

Coriander production system in Puebla and its impact on safety

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Abstract

Coriander (*Coriandrum sativum* L.) is one of the main vegetables produced in the municipality of The Reyes of Juárez Puebla. However, this crop has been subject to health warnings due to outbreaks of cyclosporiasis in the USA due to the consumption of Coriander from Puebla. Recognizing its economic importance and the need to improve the production system, this work aimed to register current agricultural practices in coriander production and analyze its impact on product safety to identify opportunities for improvement. From an official list, a simple random sampling and maximum variance 73 (n) producers were selected to whom a questionnaire was applied to gather information on the activities they implement during crop production. Field visits were made in the period from January to September to make ocular observations of said activities. The results indicated that the current production system has a strong impact not only on the safety of the product but also on the health of the people involved in the agricultural activities of the crop, which requires the implementation of pollution prevention programs.

Keywords: *Coriandrum sativum*, hygiene, risks, health.

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Introduction

Globalization and changes in eating habits have generated more movement and demand for fresh fruits and vegetables not only nationally but internationally. However, in recent years there have been numerous cases of rejection of these horticultural products in major consumer markets for the detection of pathogenic microorganisms of humans, as well as pesticides not allowed or concentrations exceeding the limits allowed in these products (Piñeiro and Díaz, 2004).

As a result of the above, the main producing and exporting countries have had to adopt pollution risk reduction systems in primary production and postharvest handling, to guarantee supplies of fresh and safe fresh horticultural products and the welfare of the population and the national economy (FAO, 2009).

In 2000 the World Health Assembly adopted a resolution requesting the World Health Organization (WHO) and its member states to recognize the importance of producing safe food and to maintain this characteristic along the chain of production and management to safeguard the health of people when the products are consumed fresh or semi-processed (FAO and WHO, 2004). Safety is defined as the guarantee that a food will not cause harm to health when it is eaten fresh or processed (Avendaño *et al.*, 2006).

It should be noted that the production of innocuous horticultural products in the field or in the greenhouse requires knowledge and training by producers and all those involved in the production and handling of these products on the impact of different environmental factors on the crop, the good use of agricultural inputs and the best farming and management practices, among others, to reduce or eliminate physical and chemical biological hazards that compromise the safety of the product.

In the state of Puebla, 2 380.00 hectares of coriander are grown annually, generating 71 400 direct jobs and 204 058 indirect jobs with a production volume of 19 557.74 tons per year, with a production value of 48 535.95 million (SIAP, 2014).

The state of Puebla has geographical regions with optimal environmental conditions for agricultural production, open-pit, various crops. In the state, the agricultural region of The Reyes of Juarez stands out, with 62% of its land dedicated to the production of vegetables and an area planted with 2 970 ha exclusively for the cultivation of coriander. Of this area, 2 590 ha are irrigated and record a production of 22 033.00 t, valued at \$53 176 000.00 (SIAP, 2014). Although most of the production (70%) is commercialized nationally, a significant percentage (30%) is exported to the United States of America, Mexico's main trading partner.

In June 2016, the Food and Drug Administration (FDA) of the United States of America issued the import alert # 24-23 related to the detection without physical examination of fresh coriander from the state of Puebla. The foregoing, as a consequence of the recording of recurrent

outbreaks during the years 2012 to 2015 of cyclosporiasis due to the consumption of coriander from Puebla, in that country. Cyclosporiasis is a disease caused by *Cyclospora cayetanensis*, a parasite of the group of protozoa that causes prolonged and severe diarrhea in people who consume contaminated food.

In official inspections carried out by the national agencies and the FDA, unacceptable conditions were registered during the production and postharvest handling of the coriander crop, in different companies and fields in the state of Puebla. Among these conditions were the lack of sanitary facilities and hand washing, lack of hygiene in facilities, equipment and packaging materials and water sources vulnerable to contamination (FDA, 2016).

Currently there are no bibliographic references that indicate and describe how the activities are carried out and what inputs are used in each of the stages of coriander production in Puebla. For the above and recognizing the importance of coriander production in the state for the numerous direct and indirect jobs and the foreign currency it generates for the country, this study aimed to: 1) register current agricultural practices in production of coriander in The Reyes of Juárez, Puebla to identify the main sources of contamination that compromise the safety of coriander leaves; and 2) obtain a score for the basic components with the potential to irrigate the product. The information generated in this study is basic and relevant to implement strategies to reduce contamination risks that compromise the safety of coriander in the state.

