8
$x_8$ -The shape of the fruit at the junction with the pedicel is cordate and the neck at the base is absent.	0.2	0	0.2	0.6	0	0.2	0.6
$x_9$ -The shape of the apex of the fruit is pointed.	0.8	1.0	0.6	0.8	0.2	0.6	0
$x_{10}$ -The color of the ripe habanero is determined by two pigments: carotenoids (yellow, orange and red) and anthocyanins (red, purple or blue).	0.6	0.6	0.6	1.0	0.8	0.6	1.0
$x_{11}$ -Free of rot, stains, diseases and pests	1.0	1.0	1.0	1.0	0.4	1.0	1.0
$x_{12}$ -Clean and exempt of any foreign matter	1.0	0.8	1.0	1.0	0	1.0	1.0

Source: prepared by the authors.

City is lower than the chili peppers exported. The smallest values of the distances are:

$$d(y_{1.10}, I), d(y_{1.12}, I), d(y_4, I), d(y_{1.5}, I), d(y_{1.2}, I) \text{ y } d(y_{1.3}, I)$$

The comparison of these values is shown in Figure 4. The average in total is 0.18, the average of the results obtained for the exported chili pepper is 0.15 and for the habanero pepper sold in Mexico City markets is 0.22 with a difference between one another of 0.06. Analyzing the differences between each habanero pepper, it is concluded that there is a close relationship between all of them given that the difference is minimal between exported chili peppers and those sold in Mexico City.

As Figure 4 shows, 85.7% of the export products are below the average of 0.18, that is, 85.7% of the products evaluated are similar to the ideal product. Meanwhile, 50% of the products of local consumption are above this average, that is, half of the products are not similar to the ideal product and, therefore, habanero peppers for export have better quality than those sold in Mexico City.

It should be highlighted that the results show the existence of a regulation to ship habanero chili peppers to Mexico City and for their distribution in markets, although

**Table 6.** Evaluations of chili peppers for export.

Characteristic	Chili	Chili	Chili	Chili	Chili	Chili	Chili
	$\mathcal{Y}_{1,1}$	$\mathcal{Y}_{1,2}$	$\mathcal{Y}_{1,3}$	$\mathcal{Y}_{1,4}$	$\mathcal{Y}_{1,5}$	$\mathcal{Y}_{1,6}$	$\mathcal{Y}_{1,7}$
$x_1$ -Hollow flared berry, with a pointed end.	0.6	1.0	1.0	0.2	0.8	0.8	0.6
$x_2$ -The gynoecium is made up of two or four carpels.	0.8	0.8	0.8	0.6	0.8	0.8	1.0
$x_3$ -Little fleshy and the walls that divide the interior are incomplete (they do not have the locules).	0.8	1.0	1.0	0.4	0.6	0.6	0.8
$x_4$ -Thin skin that covers the chili.	1.0	1.0	1.0	1.0	1.0	1.0	1.0
$x_5$ -They have the same characteristic smell and taste, regardless of the color of maturation.	1.0	1.0	1.0	1.0	1.0	1.0	1.0
$x_6$ -Average length from 4.5 to 6.0 cm.	1.0	0.8	0.8	0.8	1.0	1.0	0.8
$x_7$ -An average width of 2.5 to 3.0 cm.	1.0	0.8	1.0	0.8	1.0	0.8	0.8
$x_8$ -The shape of the fruit at the junction with the pedicel is cordate and the neck at the base is absent.	0.6	0.6	0.2	0	0.4	0.8	0.6
$x_9$ -The shape of the apex of the fruit is pointed.	0.6	1.0	1.0	0.6	0.8	0.8	1.0
$x_{10}$ -The color of the ripe habanero is determined by two pigments: carotenoids (yellow, orange and red) and anthocyanins (red, purple or blue).	0.8	0.6	0.8	0.2	0.6	0.8	0.6
$x_{11}$ -Free of rot, stains, diseases and pests	1.0	1.0	1.0	1.0	1.0	1.0	1.0
$x_{12}$ -Clean and exempt of any foreign matter	1.0	1.0	0.8	1.0	1.0	1.0	0.8

Source: prepared by the authors.

not equal to the regulation for exports, because it does not show equivalency in quality. Being cultivated in different states of the republic, they do not establish and execute the norms equally to those of the “Denomination of Origin of habanero chili peppers from the Yucatan Peninsula”.

