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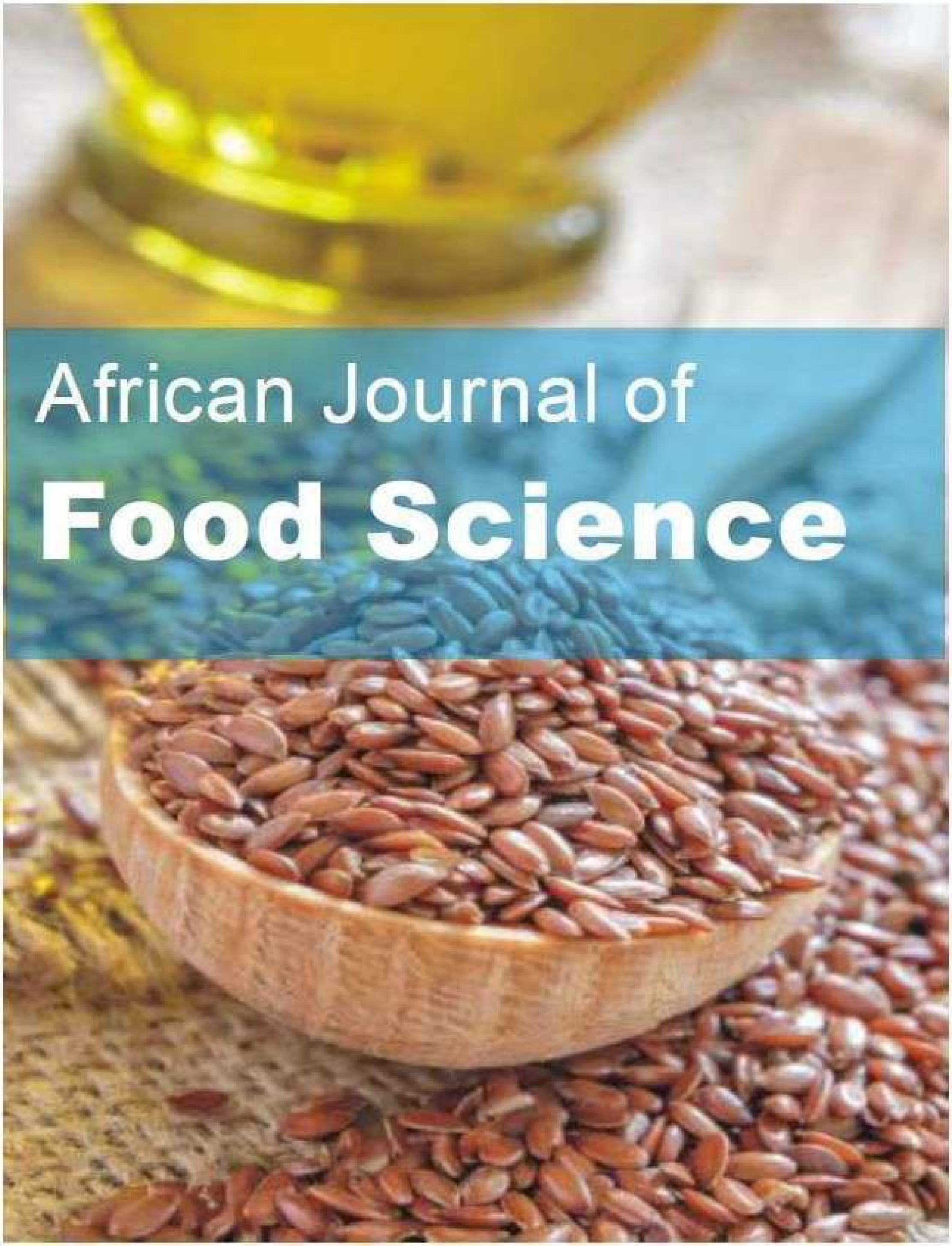

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African Journal of Food Science

Full Length Research Paper

Production, proximate and sensory analysis of canned fish in *tucupi* and *jambu* (*Acmella oleracea*) sauce