Materials and methods

Location and climatic characteristics of the study area

This work was established in the municipality of The Reyes of Juárez, Puebla. This municipality is located at 18° 57' north latitude and 97° 48' west longitude, at an altitude of 2 100 meters above sea level (INEGI, 2010). It borders on the north with Tepeaca, on the south with Cuapiaxtla of Madero, on the east with San Salvador Huixcolotla and Acatzingo, and on the west with Tepeaca. The municipality has an area of 30.55 km² of which 25.85 km² correspond to surface area with land use for agriculture. It is located in the Tepeaca Valley, a plain that extends to the center of the Puebla plateau and is characterized by its eminently limestone soil and its marble deposits (INAFED, 2010). The climate is predominantly dry. The highest temperatures occur during spring and the lowest temperatures in winter with concentrated rains in Summer.

Agricultural activities in the production of coriander

From an official list of 123 producers, a simple random sampling and maximum variance 73 (n) producers were selected to whom a questionnaire was applied to gather direct information on the agricultural activities they implement in coriander production. The official list of coriander producer's registration was provided by the municipal presidency of The Reyes of Juárez and the State Committee of Plant Health of Puebla (CESAVEP). The calculation of sample size n was made with the following formula:

$$n = (N Z^2_{\alpha/2} pq) / (N d^2 + Z^2_{\alpha/2} pq)$$

Where: n = sample size; N = population size (123); $Z_{\alpha/2}$ = standard normal distribution, represents the level of error probability (1.96); d = precision (maximum error 0.08); p = probability of success (maximum variance 0.5); q = probability of failure (maximum variance 0.5).

For the elaboration of the questionnaire, the formats of verification records in the field, of the quality manual: internal verification, POES and records for units of production and packing of fruits and vegetables of the National Service of Health, Safety and Agroalimentary Quality (SENASICA) of the Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA-SENASICA, 2002).

Irrigation factors in coriander production

In order to collect direct information on the risk factors in the production of coriander in The Reyes of Juárez, field visits were made to make ocular observations during the period from January to September 2016. During the field visits and the interviews, the questionnaire was applied to each of the 73 producers who were asked the same questions. The above, to have general information and to detect the chemical and microbiological hazards, mainly, those that are exposed during the production activities and the potential risks of contamination that affect the safety of the crop. Also, to detect priority areas that require immediate corrections or improvements during the production of coriander in the region.

In the formats, general data of the producers related to age and school level were emptied, as well as data of their plots: size, type of tenure (ejidal or small property) and application of good agricultural practices (BPA). The farmers were asked to describe in detail the agricultural activities carried out from the preparation of the land until the harvest and transport of coriander.

The questionnaire that was applied contained questions for the following basic components. 1) Irrigation water, specifying the source and distribution, maintenance of water wells and preparation of water analysis; 2) fertilization and application of pesticides, in this case it was recorded, more applied products, knowledge and handling of agrochemicals used for coriander production; 3) soils, where they inquired about the land uses, potential chemical and biological contamination and history of the lots; 4) municipal manure and biosolids, to identify the use, application and management of organic fertilizers; 5) hygiene and health of the worker to have information about their knowledge in basic standards of hygiene, use and application of agrochemicals; and 6) harvesting and transport in the field to know if measures to prevent contamination of the product are taken. In each field visit, the particular situations found were recorded and the evaluation of each of the components was expressed in terms of the relationship between the points obtained and the total points of reference for the field (325 total points). The categories were classified as illustrated in Table 1.

Statistical analysis

For the sample size, a maximum variance was established ($p=0.5$ and $q=0.5$), a tolerance (absolute error) of 0.08 and a confidence level of 95% ($\alpha=0.05$). The data from the surveys were analyzed with the statistical package SPSS version 22 (2013) and descriptive statistics.

Table 1. Classification of the categories for the interpretation of results obtained in the production of coriander.

Percentage*	Qualification
< del 80	Not satisfactory
80 al 84	Minimum satisfactory
85 al 89	Satisfactory
90 al 94	Excellent
95 al 100	Higher

*= relationship between the points obtained and the total points (325 points) in the field (SENASICA-SAGARPA, 2002).

