EFFECT OF HYDROCOOLING ON POSTHARVEST QUALITY AND SHELF LIFE OF ARUGULA

EFEITO DO HIDRORRESFRIAMENTO NA QUALIDADE PÓS-COLHEITA E NA VIDA ÚTIL DA RÚCULA

EFECTO DEL HIDROENFRIAMIENTO SOBRE LA CALIDAD POSCOSECHA Y LA VIDA ÚTIL DE LA RÚCULA

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ABSTRACT

Arugula is appreciated as a food. Hydrocooling promotes the reduction of respiration, transpiration and promotion, promoting quality and extending shelf life. The objective of this work was to analyze the influence of hydrocooling and refrigerated storage on post-harvest arugula conservation. As variable variables were: visual and shelf fresh, loss of leaf mass analysis and byl content. The experiment was fully developed in hydrores design, wet control, experimented in fully developed design (control, wet control, experimented in design) with seven procedures. Data were selected using the normality and homology of variances test, analysis of variance (ANOVA) and mean test (Tukey 5%) in software R version 3.6.3. Visual and shelf analysis on the 8th day of storage showed that arugula was not suitable for commercialization in treatments. The weight loss of fresh leaves was 39% without control, 41% without wet control and 40% without hydrocooling. The chlorophyll content differed only on day 0 of storage. The shelf life hidrolagors do not extend the shelf life 12 ºC after arugula or arugula.

Keywords: Agronomy. Foods. Shelf Life.

RESUMO

A rúcula é apreciada como alimento. O hidrorresfriamento promove a redução da respiração e da transpiração, contribuindo para a manutenção da qualidade e a extensão da vida útil pós-colheita. O objetivo deste trabalho foi analisar a influência do hidrorresfriamento e do

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armazenamento refrigerado na conservação pós-colheita da rúcula. As variáveis avaliadas foram: aparência visual e vida útil de prateleira, análise da perda de massa fresca das folhas e teor de clorofila. O experimento foi conduzido em delineamento inteiramente casualizado, com sete tratamentos. Os dados foram submetidos aos testes de normalidade e homogeneidade das variâncias, análise de variância (ANOVA) e teste de médias de Tukey a 5%, utilizando o software R versão 3.6.3. A análise visual e de vida útil no 8º dia de armazenamento demonstrou que a rúcula não era mais adequada para comercialização em nenhum dos tratamentos. A perda de massa fresca das folhas foi de 39% no controle, 41% no tratamento sem controle úmido e 40% no tratamento sem hidrorresfriamento. O teor de clorofila diferiu apenas no dia 0 de armazenamento. O hidrorresfriamento não prolongou a vida útil da rúcula armazenada a 12 ºC.

Palavras-chave: Agronomia. Alimentos. Vida Útil.

RESUMEN

La rúcula es apreciada como alimento. El hidroenfriamiento promueve la reducción de la respiración y la transpiración, contribuyendo al mantenimiento de la calidad y a la extensión de la vida útil poscosecha. El objetivo de este trabajo fue analizar la influencia del hidroenfriamiento y del almacenamiento refrigerado en la conservación poscosecha de la rúcula. Las variables evaluadas fueron: apariencia visual y vida útil comercial, análisis de la pérdida de masa fresca de las hojas y contenido de clorofila. El experimento fue realizado en un diseño completamente al azar, con siete tratamientos. Los datos fueron sometidos a pruebas de normalidad y homogeneidad de varianzas, análisis de varianza (ANOVA) y prueba de medias de Tukey al 5%, utilizando el software R versión 3.6.3. El análisis visual y de vida útil en el octavo día de almacenamiento mostró que la rúcula ya no era apta para la comercialización en ninguno de los tratamientos. La pérdida de masa fresca de las hojas fue del 39% en el control, 41% en el tratamiento sin control húmedo y 40% en el tratamiento sin hidroenfriamiento. El contenido de clorofila difirió únicamente en el día 0 de almacenamiento. El hidroenfriamiento no prolongó la vida útil de la rúcula almacenada a 12 ºC.

Palabras clave: Agronomía. Alimentos. Vida Útil.

