Coriander storage (Coriandrum sativum L) as alternative to minimize postharvest damages

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Abstract
Coriander is among the most consumed aromatics in Brazilian northeast and for its particular aroma it is used in the composition of regional recipes. Just like other leafy greenery, postharvest improper coriander storage, compromises its process of commercialization, being necessary a low cost technology research that intends to increase coriander's shelf life. In this sense this research had as objective to verify the efficiency of packaging, storage temperature and postharvest sanitation treatment for commercialization purpose. The experiment was conducted in completely randomized experimental design in factorial scheme 4x2x2, with four repetitions, represented by 4 packaging types (PVC film, paper towel, PVC film + paper towel and plastic bag - LDPEB, two storage environments (refrigerated at 10°C and at room temperature of 25°C) and two sanitation treatments (with and without sanitization). The coriander packs of 50g were treated and stored for 10 days according to each environment condition. After storage period, the coriander was rated for its final fresh mass and its quality for commercialization, based on the parameters: coloring, darkening, odor and overall quality. It is concluded that refrigerated storage contributed to minimize storage damages in all sensory qualities, specially when associated to the use of the plastic bag. The fresh mass was individually influenced by the type of packaging, sanitization and storage conditions where there was less mass loss under refrigeration conditions and in plastic bag (LDPEB), but as for the dry mass, sanitization was not efficient when coriander was conditioned to room temperature.

Key-words: Coriandrum sativum L., Postharvest Treatment, Refrigeration, Shelf Time Packaging

Introduction
Coriander (Coriandrum Sativum L.) is an oleraceous belonging to apiaceae family, classified as vegetable condiment, being widely used in northeastern cuisine (Pinto at. al., 2018). Currently coriander cultivation is widespread by other countries because of its use in cuisine and as adornment in the presentation of dishes, and in Brazil it is cultivated specially in the north and northeastern semi-arid regions, in a very rustic way by family farmers (Almeida et. al., 2019) where the leaves are mainly consumed in salty dishes in northern and northeastern kitchens of the country, besides being specially appreciated in fish restaurants in this region and in moquecas in espírito Santo (stew) (Reis and Lopes, 2016).

Mostly consumed while being fresh and preferentially in its earliest form, coriander is a highly perishable horticulture, and therefore has a short shelf life and its leaves are susceptible to rapid loss of water after harvest, making them unfeasible for commercialization. (Oliveira et. al., 2015, Souza et. al., 2017) requiring its immediate consumption or the use of technical conservation measures aiming to
Material and methods

This research was developed by the academic unity of Serra Talhada from the Federal Rural University of Pernambuco in two steps. The first step occurred in the period of May 25th to June 28th in the year of 2019 for coriander production and the second in the period of June 30th to July 10th, when the storage treatments were applied. For the production of coriander the variety used was VERDÃO, sown in 15 kg capacity buckets which were used the following substrates: soil (60%), organic compost (40%) putting up 20 seeds per pot, receiving daily irrigation according to the crops needs the invasive plants were removed manually and there were no pest incidences. The harvest was done 34 days after sowing, preferably between 16:00 and 17:00 hours because of the milder time, to minimize the wilting effect. After the reap and in proper environment, the roots were extracted.

The plants were weighed on precision scales and divided in two lots (with and without hygienization) of equal amount, then each batch was prepared to receive the pre-established treatments.

The experiment was composed by four types of packagings (PVC film; paper-towel, PVC film packaging + paper towel and polyethylene low density plastic bag - LDPEB).

Two levels of hygienization (with hygienization and without hygienization) and two storages environments (refrigerated and at room temperature) distributed in factorial scheme, the experimental design was completely randomized with four repetitions. To compound the treatments the amount that would pass through the sanitation process was put in plastic trays of culinary use and submitted to immersion of 1% sodium hypochlorite solution for 15 minutes. Then the amounts were washed into running water for equal time to eliminate possible sodium hypochlorite residues. After washing the excess water was removed with the aid of a paper towel.