Results and discussion

Agricultural activities and risk factors in the production of coriander

As a result of the field visits and the analysis of the answers given by each of the 73 producers to whom the questionnaire was applied, it was found that the majority of the people dedicated to the production of coriander in the region of the Reyes of Juárez, Puebla are men (87.7%) and in smaller number women (12.3%), who participate only during sowing, weeding and harvesting. The interviews indicated that the education level of coriander producers is mostly from medium to basic: 27.4% of the people have primary school, 39.7% of secondary school, 30.1% of high school and 2.7% of university.

When dealing with the characteristics of the production units, 56.2% of the people commented that they have plots (plots) of less than 0.5 hectares, where 64.4% of the labor used for the development of the crop is of family type and 35.6 % by contract to workers. The lands are their own or their relatives and none is income for the production of coriander. Regarding the application of BPA, 41% of producers indicated that they have received information and training on issues related to BPA and implementation of a program of good use and management of agrochemicals (BUMA); however, during the interviews they did not specify if the acquired knowledge applied them in the production of the crop.

It was found that, in the Reyes of Juarez, Puebla, coriander production is concentrated between the months of February to September, basically during the spring and summer seasons. The production cycle of coriander in the region lasts 60 to 70 days, but if it is in winter, it can be increased from 10 to 15 days depending on the environmental conditions. As a result of the observations made during the field visits and with the information provided by the producers during the interviews, it was found that the coriander production system consists of the practices described, in general, in Figure 1. Below is information on each of them and their potential impact on the safety of the product.

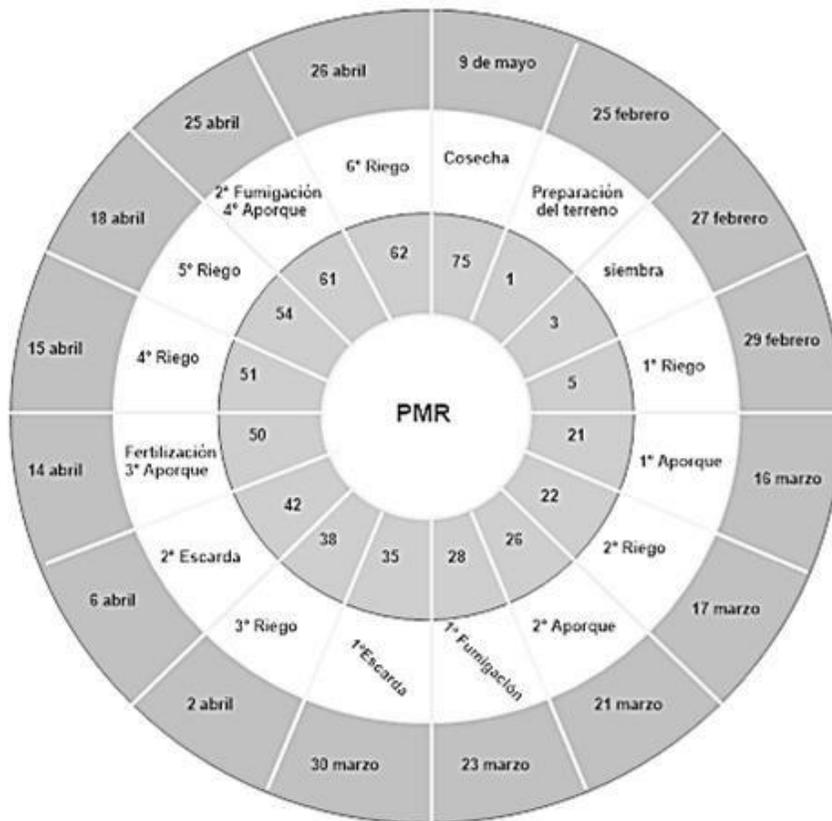


Figure 1. Diagram of practices carried out during the production of coriander in The Reyes of Juárez, Puebla. The internal circle in gray indicates the day in which the activity is done, the average target, the agricultural activity and the gray external one, the date in the calendar. The days and months indicated are approximate.

Preparation of the land

The preparation of the land is carried out with a team of draft animals (equines, mules, asnales) for fallowing, tracking and furrowing. This activity also includes leveling the terrain with level curves. The preparation of the terrain begins at the end of February and lasts for half a day.