1 INTRODUCTION

1.1 PROBLEMATIC

Arugula (Eruca sativa M.) is a leafy vegetable with a short post-harvest shelf life, small size, and tender leaves with a pungent flavor. It originated from the Mediterranean region and belongs to the Brassicaceae family (BARREIROS et al., 2021). Arugula is highly appreciated as a food, particularly in raw salads, due to its mineral content, such as calcium, sulfur, iron, and potassium (YANG et al., 2021). It is also a source of omega-3 fatty acids and possesses medicinal properties in combating diseases like cancer (TRAKA et al., 2016; WILSON et al., 2017). However, one of the main limitations in arugula production and post-harvest is high temperature, which causes changes in its morphology, metabolism, and preservation (BARREIROS et al., 2021).

Leafy vegetables like arugula are sensitive to high temperatures and prone to dehydration due to their smaller surface area (ÁLVARES et al., 2007). Temperature is the most important factor in the preservation of harvested fruits and vegetables (REES; FARREL; ORCHAD, 2012), once that regulating biochemical and physiological processes, affecting consequently preservation of the nutritional and sensory characteristics of fruits and vegetables (CENCI, 2006).Lower temperatures reduce respiration, preserving aroma, color, flavor, texture, and other quality attributes. Refrigerated storage is recommended as it delays water loss, undesirable metabolic reactions, and decomposition caused by fungi and bacteria (CHITARRA & CHITARRA, 2005).

Various techniques are used in the preservation of fruits and vegetables, such as modified atmosphere packaging with films and waxes, controlled atmosphere storage, refrigerated storage, growth regulators, and irradiation (CARVALHO, 1994).Refrigerated storage aims to reduce the biological activity of the product, inhibit the growth of unwanted microorganisms, lower the ambient temperature, reduce transpiration through the temperature difference with the product, and increase the relative humidity of the environment (CHITARRA & CHITARRA, 2005).Pre-cooling techniques prior to refrigerated storage are employed to rapidly reduce respiration, transpiration, senescence, and ethylene production in harvested produce, thus promoting higher quality for commercial purposes. These techniques delay physiological and biochemical processes that are directly influenced by temperature (FRANÇA et al., 2015; TRAVASSOS et al., 2017; MOREIRA et al., 2019; GUERRA et al., 2020a).Hydrocooling is a pre-cooling technique that utilizes chilled water to lower the temperature of harvested vegetables before transportation, storage, packaging, and marketing. Hydrocooling is a simple, efficient, fast, inexpensive, and beneficial method as it reduces losses and moisture during the cooling process (GUERRA et al., 2020a). Hydrocooling has proven to be effective in extending the post-harvest shelf life of fruits and vegetables, such as lychee, peach, asparagus, sweet corn, cherry, lettuce, and parsley (ALIQUE et al., 2006; ÁLVARES et al., 2007; AGUILA et al., 2009). Given the context, hydrocooling is a viable and cost-effective alternative as it reduces the "field heat" and leaf dehydration by absorbing water throughout the storage process (TRAVASSOS et al., 2017; MOREIRA et al., 2019).

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Harvested vegetables retain field heat, which needs to be rapidly removed before transportation and storage to maintain their quality. Failure to do so can lead to quantitative losses (mass loss), qualitative changes (flavor, aroma, texture, and appearance), and nutritional losses (GUERRA et al., 2020a). Furthermore, improper management of temperature and air humidity in storage facilities can reduce their shelf exposure time in supermarkets, grocery stores, or farmers' markets, resulting in higher prices and impacting consumers' expenses (TRAVASSOS et al., 2017). Fruits and vegetables are perishable due to their high water content in plant tissues, resulting in a short postharvest shelf life (COELHO et al., 2015). In an attempt to maximize the postharvest shelf life of fruits and vegetables and reduce postharvest losses, it is necessary to understand appropriate practices and technologies for managing each phase, including harvesting, postharvest handling, storage, transportation, distribution, marketing, and consumption (FREITAS-SILVA & VENANCIO, 2010).Knowledge derived from postharvest physiology provides technical insights that can be obtained and applied to extend the storage time without altering their physical, chemical, nutritional, and organoleptic characteristics (ABREU et al., 1998; ANTUNES et al., 2003). The objective of this study was analyze the influence of hydrocooling and refrigerated storage on the post-harvest preservation of arugula. The hypothesis of the study consisted that hidrocolling reduces.