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The objective of the study was to develop canned fish with *tucupi* and *jambu* sauce from king weakfish, sardines and white mullet species. The elaborated products were submitted to sensorial, microbiological and centesimal analyses. The experimental design consisted of three treatments and five replications; 15 containers were processed at 121°C for 15 min. For sensory analysis, the 9-point hedonic scale was used. Frequency of consumption, purchase intention, acceptability index (AI%) and global acceptance (GA) were evaluated. Microbiological analyses were coliforms, coagulase positive *Staphylococcus*, *Salmonella* species and *Clostridium*. The proximate analysis followed the AOAC methodology. Data were submitted to ANOVA and Tukey test ($p<0.05$). For sensory analysis, the products had averages above seven, with no significant effect between treatments, except for the color attribute, where sardines stood out with eight points. The frequency of consumption and purchase intention did not show significant variation either. Microbiological analyses were within legal standards, with absence of *Salmonella* spp. and *Clostridium* $<10^3$ CFU/g. The canned, after thermal processing, present average levels of 17.59% of protein and 5.14% of lipid. The centesimal and microbiological analyses confirmed the nutritional quality and food safety of the developed products.

Key words: Thermal processing, amazon sauce, sardine, white mullet, weakfish, microbiological analysis, amazon food culture.

INTRODUCTION

World fish production in 2016 was 171 million tons, where about 88% (over 151 million tons) was destined for human consumption. The per capita consumption in 2016 was 14.4 kg, it is estimated that by 2020 consumption will exceed the values of 20.3 kg (FAO, 2018). Brazil does not follow this trend where consumption is around 9 kg

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(Lopes et al., 2011). Several factors contribute to the low consumption of fish in the country, such as social, cultural and economic status, as well as the lack of product standardization and diversification (Ostrensky et al., 2008).

In the northern region of Brazil, several fishing modalities capture several species of economic importance for the region (Espírito Santo et al., 2005),with potential for the elaboration of pre-prepared and industrialized products. Among these species, there is the king weakfish, *Macrodon ancylodon* (Bloch and Schneider, 1801), also known as *pescada-foguete*, *pescada gó* or *pescadinha real*. Species belonging to Sciaenidae family, which has an elongated body, silver staining and maximum length of 45 cm. Its distribution occurs from Venezuela to Argentina, in regions of muddy and sandy sediment (Ikeda, 2003).

The sardine *Cetengraulis edentulus* (Cuvier 1828) is known as the yellow-tailed sardine or *manjubas*, belongs to the family Engraulidae, has a wide occurrence in the tropical western Atlantic Ocean, from the Caribbean to the south of Brazil (Figueiredo and Menezes, 1978; Fishbase, 2019), adult individuals of the species are 11 to 17 cm in total length (Franco et al., 2014).

The white mullet, *Mugil curema* (Valenciennes, 1836), also known as *taínha* and *pratiquiera*, is a species of the Mugilidae family, inhabits coastal and estuarine regions with turbid and hypersaline waters, its average catch size is 30 cm (Cervigón et al., 1992). It has a robust and fusiform body with silver tone, which occurs in the Pacific and Atlantic Oceans, from the Western USA to the South of Brazil (Fischer et al., 2011).

Due to several factors, fish is among the most susceptible meats to deterioration processes, such as pH near neutrality, high nutrient content as protein and lipids, and high water activity (Pereira, 2014; Teodoro et al., 2007). Some techniques are used to prevent fish spoilage as well as squeezing, popularly known as canning, giving increased shelf life of these foods by applying pressure and controlled temperatures to the final product container itself (Gava et al., 2008).

Among the many varieties of plants used for food, jambu, Acmella oleracea, which is characteristic of the Amazon region, plays an important role in regional cuisine, usually associated with regional tucupi sauce in various dishes. Studies with medicinal use of jambu have shown a positive effect on several organ dysfunctions, specifically related to spilanthol, an alcamide present in its constitution that gives a unique characteristic of numbness and tingling when ingested (Malosso et al., 2008; Cheng et al., 2015; Barbosa et al., 2016).