The productive and economic importance of habanero chili peppers is still not consolidated. This is due to a large extent to the fact that production of this agricultural product was done for self-supply. Therefore, the production of high-quality products can respond to one of the main demands of habanero chili pepper: exports.

The habanero peppers for export are of higher quality than those sold in Mexico City, which favors the accessibility to international markets (Maldonado-Siman, Bernal-Alcántara, Cadena-Meneses, Altamirano-Cárdenas and Martínez-Hernández, 2014). However, the exporting sector will face competitive pressures in the commercialization of habanero chili pepper, particularly in the North American market (Arana-Coronado, Trejo-Pech, Aguilar-Candelas, Martínez-Damián, and Mondragón-Hernández, 2019).

On the other hand, there are differences in the regulatory frameworks between the local consumption and the export product. The habanero chili pepper is produced in states such

**Table 7.** Evaluations of chili peppers for export.

Characteristic	Chili	Chili	Chili	Chili	Chili	Chili	Chili
	$\mathcal{Y}_{1,8}$	$\mathcal{Y}_{1,9}$	$\mathcal{Y}_{1,10}$	$\mathcal{Y}_{1,11}$	$\mathcal{Y}_{1,12}$	$\mathcal{Y}_{1,13}$	$\mathcal{Y}_{1,14}$
$x_1$ -Hollow flared berry, with a pointed end.	0.0	0.6	0.6	0.6	0.8	0.8	0.8
$x_2$ -The gynoecium is made up of two or four carpels.	0.6	1.0	0.8	0.8	1.0	1.0	1.0
$x_3$ -Little fleshy and the walls that divide the interior are incomplete (they do not have the locules).	0.2	1.0	0.8	1.0	1.0	1.0	1.0
$x_4$ -Thin skin that covers the chili.	1.0	1.0	1.0	1.0	1.0	1.0	1.0
$x_5$ -They have the same characteristic smell and taste, regardless of the color of maturation.	1.0	1.0	1.0	1.0	1.0	1.0	1.0
$x_6$ -Average length from 4.5 to 6.0 cm.	0.6	1.0	1.0	0.8	1.0	1.0	1.0
$x_7$ -An average width of 2.5 to 3.0 cm.	0.8	1.0	1.0	1.0	1.0	0.8	0.8
$x_8$ -The shape of the fruit at the junction with the pedicel is cordate and the neck at the base is absent.	1.0	0.8	1.0	0.8	0.6	0.4	0.4
$x_9$ -The shape of the apex of the fruit is pointed.	0.6	0.6	0.8	0.4	0.6	0.8	0.8
$x_{10}$ -The color of the ripe habanero is determined by two pigments: carotenoids (yellow, orange and red) and anthocyanins (red, purple or blue).	1.0	0.8	0.8	0.8	0.8	0.8	0.8
$x_{11}$ -Free of rot, stains, diseases and pests	1.0	1.0	1.0	1.0	1.0	1.0	1.0
$x_{12}$ -Clean and exempt of any foreign matter	1.0	0.8	1.0	1.0	1.0	1.0	1.0

Source: prepared by the authors.

as Baja California Sur, San Luis Potosí, Sonora and Tabasco. However, the one produced in the Yucatan Peninsula has the Denomination of Origin of habanero chili pepper since the year 2010 (Fideicomiso de Riesgo Compartido, 2017). In other states of the country, there are subsistence producers and to trade their product they require intermediaries, although there is neither organization nor integration to trade and industry (Corrales-García *et al.*, 2002).

### CONCLUSIONS

This study emerges from the concern of farmers to produce goods of better quality to compete in the international and national markets. Fuzzy logic was used to demonstrate that the quality of the products for domestic consumption and for export is different, specifically the habanero chili pepper produced in Mexico. For this purpose, the characteristics of habanero chili peppers for export were contrasted against habanero peppers sold in Mexico City markets.