2 THEORETICAL FRAMEWORK

2.1 HYDROCOOLING

The high perishability and susceptibility of fruits and vegetables to water loss, intensified by high temperatures and improper temperature and humidity management in storage facilities, necessitate the use of post-harvest techniques aimed at reducing metabolic activity and extending the shelf life of the products, both at the shelf and in refrigeration (SOUZA et al., 2017).

Hydrocooling is performed through the application of water spray onto the product or by immersing it in chilled water (water mixed with ice), immediately after fruits and vegetables are harvested and prior to the processes of packaging, storage, and distribution (BETIN et al., 2018). This technique represents a simple, efficient, and cost-effective alternative for vegetable preservation, as its objective is to remove field heat, thereby reducing the metabolic processes that lead to senescence (TEXEIRA et al., 2016).

Post-harvest control methods are employed to minimize or delay deterioration processes in products through storage, transportation, and other techniques, with hydrocooling being one of the most advantageous methods for fresh vegetables (TEXEIRA et al., 2016).

The application of this pre-refrigeration cooling technique is viable in reducing the temperature of harvested fruits and vegetables, which would otherwise occur slowly in a cold storage room. Hydrocooling enables rapid control of temperature and transpiration in harvested fruits and vegetables. Moreover, it can reduce microbial activity, respiratory rates, senescence, and ethylene production (KALBASI-ASHTARI, 2004).

Studies conducted with hydrocooling have shown that this method yields satisfactory results in leafy vegetables by delaying visual wilting, increasing shelf life, and reducing water loss in lettuce (FRANÇA et al., 2015), scallion (TRAVASSOS et al., 2017), and basil (TEXEIRA et al., 2016).

In addition to these vegetables, hydrocooling has proven to be efficient in the post-harvest conservation and extension of shelf life in lychee, peach, asparagus, sweet corn, cherry, lettuce, and parsley (ALIQUE et al., 2006; ÁLVARES et al., 2007; AGUILA et al., 2009; OLIVEIRA et al., 2015).

In lychee fruits, hydrocooling promotes the maintenance of fruit glossiness and delays fruit darkening (AGUILA et al., 2009). In parsley, hydrocooling is effective in reducing temperature, fresh matter loss, and water loss (ALVAREZ et al., 2007).

Fruits and vegetables that are insensitive to excessive moisture or unaffected by it, such as melon, kiwi, leek, spinach, and scallion, can use hydrocooling with refrigerated water as a post-harvest treatment due to its simplicity, practicality, efficiency, and low cost (BETIN et al., 2018).

2.2 POST-HARVEST CONSERVATION

Fruits and vegetables are perishable due to their high water content in plant tissues, resulting in a short postharvest shelf life (COELHO et al., 2015). In an attempt to maximize the postharvest shelf life of fruits and vegetables and reduce postharvest losses, it is necessary to understand appropriate practices and technologies for managing each phase, including harvesting, postharvest handling, storage, transportation, distribution, marketing, and consumption (FREITAS-SILVA & VENANCIO, 2010).

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Refrigerated storage aims to reduce the biological activity of the product, inhibit the growth of unwanted microorganisms, lower the ambient temperature, reduce transpiration through the temperature difference with the product, and increase the relative humidity of the environment (CHITARRA & CHITARRA, 2005).

2.3 REFRIGERATED STORAGE

Maintaining relative humidity below the ideal range for fruits and vegetables leads to water loss and alters their quality. On the other hand, relative humidity above the maximum saturation limits (98 to 100%) promotes the development of postharvest rot-causing fungi and bacteria (CHITARRA & CHITARRA, 2005).

Finger & Vieira (2007) recommend that regulating relative humidity should be coupled with a reduction in storage temperature.