Tucupi is produced during the pressing and grinding process of cassava roots, *Manihot esculenta* (Crantz), for flour production, which results in a liquid residue that is called manipueira, this residue can be discarded or turned into *tucupi* (Chisté et al., 2007). The cassava, *M. esculenta*, is a cyanogenic plant containing cyanides in its composition, which is highly toxic and may cause asphyxiation when ingested, but due to its high volatility, the fermentation and boiling process in *tucupi* production are sufficient to lowering cyanide levels to safe values for human health (Amorim et al., 2005;Chisté and Cohen, 2011).

The combination of tucupi and jambu as a cover sauce for canned fish is an alternative in offering a product with different characteristics from conventional canned products available on the market. Therefore, the objective of this study was to develop canned fish from different species, sardines (*C. edentulus*), white mullet (*M. curema*) and king weakfish (*M. ancylodon*) with *tucupi* and *jambu* (*A. oleracea*) sauce, besides performing sensory, microbiological and proximate analyses of the product.

MATERIALS AND METHODS

Raw material

Five grams of each species of king weakfish (M. ancylodon), white mullet (M. curema) and sardines (C. endentulus), obtained in the municipal market of Bragança-PA was used. The fish were immediately stored in coolers with ice in the proportion of 1:1 and sent to the Fish Technology Laboratory (LATEP) at the Federal University of Para campus - Bragança. Each species was properly classified following its identification key. Also, 8 L of *tucupi* and three packs of *jambu* (*A. oleracea*), were used referring to the cover sauce, purchased at local shops.

Treatment of raw material and sterilization

The fish processing follows the fish gutting, scaling, heading and removal of fins, according to SDA Normative Instruction nº 22 of 11/07/2011 (IBAMA, 2011). The fish, in the form of a clean stem, were roasted for 15 min in a conventional oven at 250°C to minimize exudate. 200 g of fish were placed in 330 ml cylindrical glass containers. After that, the cover sauce was added at a temperature of about 80°C, performing exhaustion inside the container, and then the manual resealing of the container was made.

To prepare the topping sauce, tucupi was seasoned and boiled for 30 min to reduce free cyanides that might have been left from the fermentation process of its production, and the jambu was dehydrated at 70°C to its constant weight.

Autoclave sterilization time was 15 min at 121°C, applied to 15 containers, five for each treatment, where one container was quarantined for 30 days for microbiological analysis, one container for proximate analysis and three containers for sensory analysis. The thermal sensitivity of the glass did not allow thermal shock after sterilization. The products were stored at room temperature for further analysis.

Sensory analysis

Sensory analysis were performed at the fish technology laboratory campus - bragança, with 40 untrained tasters, using the 9-point hedonic scale test (scale ranging from very much disliked to very much liked), distributed in disposable plates with random markings, with the objective to evaluate the acceptability of the product (Instituto Adolfo Lutz, 2008).

Table 1. Sensory analysis, acceptance test, purchase intention analysis and frequency of canned consumption.

Attribute	Treatments		
	King weakfish	White mullet	Sardine
Appearance	7.50	7.25	7.50
Color	7.23[a]	7.25[a]	8.00[b]
Aroma	7.58	7.53	7.50
Flavor	8.15	8.08	8.03
Texture	7.68	7.65	7.80
A.G	7.73	7.70	7.90
IA (%)	85.83	85.56	87.78
Purchase Intent	3.97	4.02	4.07
Consumption frequency	5.42	5.17	5.42

Different letters on the same line differ from each other by the Tukey test ($p<0.05$). IA = acceptability index; AG = global acceptance.
Source: Authors

A consumption frequency and purchase intent test was applied. The frequency of consumption with seven options, ranging from one (would never eat this) to nine (would eat this always) and the purchase intention test with five options, ranging from one (certainly would not buy) to five (would certainly buy), methodology proposed by the Adolfo Lutz Institute (2008). The acceptability index was obtained by the formula using the average global acceptance (g.a) (Dutcosky, 2015):

Ai (%) = average g.a × 100 / maximum product rating

Microbiological analysis

Microbiological analyses were performed at the Microbiology Laboratory, Faculty of Food Engineering, Federal University of Pará-Belém. Coliforms were analyzed at 45°C coagulase positive *Staphylococcus* and *Salmonella* spp., with added *Clostridium* sulfite reduction analysis at 46°C, the most dangerous canned bacteria, due to its higher resistance to acid pH, superior than 4.6 (Evancho et al., 2009; Gava et al., 2008).