The amount that was not submitted to hygienization was quickly washed into running water and had its excess water removed with paper towel. After such procedures, each amount was subdivided in packs of 50g, tied by a cotton cord, weighed and packed according to each treatment. Sample preparation in packaging in each treatment: a) PVC FILM PACKAGING (The producted used was lusafilm's R105 PVC film, recommended for domestic and commercial use, packing coriander without letting any air rift), b) PAPER TOWEL PACKAGING (It was used the domestic paper towel, where the paper tower was completely covering the coriander in a cone shape), c) PVC FILM PACKAGING + Paper towel (The pack of coriander was completely covered by paper towel in cone shape and then covered by PVC film to seal the air conduction), d) PLASTIC PACKAGING (For this case It was used the low density polyethylene plastic bag (LDPEB), the coriander amount was put inside the plastic bag, removed air excess and sealed with a sealer). The samples were prepared according to each treatment and subjected according to each storage condition, half by refrigeration (average temperature of 10°C) and half by room temperature (average temperature of 25°C) in plastic trays of culinary use.

The plants remained under these conditions for 10 days and every 3 days it was performed the sample position change inside each packing place.
Thermometers were installed both inside the refrigerator and in the kitchen. At the end of the storage period, mass loss was evaluated. On this occasion coriander packs were also evaluated with respect to their quality for commercialization based on the parameters: coloring, darkening, odor and overall quality, through a table where these attributes received scores from 5 to 1 (AOAC, 2012), and assuming as 3 the note, whose quality was a limit for marketing and as 1 the note, whose quality was totally discarded for marketing (Table 1).

The data were submitted to the normality and homogeneity test and then to variance analysis and comparison of means by the Tukey test at 5% probability. When there was significant interaction between packaging, storage site temperatures and sanitation, the factors were studied together, but when there was no effect of interaction, the factors were analyzed separately.

Table 1. Quality assessment on the attributes colour, darkening, odour and general quality in coriander leaves submitted to different packaging, under refrigeration or at room temperature, sanitized or not. Serra Talhada-PE, July 2019.

<table>
<thead>
<tr>
<th>Coloring</th>
<th>Darkening</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Green leaves</td>
<td>5. None</td>
</tr>
<tr>
<td>4. Light Green leaves</td>
<td>4. Light</td>
</tr>
<tr>
<td>3. Yellowish Green leaves</td>
<td>3. Moderated</td>
</tr>
<tr>
<td>2. Greenish yellow leaves</td>
<td>2. Severe</td>
</tr>
<tr>
<td>1. Yellow leaves</td>
<td>1. Extreme</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Odor</th>
<th>Overall quality analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Absent/faint</td>
<td>5. Excellent, no defects</td>
</tr>
<tr>
<td>4. None, non-standard</td>
<td>4. Good, minor defects</td>
</tr>
<tr>
<td>3. Moderated</td>
<td>3. Average defects, limited for consumption</td>
</tr>
<tr>
<td>2. Faint characteristic odor</td>
<td>2. Excessive defects</td>
</tr>
<tr>
<td>1. Strong rotten odor</td>
<td>1. Rotten, unsuitable</td>
</tr>
</tbody>
</table>

Results and discussion

Among the packages (Figure 1) the LDPE plastic bag showed greater efficiency with respect to water loss at the end of the coriander storage period, reaching only 1.5% loss in relation to initial mass (50 g). This possibly happened due to the fact that it is sealed and the material is waterproof, which made it difficult to exchange mass and gases with the external environment, regardless of whether it is refrigerated or not. Due to the fact that it is sealed and the material is waterproof, which made it difficult to exchange mass and gases with the external environment, regardless of whether it is refrigerated or not.

With reference to PVC film packaging alone or in combination with paper towels, no significant difference was observed in relation to water loss and 17% in relation to the values obtained at the beginning of storage (50%). It is possible that the PVC film packaging is not as efficient to inhibit gas exchange with the outer packaging medium as was LDPEB.