Fruits and vegetables have a minimum temperature threshold, and temperatures below the tolerated range can cause injuries. This physiological alteration is known as chilling, which leads to poor ripening, sensory changes, and darkening of the pulp and epidermis. Several factors should be considered before choosing the storage temperature, such as ripeness stage, cultivar, and exposure time (ROSA et al., 2018).

The success of storage depends on certain precautions, such as storing high-quality and healthy fruits and vegetables, as refrigerated storage alone does not prevent the action of pathogens. Temperature should be regulated immediately after harvest, and the ideal temperature for each fruit or vegetable should be determined. Furthermore, the cold chain should not be interrupted until consumption (LUENGO et al., 2007).

2.4 ARUGULA (*ERUCA SATIVA* M.)

The Brassicaceae family is the botanical family with the largest number of vegetable species, and among these, arugula (Eruca sativa M.) stands out, being highly appreciated as a food (Figure 1) (FILGUEIRA, 2008). Additionally, arugula is a vegetable of interest due to its hardiness, early maturity, and popular acceptance (VENZON & PAULA JÚNIOR, 2007).

Figure 1

Arugula (E. sativa M.)

Source: Authors, 2022.

Arugula is native to Southern Europe and Western Asia, and in Brazil, it was introduced by the Italians. It possesses a pungent taste and pleasant aroma, along with rapid development and a short life cycle (FERRO et al., 2013; PÉLA et al., 2017). Arugula is predominantly consumed in the form of salads (VENZON & PAULA JÚNIOR, 2007).

In Brazil, the most cultivated species is Eruca sativa Miller, represented by the cultivated and broadleaf cultivars. Additionally, there are other smaller-scale crops of the species Diplotaxis tenuifolia (L.), known as wild arugula. Harvesting of arugula is done 30 to 40 days after sowing. The leaves should have a length of 15 to 20 cm, be well-developed, green, and fresh (MINAMI & TESSARIOLI NETO, 1998). In commercial cultivation, arugula is harvested all at once by uprooting the entire plants with leaves and roots. However, it can also be harvested multiple times through leaf cutting, always above the apical bud, promoting regrowth (MINAMI & TESSARIOLI NETO, 1998).

The Southern and Southeastern regions are the major producers of arugula in the country. Arugula can be sown year-round, but satisfactory development occurs only in mild temperatures (FILGUEIRA, 2008). High temperatures stimulate the reproductive phase, resulting in premature flowering and the development of tough and pungent leaves. Despite being a temperate climate vegetable, arugula meets the requirements for cultivation in regions such as the Northeast, as its cycle and cultivation methods resemble those of lettuce and coriander (FILGUEIRA, 2008). Physicians and nutritionists recommend the consumption of arugula due to its essential role as a vegetable in human nutrition. This is attributed to its content of vitamins A and C, minerals such as calcium, sulfur, iron, and potassium, as well as being a source of omega-3 fatty acids and dietary fibers (BARREIROS et al., 2021), all of which are vital for the proper maintenance of the human body (LAURETT et al., 2017).

Furthermore, arugula has a low caloric value, with only 12 calories per cup, making it suitable for inclusion in most diets. It can stimulate the appetite due to its bitter and strong flavor, often added to heavier dishes. However, arugula can also be consumed sautéed, in salads, or as a pizza topping. The combination of arugula and watercress juice promotes detoxification of the body (TRANI et al., 1992). The commercialization of arugula is done in bunches, which are determined by the product packaging, containing 100 to 150 g for plants in conventional cultivation systems and 250 to 300 g in hydroponic systems. The weight and quality of the product depend on the seasonality of production, meaning that during hotter periods, the product has lower quality and availability, while during colder periods, it has higher quality and availability (LIMA, 2018).

The consumer market for arugula in Brazil is small but has the potential for expansion with regular supply and low prices. Arugula prices can reach over R$ 4.00 in supermarkets in the northern region of the country. In Alagoas, arugula can cost R$ 1.00 in open markets and R$ 2.00 in supermarkets (PURQUERIO et al., 2007).