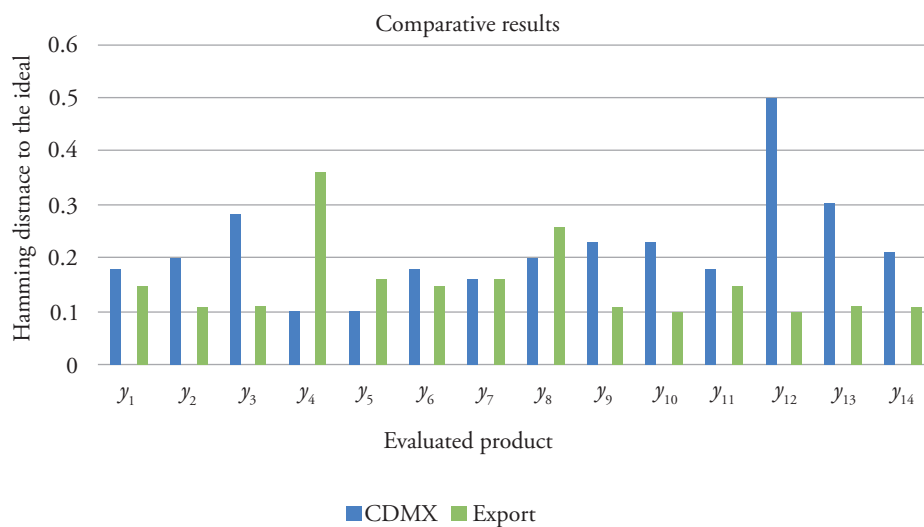
**Table 8.** Hamming distance between the evaluated products and the ideal  $d(y_i, I)$ .

Habanero chili	Hamming distance	Habanero chili	Hamming distance
$y_1$	0.18	$y_{1,1}$	0.15
$y_2$	0.20	$y_{1,2}$	0.11
$y_3$	0.28	$y_{1,3}$	0.11
$y_4$	0.10	$y_{1,4}$	0.36
$y_5$	0.10	$y_{1,5}$	0.16
$y_6$	0.18	$y_{1,6}$	0.15
$y_7$	0.16	$y_{1,7}$	0.16
$y_8$	0.20	$y_{1,8}$	0.26
$y_9$	0.23	$y_{1,9}$	0.11
$y_{10}$	0.23	$y_{1,10}$	0.10
$y_{11}$	0.18	$y_{1,11}$	0.15
$y_{12}$	0.50	$y_{1,12}$	0.10
$y_{13}$	0.30	$y_{1,13}$	0.11
$y_{14}$	0.21	$y_{1,14}$	0.11

Source: prepared by the authors.

Results show the existence of regulations for shipping habanero peppers to Mexico City and for their distribution in markets, although not equal to the regulation of exports, since they do not show equivalency in quality because they are grown in different states of the Republic and the norms of the “Denomination of Origin of habanero chili pepper from the Yucatan Peninsula” are not established and executed equally.

After comparing the characteristics of the habanero chili peppers for export and sale in Mexico City markets, the study found that the quality of the products of local consumption



Source: prepared by the authors.

**Figure 4.** Results from evaluations of habanero chili peppers.

is lower than the quality of export products and the characteristics that these products least fulfill are shape and color.

Specifically, the results indicate that 85.7% of the export products are below the average 0.18, that is, 85.7% are similar to the ideal product. Meanwhile, 50% of the products for local consumption are above this average, which translates into 50% of the products evaluated being far from the ideal product.

The quality of the products for local consumption is lower compared to the export products, which implies that the farmers must generate a connection or support circle among members in terms of issues of agricultural inputs, credits, training, promotion activity, and product commercialization. These associations can also serve as a basis to obtain public backing and access to technology to improve the quality of their products. On the other hand, the state or federal governments ought to grant support, develop public policies in favor of the promotion, and improve the quality of the products from the local market. Likewise, this public backing (as well as private) ought to have the aim of supporting the operations of national farmers; maintaining the levels in national prices; supporting consumption, distribution and commercialization of goods; motivating investment; and promoting technological innovation.

This study can benefit decision makers in international trade. And due to the high global competition of this market, the farmers will find benefits because the production of goods of better quality is priority. This is useful to generate specific regulation policies and programs of differentiated backing, according to the types of crops and of the states in Mexico.

As any research study, this document has some limitations or obstacles that did not allow reaching more conclusive results; the difficulty to obtain the products outside Mexico City and Estado de México can be mentioned, and naturally in other states as well. Other elements that have favored or restricted the course of the study are the change in unit of analysis, the participants, access to the products, and the season.

Future research lines that arise consider the need to test the functioning of the proposed tool first, in the states suggested for the study and then in the entire Mexican Republic. Lastly, the fuzzy evaluation proposed in this article shows an application that brings back our attention to the urgency of retaking the farmland as priority axis of economic growth.

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