Sowing

The sowing is manually, at a distance of approximately 20 cm, to double row in a “three bolillo” design placing an indeterminate number of seeds in each stroke. The most widely used seed varieties in the region are Pacifica® and Caloro®. This activity is given the second day at the most, after preparing the land, with family labor, requiring between 6 and 8 hours of work.

Irrigation

The production of coriander in the region is irrigated by rolling with water from wells. Depending on the season and environmental conditions, between 6 and 11 irrigations may be required during the crop cycle. In the region, there are 46 water wells for irrigation, which have

an approximate depth of 60 m. The water is distributed in piped form (in 83.6% of cases) and in a lower percentage (16.4%) through uncovered coated channels. The route of the water, from the well to the lot, is largely in piped form; however, when arriving at the lot it is through open channels. That is to say, the water that arrives directly to the lot moves by gravity through the furrows running through the entire crop. Each producer has a different irrigation day and the furrows and channels are designed in such a way that only one lot is irrigated, an activity that takes approximately two hours.

Each producer is responsible for diverting the water within their crop using sacks with dirt and shovels to open furrows through which the water is distributed throughout the lot. Approximately three irrigations occur during the first 30 to 40 days after sowing (dds); the first irrigation at 2-5 dds and the next two, between 22 and 38 dds. An over-watering can occur between 9 and 11 dds, when the seed has already germinated (“tornado”), to soften the surface layer of the land and allow the emergence and establishment of the plant. Between the 50 and 70 dds the following three risks are applied considering the wind speed, the relative humidity and the level of the furrow. The latter referring to whether the beginning or end of the groove is loaded or hung, respectively.

The 60% of the producers indicated that they do not perform laboratory analyzes on irrigation water, but 100% of the producers affirmed that the pipes are in good condition without leaks or damages that allow the entry of possible contaminants into the water. However, because the irrigation water is distributed, in some sections or enters the lot on the ground, the opportunities for contamination in its journey, from the water source to the coriander crop, are numerous given that it is common for the cattle graze near the farmland. That is, there is a high risk of water contamination for the irrigation of coriander in the region, together with the fact that 58% of the producers reported that because there are no barriers that limit the access of animals such as cattle, dogs and horses. they have direct access to water sources.

It should be noted that irrigation water is considered the main source of microbiological contamination of horticultural products (Acedo *et al.*, 2009; Salgado and Vallejo, 2015). In Mexico, Acedo-Felix *et al.* (2009) reported the presence of *Salmonella* in samples of coriander from the field and in Ecuador the coriander is among the fresh consumption vegetables as a carrier of enterobacteria that cause gastrointestinal diseases (Salgado and Vallejos, 2015).

Cultivation maintenance

Among the common coriander maintenance practices were the following.

Aporque

This activity is implemented by the producers after each irrigation by introducing grilles or metal discs (metallic plow) to loosen the soil and allow the oxygenation of the plant root. They also establish it after applying fertilizer or fertilizers in order to pile the soil to the root or to support the plant. This activity is carried out with draft animals (equines, mules, asnales). In general, during the cultivation cycle, the producer gives between 3 and 4 hives, mainly after the first irrigations or having fertilized and fumigated the crop.

Weeding

The producers give two weeds between 35 and 45 dds. The herbs that were born between the cultivation of coriander are started manually with the help of a metallic tool, triangular in shape, or with the plow dragged by animals. This as indicated to save on labor payment.

Fumigation

Producers usually give two applications with agrochemicals containing Carbofuran (2,3-dihydro-2,2-dimethyl-7-benzofuranyl-methyl carbamate) and Methomyl (S-Methyl-N - [(methylcarbamoil) oxy] thioacetamidate) as an active ingredient, for the control of pests and diseases. Specifically apply methyl thiophanate (Dimetil-4,4-0-Phenylenebis (3-thioalophonate) (300 g/200 L of water) for the control of the disease known as “secadera” and Furadan[®], which is a commercial presentation of Carbofuran (330 mL 200 L⁻¹ of water) for the control of phytopathogenic insects (aphids). The first application is made at approximately 28 dds and the second at 60 dds. Some producers mentioned giving a preventive fumigation with copper-based products and sulfur for the control of fungal diseases (“damping off”) caused by species of *Phytophthora* and *Fusarium*.