Leafy vegetables undergo senescence due to rapid water loss and catalytic enzymatic action (WILLS et al., 1981). During harvest, the water supply from irrigation and the soil to the plant is interrupted, resulting in transpiration and a reduction in water content in the leaves due to exchange with the environment (SANTOS et al., 2001).

The loss of water accelerates deterioration, primarily through increased catabolic reactions such as chlorophyll degradation (FINGER & VIEIRA, 1997). Senescence in lettuce, as well as in arugula, can be indicated by the degradation of chlorophyll (SANTOS et al., 2001).

3 METHODOLOGY

3.1 RAW MATERIAL, EXPERIMENTAL LOCATION, AND DETERMINATION OF THE HYDROCOOLING TIME PERIOD FOR ARUGULA

The arugula plants were sourced from a local producer and harvested in the early morning hours. They were immediately transported to the laboratory and classified into bunches weighing 80-112g. The temperature of the bunches was then measured using an infrared thermometer (TRAVASSOS et al., 2017).

The bunches were immersed in a bucket containing a 3:3 (v/v) ratio of water and ice at 4ºC. Every 5 minutes, two bunches were removed, and their temperature was measured. The hydrocooling time was determined when the temperature stabilized (TRAVASSOS et al., 2017).

The temperature stabilized after 25 minutes, with the bunches reaching 8ºC.

The treatments applied were: I - dry control; II - wet control (submerged in distilled water at room temperature); III - hydrocooled arugula (TRAVASSOS et al., 2017). Finally, the plants were stored at 12ºC (Figure 2).

Figure 2

Treatments applied in the experiment

Source: Authors, 2022.

3.2 VISUAL ANALYSIS AND SHELF-LIFE EVALUATION

The arugula bunches were evaluated from the moment of harvest and treatment application until the end of the shelf-life period using subjective scores ranging from 0 to 3 (TRAVASSOS et al., 2017), as follows:

0 = no symptoms of wilting, yellowing, oxidation, or any other visual sign indicative of quality loss;

1 = intermediate symptoms of wilting, yellowing, oxidation, or other visual signs indicative of quality loss;

2 = advanced symptoms of wilting, yellowing, oxidation, or other visual signs indicative of quality loss; and

3 = unsuitable for commercialization, indicating the end of shelf-life.

3.3 FRESH LEAF MASS LOSS

Throughout the storage period, the arugula bunches will be weighed daily until the end of the shelf-life, as determined by visual analysis. This will be estimated using the equation:

$$\mathrm{PMF} = \frac{[(\mathrm{FML} - \mathrm{FFM})]}{\mathrm{IFM}} \qquad (1)$$

Where: FML: leaf mass loss (%);
IFM: initial fresh mass (g);
FFM: final fresh mass (g).

3.4 CHLOROPHYLL CONTENT

The chlorophyll content was measured using a SPAD (Soil Plant Analysis Development) meter.

3.5 STATISTICAL ANALYSIS

The experiment was conducted in a completely randomized design (CRD) with 3 treatments (dry control, wet control, hydrocooled arugula stored at 12ºC) and seven replicates. The data were subjected to tests for normality and homogeneity of variances, analysis of variance (ANOVA), and mean comparison using the Tukey test at a significance level of 5% in the statistical software R version 3.6.3 (R CORE TEAM, 2021). Graphs and tables were created using the SIGMAPLOT software.

4 RESULTS AND DISCUSSION

4.1 VISUAL AND SHELF-LIFE ANALYSIS

The visual and shelf-life analysis of rucola stored at 12°C showed the following observations:

On the 4th day of storage, rucola exhibited an intermediate level of wilting, yellowing, oxidation, or other visual signs of quality loss (rating 1).

By the 6th day of storage, rucola showed advanced symptoms of wilting, yellowing, oxidation, or other visual signs of quality loss (rating 2).

Finally, by the 8th day of storage, rucola displayed symptoms that rendered it unsuitable for commercialization, indicating the end of its post-harvest shelf life (rating 3) (Table 1).

The rucola samples already exhibited wilting symptoms in the control, moist control, and hydrocooling treatments after the first day of storage. Between the 4th and 6th day of storage, the rucola samples showed characteristics unsuitable for commercialization but still within the standards observed in some markets and farmer's markets. At the end of the storage period (8th day), the rucola samples demonstrated a deterioration in quality, particularly in terms of weight loss (Figure 3).