In this context, Oliveira et al. (2017) evaluating the postharvest quality in the conservation of jambu according to the type of packaging and hydrothermal treatment, also observed that the reduction of the jambu temperature, through cooling, as well as the use of plastic packaging can prolong the shelf life of this hardwood. They reached this conclusion when they evaluated these treatments and verified that these, individual or associated, caused the plant to present less water loss at the end of storage, which was 12 days.
The treatment only paper towels (Figure 1), proved to be less effective than the other packages, according to physical parameters that the center sheets presented. In this treatment, the percentage of water mass lost at the end of the experiment was 43.88%. It was observed in the first evaluation (at three days) of the weighing that the use of this material as packaging in the conservation of coriander is not viable; because it is of high permeability the anaerobic breathing and the loss of quality increase the speed of deterioration.

Another factor that may have influenced the lower efficiency of the paper towel in the preservation of coriander is that this product presents great power of water absorption and in cold environment the thermal sensation tends to decrease by the crystallization of water particles, allowing greater loss of water by the coriander leaves.

Assessing the effect of the coriander storage environment (chilled or at room temperature) on the final fresh mass (g/packet) (Figure 2) shows that a large variation in the loss of fresh mass has occurred.

When storing coriander at different temperatures Silva (2016) noted that when the ambient temperature was close to 20ºC, the coriander leaves had greater loss of fresh mass compared to leaves that were in storage conditions of 10ºC. In this way, the author also confirms that temperature plays a key role in maintaining longer shelf life.

From the final fresh pasta (g/packet) data observed in Figure 3, it can be seen that sanitization contributed to reduce the shelf life of the coriander, becoming an unfeasible alternative as compared to treatments that did not receive sanitization and, regardless of the type of packaging and storage, showed better results.

In this particular case, two possibilities are suggested: in the first case, it is possible that the coriander leaves have not been sufficiently dried when subjected to sanitization, leaving a certain amount of water remaining, which during storage may have contributed to the fermentation and deterioration of the plant material; the second possibility is that, having been immersed in 1% sodium hypochlorite solution for 15 minutes, the coriander leaves have absorbed this substance and, even being washed for the same time in tap water treated by the supply company (COMPESA) with 2% sodium hypochlorite, it is suggested that the content of this substance contained in the leaves has contributed to accelerate the fermentation process, justifying this loss of mass.

It is noted that storage in a refrigerated environment has contributed to the maintenance of the fresh mass of the coriander, whereas when it was stored at room temperature, it was found that this mass was reduced by 4 grams per packet. In this case, the ambient temperature, as it oscillated two and a half times in relation to the refrigerated environment temperature, approximately 25ºC was responsible for influencing the greater loss of water in the coriander, as in the refrigerated environment the temperatures were around 10ºC and in natural conditions around 25ºC to 27ºC, throughout the storage period.
(refrigerated environment or not) and the type of hygienic treatment or not (Figure 4), it was found that, regardless of the type of packaging and hygienic treatment, the coriander when stored under refrigeration had an original odor (note 5, Table 1), revealing that at a storage temperature of 10ºC, its original odor was not altered, keeping it in perfect conditions for sale. However, when the coriander was stored at room temperature, there were changes in the odor of the product depending on the type of packaging, stressing that the LDPEB packaging provided moderate odor and average defects in terms of general quality analysis, limiting the coriander for marketing and consumption (note = 3) in compliance with the AOAC standards (2012).

According to Pereira et al. (2017) the temperature allied to the relative humidity of the air are responsible for maintaining the useful life of the plants. The coriander that was kept in paper towels + PVC film packages submitted or not to sanitization and at room temperature and only the PVC film packages submitted to sanitization maintained at room temperature, had the same classification with respect to strong and rotten odor, showing that the packaging under natural conditions compromised the quality of coriander. According to Silva et al. (2017) quality characteristics include strong color, aroma and taste and characteristic, no signs of yellowing and rotting. Therefore, storage conditions that compromise these characteristics should be avoided.