The 100% of the producers interviewed affirmed applying pesticides authorized by the Federal Commission for the Protection against Sanitary Risks (COFEPRIS); however, the producers also said they did not know the lists of pesticides approved by this regulatory agency for the cultivation of coriander. They consider that the products they apply are authorized only because they are available for sale without any restriction in the agro-stores. In observations made in the field it was found that some unregistered and authorized products are applied for the pests that are tried to control in the cultivation of coriander. Among these, Furadan[®] stood out, a product used by 100% of the producers interviewed. According to COFEPRIS (2004) in its catalog of authorized pesticides available online, coriander is not referenced as a crop in which the use of this pesticide is allowed. The Carbofuran or carbofuran is a systemic pesticide used as a broad spectrum acaricidal and nematicidal insecticide.

Fertilization

The producers in the region give up to two applications of fertilizers with chemical products to the crop. Fertilization depends on the producer’s economy, as well as the environmental conditions (precipitation and temperature). The totality of the producers indicated that the fertilization of the crop is done with ammonit, 18-46, ammonium sulfate; and several of them (81%) complement the chemical fertilization with organic fertilizers of poultry production (chicken manure). The application of chicken manure is carried out manually and broadcast in the bottom of the furrow to later be incorporated by means of the hilling, with the help of animal traction. Fertilization is done between 35 and 50 dds.

Although the producers indicated that they do not make fresh manure applications in coriander cultivation, they do not know if the organic fertilizer they apply is well composted. They also said they were unaware of the composting process, as well as the provision of specification sheets of the treatment received to the chicken manure to comply with the requirements of the component manure and municipal biosolids (EBM).

In the field, it was observed that the producers and the people who support them, apparently, do not have the skills for the preparation and application of the chemical products or with the personal protection equipment (covers mouths, gloves, among others) and application of pesticides. For example, people can absorb Furadan[®] by inhalation, by ingestion, through the skin and through the eyes. The Environmental Protection Agency of the United States (EPA) states that it is highly toxic and generates significant health risks, as it can not only cause skin irritations, but also affect the respiratory system, digestive system, central nervous system, male reproductive system and cause muscle disorders. In addition to the damage to human health, Furadan[®] also presents worrisome risks for aquatic species, for birds, mammals and invertebrates (RAP-AL, 2005).

In the field, it was also found that the storage of fertilizers and pesticides is not done separately or in an appropriate place, the equipment is not calibrated and the dosage recommendations are not met, so it is possible that higher doses of these products are being applied. In general, it is summarized that the producers of the region do not apply measures that allow to prevent the contamination of the coriander cultivation, damages to the health of the people involved in their production, of the consumers and the environment.

Harvest

Coriander harvest is done manually at 60-90 dds and in a single cut. After removing the entire mat, bundles of approximately 50 g are tied manually and the bundles (60 bundles) are placed in approximately 20 kg plastic boxes without a cover. The boxes with bunches are placed one on top of the other for transport to the final destination. According to SIAP (2013) the yield reported for the cultivation of coriander in the municipality is 5.7 t ha⁻¹; however, one of the producers interviewed said that they harvested 0.15 t, equivalent to 3 thousand bundles, in a quarter of a hectare.

Before or during harvesting and transportation, it is not common for sanitization and cleaning processes to be carried out on the tools used in the production or on the boxes or elements used to place the coriander bunches or on the vehicles in which the harvested product is transported. The 16.4% of the producers declared using the boxes, as well as the vehicles to transport and transport products other than coriander or for other purposes.

According to the information registered during the interviews applied to the producers, as well as the ocular observations in the field, the production units of coriander were placed in the category of unsatisfactory, with grades less than 80%. The registered ratings were negative values with an average score of -69.2 points, with a range of -35.4 maximum and -95.4 points as a minimum. Most units were found with values of or less than -35.73. That is, no production unit was found within the optimum quality ratings (Figure 2). The above indicates that the opportunities for fresh coriander to become contaminated by chemical and biological agents are numerous, which represents a high risk not only for the health of the producers themselves during crop production but also for the consumers of this crop horticultural product.