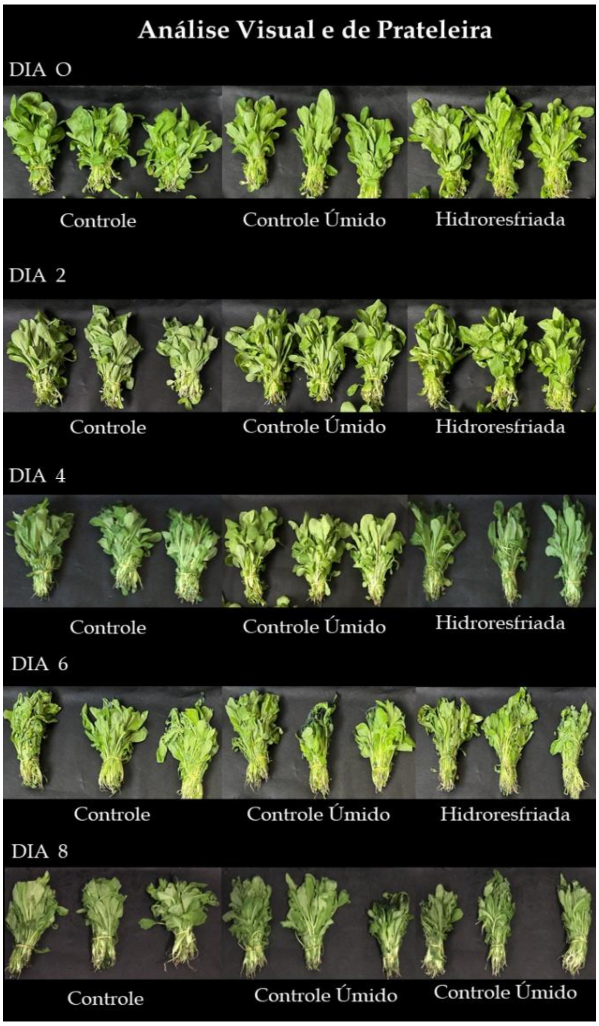
Table 1

Visual and Shelf-life Analysis of Rucola Stored at 12°C

	Subjective ratings		
Days	Control	Moist control	Hydrocooled
0	0	0	0
2	1	1	1
4	1	1	1
6	2	2	2
8	3	3	3

Figure 3

Visual and Shelf Life Analysis of Arugula Stored at 12ºC



Source: Authors, 2022.

The visual and shelf life analysis is a measurement used to monitor the visual and nutritional deterioration of fruits and vegetables during storage (TRAVASSOS et al., 2017). It also serves as a means to identify the optimal storage period after a treatment is applied to any plant or animal-derived product, such as oranges or tomatoes subjected to refrigerated storage. In our study, the period was set at 8 days after cooling.

The visual and shelf life analysis can be performed using developed scoring scales, such as the one proposed by Travassos et al. (2017), or it can be provided by specific institutions, such as the United States Department of Agriculture (USDA) for the classification of potato sticks (CRUZ et al., 2021).

4.2 PERCENTAGE LOSS OF FRESH LEAF MASS (%)

The percentage loss of fresh leaf mass of arugula stored at 12°C did not differ statistically among the treatments (Table 2).

Table 2

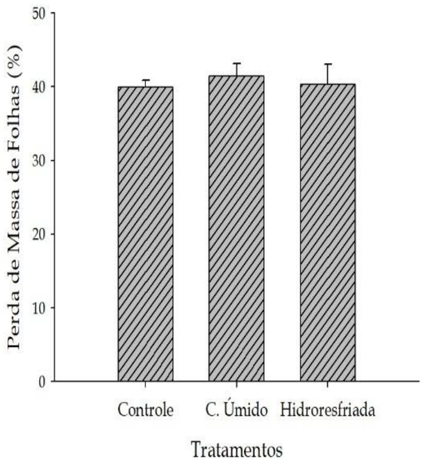
Analysis of Variance (ANOVA) of the percentage loss of dry leaf mass

	GL	**SQ**	**QM**	**Fc**	Ft
Trat.	2	7,4	3,7	0,01	0,98
Res.	19	3451,8	191,77		
Total	21	3459,2			
C.V.	34%				

The percentage loss of fresh leaf mass of arugula stored at 12°C was 39% for the control, 41% for the moist control, and 40% for the hydrocooled arugula on the 8th day of storage (Figure 4).