Since the results are different when subjected to ambient temperature conditions, we highlight the influence of many variables, such as constant changes in air temperature and humidity, influencing the useful life of the product. According to Pereira (2017), there are changes in the appearance and chemical composition of vegetables in storage, taking into account the following variables responsible for such changes, the temperature, relative humidity of the air and the presence of gases, since they are responsible for the useful life of the products.

According to Figure 5, which deals with the characteristic colour in coriander plants, it can be seen that in all packages, whether or not they have been sanitized, with regard to storage under refrigeration, the leaves have remained with their characteristic colour of green. In this case, refrigeration was the main determining factor in maintaining the quality of the coriander so that, by lowering the temperature of the storage environment, the perspiration of the plant was reduced while maintaining its quality.

In this context, one of the works developed by France (2011) in which it evaluated the hydrocooling at 4ºC and 5ºC for 10 minutes in lettuce plants and then stored under refrigeration at 5ºC, concluded that this is an efficient technique and maintains the water balance of the leaves providing a longer shelf life of the products due to the decrease of the temperature in the storage place.

It is also observed in Figure 5 that in the coriander packets packed in LDPEB, sanitized or not and remaining under refrigerated environment, the
Coriander storage (Coriandrum sativum L) as alternative to minimize postharvest damages

leaves were yellowish green and moderately darkened, placing them according to AOAC (2012) standards, therefore, at the minimum limit of the commercialization standards.

![Fig. 5. Coriander colour according to the type of packaging, sanitization and refrigeration. Serra Talhada-PE, 2019. Colour/notes: Green leaves-5; light green leaves-4; yellowish-green leaves-3; Greenish-yellow leaves-2 and yellow leaves-1.]

On the other hand, in the coriander packets packed in paper towels, independent of the sanitization, and kept in an environment without refrigeration, as well as those of the PVC film and sanitized packaging, the coloring of the sheets was in the greenish-yellow sensory classification, receiving a grade of 2, therefore, out of the selling standards.

When packed with paper towels + PVC film, the coriander, regardless of being submitted to sanitization and when not refrigerated, as well as the PVC film without sanitization, presented characteristics of yellowish tint and extreme darkening (note 1), making them unfeasible for the sale.

Regarding the sensory characteristic of coriander, it was strongly influenced by the storage environment, because although there was a variation in the color due to the packaging and sanitization factors, it can be observed that the refrigeration contributed to maintain the color of the vegetable, since lower temperatures retard the metabolism of the vegetable, thus increasing its durability.

On the other hand, the coriander preserved without refrigeration has turned yellow, thus compromising its quality for marketing, demonstrating once again the importance of lowering the temperature of the storage environment as a requirement to ensure the maintenance of the useful life of leafy vegetables. Silva et al. (2016) studying the useful life of coriander at different temperatures, found a drop in leaf quality below the temperature studied in this experiment, which was approximately 25°C. In this experiment, the coriander leaves were very deteriorated, with the presence of fungi and unfit for consumption after 10 days of storage in an environment without refrigeration.

Analyzing the sensory parameter of darkening (Figure 6), it was observed that, in all packages packed under refrigeration, regardless of sanitization, the coriander leaves had no darkening characteristic, receiving maximum score by the AOAC standards (2012), remaining appropriate for commercialization. The exception was for paper towels, which showed slight darkening, but still within the expected standard for the market.

Regarding the packaging at room temperature, the coriander that was in the packages of PVC film, paper towels alone or associated with PVC film, and LDPE plastic bag had severe darkening when not sanitized. Concluding that the packaging at room temperature, once again, contributed to increase the deterioration of vegetables, showing that in the case of hardwoods commercialization, the storage conditions should foresee concern with temperature. On the other hand, the non-sanitizing helped in the loss of quality of the leaves.