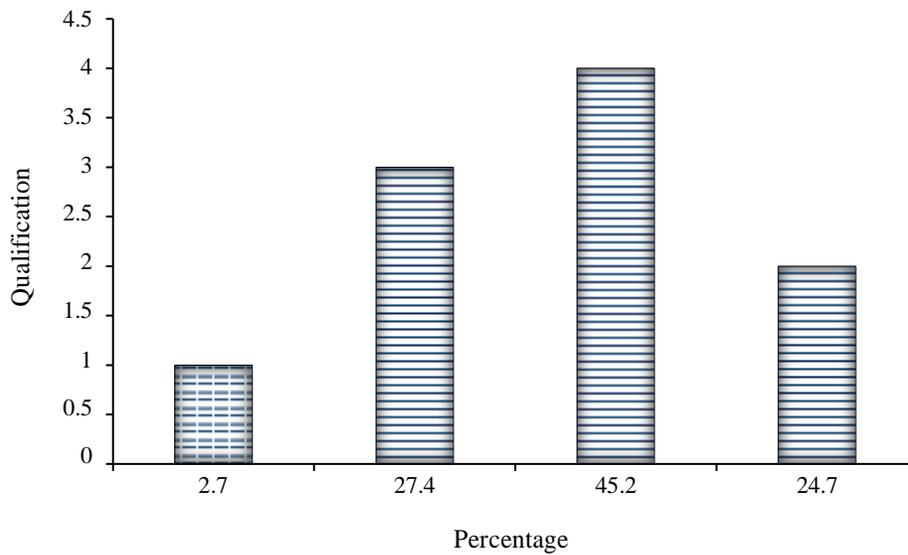


Figure 2. Qualification registered by the production units of coriander, in The Reyes of Juarez, in the quality components during the winter-spring period of 2016. The frequency is in relation to the total of units (73 n) visited. Rating value: 1= -95.4 to -75.4; 2= -75.4 to -55.4; 3= -55.4 to -35.4; 4= -35.73 to 0.

When analyzing each component separately, it was found that worker health and hygiene (HST), followed by fertilization and pesticide application (FP) were found to be the most non-compliant with BPA and in which immediate actions should be applied. corrective Although with a low value, the Irrigation Water component (AR) was the only one that recorded a positive value (Figure 3).

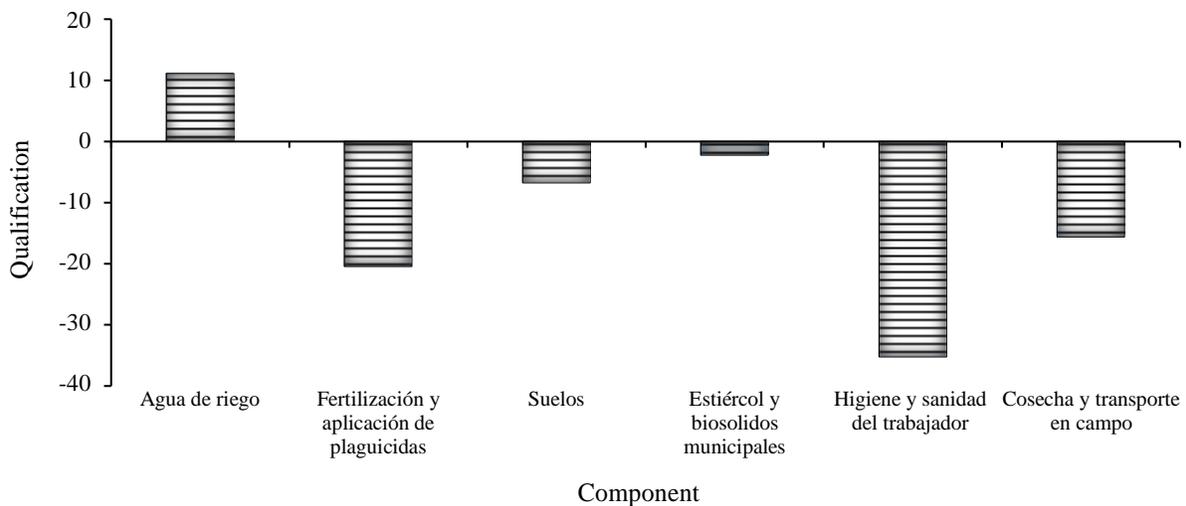


Figure 3. Scores recorded by the components of the coriander production process under the format of the quality manual (SAGARPA-SENASICA, 2002).

It was found that 61.6% of producer's lack access to drinking water in their production lots to meet their basic needs and hand washing, taking into account that, in general, the work of cultivation is done manually. Likewise, they do not have an area destined for food consumption, an activity that they do at the edges of the lot, nor toilets close to their place of work. It was also recorded that both producers and support people dress inappropriately, 85% of people wear shoes discovered. The lack of hand washing, the direct manipulation of the product during harvest and the work with animals are factors that increase the risk of microbiological contamination of coriander bunches for fresh consumption.