Physicochemical analysis

The centesimal analyses were performed at the Microbiology Laboratory, Faculty of Food Engineering, Federal University of Pará-Belém, according to AOAC methods (AOAC, 1990).

After the quarantine period, the samples were submitted to pH analysis at room temperature (25°C) in bench pH meter. The total titratable acidity of *tucupi* was obtained by the titration methodology with 0.1N NaOH (sodium hydroxide) solution, using phenolphthalein as an indicator (Instituto Adolfo Lutz, 2008).

Statistical analysis

Sensory analysis, frequency of consumption and purchase intention data were submitted to the Shapiro-Wilk and Bartlett test to verify the assumptions of normality and homoscedasticity, respectively. Subsequently, treated by one-way ANOVA, where the values that obtained significant difference were submitted to Tukey's post hoc test, considering the significance level of 5%. Statistical analyzes were performed using Statistica 7.0 software.

RESULTS

The results of the sensory analysis demonstrate that only the color attribute presented significant differences between the treatments, being the sardine, the one that obtained the best result (Table 1).

The average values of all attributes (except for Purchase Intent and Consumption Frequency) were higher than 7, showing good acceptance of the product, with emphasis on the “flavor” attribute, which obtained an average of 8.00 for sardines. For the attributes “G.A” and “AI%” the treatment of canned sardines obtained better average among the others, values that also reflect the purchase intention, where sardines stand out, but not enough to significantly vary from other treatments.

The results related to sensory analysis for king weakfish registered comments regarding the improvement of “appearance” and “color”, with five (12.5%) comments inherent to this attribute. The white mullet obtained three (7.5%) comments on improving bone consistency. There were no significant comments for sardines.

The results of the microbiological analyses were presented in accordance with current legislation, resolution - RDC nº 12, of January 2, 2001, of the National Health Surveillance Agency - ANVISA (ANVISA, 2001) (Table 2).

The pH value obtained was 4.4 and the total titratable acidity was 5 mEq NaOH/100 mL, this value is within the established standard for canning, similar to those found by Chisté et al. (2007).

The values of the proximate analyses of the preserves fit the values for this product with the use of fish, especially carbohydrate, which in the treatment of king weakfish obtained an average of 4.24%, being superior to the other treatments. The averages of proteins, lipids and energy value also had great variation, where the canning of white mullet stood out among the others, with average

Table 2. Microbiological analysis of King Weakfish, White Mullet and Sardine canned.

Analysis	Sample			Legislation (ANVISA, 2001)
	King weakfish	White mullet	Sardine	
Salmonella	Absent	Absent	Absent	Absent
Staphylococcus	< 10 CFU/g*	< 10 CFU/g*	< 10 CFU/g*	Max 10^3 CFU/g*
Coliforms at 45°C	< 3 MPN/ml**	< 3 MPN/ml**	< 3 MPN/ml**	Max 10^3 MPN/g*
Clostridium	< 10 CFU/g*	< 10 CFU/g*	< 10 CFU/g*	-

*Colony-Forming Unit. **Most probable number.
Source: Authors

Table 3. Centesimal characterization of King Weakfish, white mullet and sardine canned.

Variable (%)	Sample		
	King weakfish	White mullet	Sardine
Moisture	70.34	71.24	76.73
Protein	16.34	19.07	17.36
Lipids	6.72	7.15	1.55
Ashes	2.36	1.66	3.30
Carbohydrates	4.24	0.88	1.06
Energetic value (Kcal)	142.80	144.15	87.63

Source: Authors

values of 19.07, 7.15 and 144.15 Kcal, respectively (Table 3).