Figure 4

Percentage loss of leaf mass (%) of arugula stored at 12°C



The main cause of fresh mass loss in leafy vegetables is the transpiration process during storage. This not only leads to mass loss but also decreases the overall quality of the product (SILVEIRA et al., 2015).

Water loss promotes various changes in the appearance (Figure 2), metabolism, and composition of leafy vegetables (KAYS & PAULL, 2004), resulting in alterations in color, nutrients, and vitality (WILLS et al., 2007). Some water loss is allowed during refrigerated storage as long as it does not compromise the quality of the product displayed in commercial locations, due to wilting and wrinkling (GUERRA et al., 2020b).

On the 8th day of storage, the arugula in terms of fresh leaf mass loss was already unsuitable for commercialization, as percentages >40%, in the case of both the moist control and hydrocooled samples, are not acceptable. This result is due to leafy vegetables like arugula being composed mainly of water, constituting a content of 85 to 95% (NUNES et al., 2013).

In addition to the composition of arugula, another crucial factor is the relative humidity (RH) during refrigerated storage. The composition of 85 to 95% water, small specific area, and 100% intracellular spaces promote transpiration and water exchange to the environment with lower humidity (CRUZ et al., 2021).

Furthermore, the fresh mass loss in stored fruits and vegetables can be attributed to the evaporation of retained water after washing, as respiration, which involves the oxidation of carbohydrates into carbon dioxide and water, occurs due to the dehydration process caused by the difference in water vapor pressure between the vegetable's interior and the surrounding environment (MOREIRA et al., 2006).

As a result, wilting caused by water loss during storage is considered a significant quality attribute, as it is not accepted from a consumer's perspective (NUNES et al., 2013).

4.3 TEOR DE CLOROFILA

The chlorophyll content differed among the treatments on day 0 of storage, but there was no significant difference on the subsequent storage days (Table 3).

Table 3

Chlorophyll content of stored arugula 12ºC

	Chlorophyll		
Dias	Control	Moist control	Hydrocooled
0	34,9a	35,3b	32,9b
2	35,5	35,1	33,8
4	33,7	35,0	33,5
6	32,6	32,6	33,2
8	29,7	31,7	33,0

Different letters in the rows indicate that the treatments differ significantly from each other at a 5% level of significance based on the Tukey's test.

The chlorophyll content indicates the amount of nitrogen present in the leaves and helps in identifying possible deficiencies resulting from excess water and leaching of nitrogen from the soil (WINDER, 2018). Despite no significant differences from the 2nd to the 8th day of storage, the chlorophyll content decreases over the storage period. Therefore, it can be inferred that hydrocooling in arugula promoted chlorophyll degradation. A similar result was found by Álvares et al. (2007) in hydrocooled cilantro leaves.

The chlorophyll content can also indicate degradation due to metabolic processes occurring during storage (LANFER-MARQUEZ, 2003). Furthermore, chlorophyll degradation in senescent tissues may involve thermal alterations, which can occur in fruits or vegetables subjected to hydrocooling (HEATON et al., 1996).

Enzymatic reactions contribute to the brownish coloration in vegetables during the senescence period, attributed to the formation of phaeophytins and pheophorbides or the action of polyphenol oxidase (PPO) and peroxidase (POD) enzymes (LANFER-MARQUEZ, 2003).

5 FINAL CONSIDERATIONS

The results of this study indicate that hydrocooling did not extend the post-harvest shelf life of arugula stored at 12 °C, based on the results of visual and shelf life analysis, fresh leaf mass loss, and chlorophyll content. The effectiveness of hydrocooling as a technique for arugula preservation needs further investigation.

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