In the Table 2 shows the main observations recorded during field visits related to the physical, chemical and biological hazards that should be addressed as a priority to improve the coriander production system and thus obtain a safe product.

Table 2. Sources of hazards associated with agricultural activities recorded during field visits that compromise the safety of coriander cultivation in The Reyes of Juarez, Puebla.

Activity	Physics	Chemical	Microbiological
Land preparation	Containers, labels and garbage on the edges of lots and roads		Activity with animals, presence of animal excrement and diverse garbage
Manual seeding	Stones, container, sacks		Unwashed hands Dirty implements
Irrigation			Water on soil, garbage and the presence of animals
Hilling and weeding			Unwashed hands, activity with animals Dirty implements
Control of pests and diseases	Containers, labels and garbage on the edges of lots and roads	Non-authorized agrochemicals	
Harvest			Unwashed hands Dirty implements

In the study region, it was recorded that it has a 100% agricultural land use (S), but no producer has a documented history of the agronomic practices previously carried out. This is important since to ensure proper management of the land it is important to know the previous activities and those carried out in places adjacent to the land to ensure that there are no risks of contamination that can remain in the ground or be transported from nearby lots.

The dangers registered in the Municipality of The Reyes of Juarez imply a high risk to the health not only of the producers and those who participate in the cultivation activities, but also of the coriander consumers due to the use of agrochemicals not authorized for cultivation. Government entities such as SAGARPA-SENASICA through the State Committees of Plant

Health promote, through training courses, the application of BPA among the producers of the various crops produced in Mexico. However, these actions may have little impact on production systems due to the diverse socio-cultural and economic patterns of Mexican agriculture, among others.

The above represents a serious inconvenience, as it is in the region of the present study, for the implementation of GAP in the production of innocuous horticultural products (SAGARPA, 2010). Evidence of the above is the numerous health alerts issued by the FDA, the scientific regulatory body responsible for the safety of the United States of America, for the detection of contaminated horticultural products and for the affectation to numerous people by the consumption of those products. To cite some examples, from 2008 to 2009 the FDA issued numerous health alerts for the presence of microorganisms such as *Salmonella* and the detection of unauthorized pesticides or limits exceeded in various horticultural products from Mexico. Only during the period from 2011 to 2013, this same agency issued 97 health alerts on the chili product due to the presence of microorganisms and pesticides and in 2014, eight alerts for the presence of pesticides in jalapeño, habanero, pasilla and bell peppers for fresh consumption (FDA, 2015).

On the other hand, Humayun and Rainis (2013), mention that the common use of pesticides represents a major challenge in the attempt to achieve sustainable agricultural systems. Production systems based on integrated pest management (MIP) can reduce the use of pesticides to a large extent without causing harm to the environment and contribute to obtaining good yields (Humayun and Rainis, 2013), while Tabares and López (2011) report that 22.3% of the producers of an important horticultural area in Antioquia, Colombia suffered some type of pesticide poisoning in their working life; the previous, associated to the lack of the use of protective equipment such as hat, hat, gloves and masks among others (Tabares and López, 2011).

Despite knowing the health risks, producers or field workers directly manipulate the pesticides during their preparation and application to the crop without taking any preventive measures (Montoro *et al.*, 2009) as what was recorded in this study in the Coriander cultivation.

Conclusions

The current production system of coriander cultivation in The Reyes of Juárez, Puebla, takes place between the months of February and September and consists of the following common practices: 1) land preparation; 2) direct seeding; 3) irrigation with well water; 4) crop maintenance (hilling, control of pests and diseases, weeding and fertilization) with draft animals and 5) manual harvesting. However, the system requires the immediate implementation of activities that reduce their impact on the health of the people involved in the crop and eliminate the chemical and microbiological hazards of contamination of the product. The implementation of programs such as the program of good use and management of agrochemicals (BUMA) and the system of pollution risk reduction (SRRC) in primary production are among the immediate operational strategies to solve the safety problems registered during production and production. Coriander harvest. Specifically, in relation to worker hygiene and health, followed by fertilization and application of pesticides. The above, to achieve the innocuous production of coriander and access to highly competitive markets in aspects of quality and safety.

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