DISCUSSION

The mean values obtained by the sensory analysis were positive, being all attributes higher than seven, showing a good acceptance of the product, considering that values with averages higher than seven fit between "liked moderately" and "liked very much". However, the “flavor” attribute, which stood out with an average of more than eight, was classified as “very liked” and “extremely liked”, higher than those obtained by Hautrive et al. (2008) in themaking of ostrich burgers, *Struthio camelus* (Linnaeus, 1758). The AI value obtained a satisfactory value, all greater than 80%, better averages than all jundiá canned treatments, *Rhamdia quelen* (Quoy and Gaimard, 1824), produced by Cozer et al. (2014), who obtained the average value of AI = 85.20%.

The variation of sardines in AI (87.78%) may possibly be due to the wide commercialization of canned sardines in the Brazilian national market, which may generate a greater familiarity with the organoleptic characteristics of the species in relation to the others. However, the small size of the species having a maximum catch size of 16 cm (Espírito Santo et al., 2005) in the coast of Pará, hinders its processing, being a species very sensitive to physical damage and its seasonality are factors that may make unfeasible its production at the industrial level.

The treatment of king weakfish differed significantly in color, mainly due to the fragility of fish muscle tissue, which has high sensitivity to heat treatment, reducing the resistance of the meat as a function of the heat exposure time (Alfaro et al., 2004).

This muscular fragility allowed fragments of fish musculature to be suspended in the glass container, which affected the visual appearance of the king weakfish conserves, resulting in comments inherent to improvements of these attributes. Such factors may also make their production unfeasible at the industrial level.

The white mullet presented greater resistance of its bones, which could be observed by the comments of the tasters, showing that the heat treatment in autoclave could be extended in time to obtain the best texture of the bones.

Tucupi, as a topping sauce, is part of the Amazonian gastronomy and is closely related to the cultural factors of this region and its indigenous roots; its production is artisanal and without standardization, as evidenced in the work of Chisté et al. (2007). This fact may affect the judgment of the tasters and the values of centesimal analyses, which justify the comments regarding the addition of pepper to the dressing and the variation of carbohydrates between treatments.

The *jambu* retained, in part, its consistency and texture, but the dormancy characteristic of the species was reduced, which was reported by only one taster (2.5%). It is necessary to apply a more suitable method for the pre- treatment of *jambu*, which maintains the maximum of its characteristics, since, in previous tests for canning production, it was noted that jambu in natura had undesirable organoleptic characteristics in relation to dehydrated *jambu*, as texture and taste. Using bleached *jambu* is an alternative to be tested.

The purchase intention value of the three preserves produced in the present study was higher than the two values recovered for conservation of jundiá in steak and vegetable oil (3.47) and conservation of jundiá fillet with vegetable oil (3.40). The frequency of consumption values was close to the preserved values of jundiá in steak in tomato sauce (4.43), which was the treatment that showed the best recovery in his experiment (Cozer et al., 2014).

The products based of meat, fish, egg and cooked similar must have a maximum microbial count for coagulase positive Staphylococcus and Sulfite-Reducing Clostridium up to 10^3 CFU/g and absence of Salmonella spp., according to the Resolution RDC nº 12/2001, of the National Health Surveillance Agency (ANVISA, 2001). Therefore, the canned fish evaluated are in accordance with current legislation, with a standard product safe for human consumption. Similar studies evaluated the microbiological quality of canned anchoita (*Engraulis anchoita*) in tomato sauce and found absence of *Salmonella* spp., coagulase positive *Staphylococcus* ($<1\times10^3$ CFU/g) and sulfite-reducing Clostridium ($<1\times10^3$ CFU/g) (Carvalho et al., 2013). Similar results were evidenced for canned jundiá (R. quelen) (Cozer et al., 2014). For tilapia, *Oreochromis niloticus* (linnaeus, 1758), heat treatment at 121°C proved to be effective in inactivating microorganisms (Pizato et al., 2012). The processing steps used were adequate and within hygienic-sanitary standards to avoid contamination of the final product, in this way the topping sauce can be applied to these fish species.