![Fig. 7. Analyzing the sensory parameter of darkening. Serra Talhada-PE, 2019.]

At room temperature, extreme darkening was observed in the coriander packets, packaged in insulated PVC film or paper towels, both sanitized, as well as for paper towels + PVC film under sanitization. When packed in LDPEB plastic bag and having passed through the sanitization, the coriander packs presented the sensorial characteristic of moderate darkening (note 3).
Thus, in the post-harvesting of leafy vegetables, the association of conservation techniques should be taken into account in order to reduce the damage caused due to their high perishability. This information is reaffirmed by Silva et al. (2016) where the authors attest as valid the use of reincarnation techniques in order to reduce the deterioration of the product.

Regarding the classification obtained in the previous situations, it can be stated that the use of LDPEB plastic bag associated with sanitization and storage under refrigeration has helped to maintain the quality of the coriander. It is possible that the sanitization, by reducing the contaminants in the plants avoided their deterioration and, being the product in impermeable packaging, avoiding recontamination by the environment, contributed even more to keep the product within the market standard.

In an analysis to verify the general quality of the coriander, under conditions of ambient temperature (Figure 7), it was observed that the packages PVC film, paper towel, and paper towel + PVC film when submitted to sanitization and kept at ambient temperature and, PVC film, paper towel isolated or associated with unsanitized PVC film and LDPE plastic bag, presented the characteristic rotten and not usable (note 1). Thus, these treatments made it completely impossible to commercialize the coriander and cannot be recommended for preservation of the coriander when stored at room temperature.

The coriander samples packed under refrigeration, in the paper towel when sanitized or not, showed excessive defects, showing that, in this case, even kept in refrigerated environment did not maintain quality for its sale. This observation shows the low efficiency of this type of packaging in the conservation of coriander, although it is widely used by some traders.

In another condition, the coriander packets, when stored in PVC film packaging and without sanitization and under refrigeration, showed medium defects, limiting the product for consumption. Still considering the refrigerated environment, for those samples that did not undergo sanitization, in the LDPEB plastic bag and paper towel + PVC film packages, as well as those in the LDPEB plastic bag and sanitized, the coriander packs showed good quality or small defects, showing that these treatments contributed to keep the coriander in condition for commercialization.

Still in a refrigerated environment, the coriander samples kept in the PVC film packages alone or associated with paper towels that underwent sanitization, presented excellent general quality and free of defects, in an excellent state of conservation and consequently, commercialization. This behavior reveals the superiority of the combination of these treatments over the others in maintaining the overall quality of the coriander and, therefore, in improving the post-harvest life of this vegetable. Therefore, the search for techniques to prolong the quality of products is very important because, according to Silva et al. (2016) when you want to produce vegetables, especially leafy, one of the most limiting causes that leads to many losses is shelf life. Additionally, Pereira et al. (2017) highlight that, during the storage period, changes in the physical-chemical characteristics of vegetables occur, being the temperature, gas concentration and relative humidity of the air the main factors in determining the useful life of the product and, these factors should be kept under control to ensure the good quality of the products.

**Conclusion**

Based on the results observed during the course of the study, it was concluded that storage in a refrigerated environment contributed significantly to maintaining the sensory qualities of coriander.

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Fig. 7. Darkening of coriander leaves depending on the types of packaging, sanitization and refrigeration. Saw Talhada-PE, 2019. General Quality/Note: Excellent, free from defects-5; Good, small defects-4; Medium defects, limited for consumption-3; Excessive defects-2; Rotten, not usable-1.
especially when associated with the use of LDPEB plastic bags.

Storage in a refrigerated environment and packed in LDPEB plastic bags contributed to keep the coriander mass fresh.

When the coriander was stored at room temperature and in packaging which allowed exchanges with the environment, sanitization was not important.

**Conflict of interest:** All authors declare no conflict of interest.

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