The moisture content of all elaborated products was lower than the raw material, mainly due to the preprocessing step in the oven, the same was evidenced by Nhavoto et al. (2018) in the canning process of tambaqui, *Colossoma macropomum* (Cuvier, 1918), to *tucupi* sauce, with the application of three distinct temperatures, finding an average of 71.29% of humidity. In general, fish moisture ranges from 70.34 to 76.73, described by Ogawa and Maia (1999).

The protein levels found in the present study were high in relation to canned tilapia, with oil as a cover sauce, which obtained a protein content of 12.20% (Pizato et al., 2012); this effect is not related to the cover sauce content, but to the processed species and factors such as habitat, diet, sex and ontogeny of the processed individuals. Some authors have reported that *tucupi* used as a cover sauce in the canning of tambaqui did not influence the increase in protein values up to 20.98% (Nhavoto et al., 2018), since this sauce contains low protein, between 0.33 and 0.66% (Chisté et al., 2007).

The canned of king weakfish and white mullet, with lipid content of 6.72 and 7.15, respectively, are considered semi-fatty fish (between 2.5 and 10%) while sardines, with lipid content of 1.55, is considered a lean fish (up to 2.5%), according to the classification of Contreras- Guzmán (1994). These values were below the 24.75% found for canned jundiá; such values may come from the composition of the vegetable oil present in this sauce (Cozer et al., 2014). High lipid concentrations may influence product shelf life, impair its value and reduce consumer market acceptance (Bombardelli et al., 2008; Soares et al., 2012).

Regarding the ash content, the values obtained in this work are compatible with those reported for canning of tambaqui, with values from 0.72 to 2.52% (Nhavoto et al., 2018). For jundiá canning, there is a record of 0.24 to 2.00% of ash (Cozer et al., 2014), where such variations are related to the presence of bones contained in the samples.

Regarding to carbohydrate values, they are commonly very low in fish, ranging from 0.3 to 1% (*Ogawa* and Maia, 1999). However, the presence of tucupi and jambu in canning topping sauce validated the relevance of this nutritional factor. The cover sauce had a direct influence on the carbohydrate concentration in the product, considering that only the treatment with the white mullet was within the estimated standard for fish, with a value of 0.88. Such variations in carbohydrate values occur mainly due to the lack of standardization in *tucupis* commercialized in the region - as evidenced by Chisté et al. (2007) and the carbohydrate-rich composition of *jambu* (Favoreto and Gilbert, 2010; Barbosa et al., 2016).

Conclusion

The conserves prepared with the target species of fishing in the northern region (king weakfish, white mullet and sardine) with tucupi and jambu sauce showed good values of global acceptance and acceptability index higher than 87%. The thermal method was effective in inactivation of microorganisms, because the results of microbiological analysis are in accordance with the standards required by legislation, ensuring safety and food safety. The proximate analysis, with average content of 17.59% protein and 5.14% lipid, confirms the nutritional quality of the elaborated product.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Interference of cultivar and ways of cultivation in lettuce (*Lactuca sativa*) yield and conservation

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This study aimed to measure the yield and postharvest conservation of three lettuce varieties (Crisp, Mimosa, and Iceberg) grown in two different cultivation systems (Conventional and Hydroponic) and stored under two conditions (Ambient temperature and Refrigerated). The experiment used a randomized design with tree factors (cultivars, cultivation systems and storage types) and 4 repetitions. The samples were collected randomly, in the city of Francisco Beltrão-PR, Brasil, from a local producer. The yield (head diameter, leaf size, number of leaves, stem length and fresh weight), the physicochemical characteristics (moisture, ash, soluble solids, pH, titratable acidity, fiber, vitamin C and nitrate), and post-harvest conservation (color/darkness and occurrence of post-harvest rots) were evaluated. The results showed that lettuce from conventional cultivation had the highest yield. The physicochemical parameters presented different behaviors related to cultivars and cropping systems. The lettuce of conventional cultivation presented higher content of minerals (ash) and vitamin C. On the other hand, the hydroponic cultivation proved to be more efficient in post-harvest conservation. The refrigerated environment proved to be more suitable for the conservation of vegetables, since they presented a better overall appearance. Storage at ambient temperature, in turn, contributed to greatest deterioration of the plants.

Key words: Lettuce, cultivation systems, cultivate, pos-harvest conservation, fresh produce, refrigerated.

INTRODUCTION

Lettuce (*Lactuca sativa* L.) is a vegetable belonging to the Asteraceae family, cultivated since ancient times by the Asians (Queiroz et al., 2017) and brought to Brazil by the Portuguese in the 16th century (Da Silva et al., 2007).

It is one of the most important vegetables cultivated in Brazil (Sala and Costa, 2012), and can be grown in conventional, organic, and hydroponic systems.

The production of lettuce depends on the interaction between genotype and environmental conditions, that is, they respond differently to the practices and means of cultivation, which determines the quality of the vegetable (Zárate et al., 2010). The cultivation methods employed for lettuce production, the most widely used today are conventional planting (soil) and the hydroponic system (NFT-nutrient film technique).

Conventional planting is a system of lower cost to the producer because it uses less water, energy, and labor. However, it becomes necessary to control the physical and chemical conditions of the soil for the correct nutritional supply to the plant, besides the incidence of diseases and pests (Arbos et al., 2010; Henz and Suinaga, 2009). Hydroponic cultivation provides greater plant uniformity and quality, requires less physical space, and provides high productivity, allowing for better commercial exploitation throughout the year (Bhering et al., 2019).

Commercially, lettuce is classified as Iceberg lettuce, Crisp, Smooth, Virella lettuce (Mimosa) and Romaine (Trani et al., 2005), with the crisp and the smooth types being the best known and consumed in Brazil. The iceberg lettuce is characterized by the formation of leaf clusters (head), leaves with greater thickness and crispness (Mota et al., 2002; Sala and Costa, 2012; Yuri et al., 2004). It is used by the minimal processing industry and fast food chains for its texture and flavor, and for presenting good postharvest conservation, resistance to transport and handling (Hotta, 2008). The Crisp lettuce is the most commercialized, it has leaves with curly edges, does not form heads, is easy to handle, and is adapted for summer cultivation (Demartelaere et al., 2020). The Virella (Mimosa lettuce), on the other hand, presents well-cut, delicate, and creepy-looking leaves (Souza et al., 2021).

In addition to green coloration, it can be found in red and purple coloration that indicates the presence of anthocyanins (Rosa et al., 2014; da Silva Santana et al., 2009), compounds beneficial to health. Independent of the variety, in general, lettuce has a fragile physical structure, sensitive to dehydration and aging, and has a limited shelf life (Moraes, 2006). They are susceptible to variations in temperature and light, factors that have an effect on the absorption of nutrients and directly influence conservation (Bezerra Neto et al., 2005).

Postharvest preservation varies with the type of vegetable, good conditions for transport, storage, distribution, and marketing are as important as producing well. Thus the choice of post-harvest conservation techniques is necessary to avoid incorrect handling and the problems arising from inefficient transport and storage (Rosa et al., 2018).

Vegetables have different behaviors in front of cropping systems, post-harvest practices. Depending on the cropping system and climatic conditions, lettuce leaf nitrate contents can vary (Bourn and Prescott, 2002; Woese et al., 1997). In addition, the nutritional composition of vegetables can be affected by fertilizers. It comes to nutrient mineralization, due to the interaction conditions in the growing medium (soil/substrate), dosage, and application time (Cheynier et al., 2013; Chiomento et al., 2019; Lee and Kader, 2000).

One of the problems in postharvest one of the challenges is the low preservability of lettuce. The speed of lettuce deterioration increases rapidly at temperatures above 0°C. The shelf life of lettuce at 3°C is only 50% of the shelf life at 0°C. In storage, however, the temperature can never be lower than -0.5°C, because in this case freezing and deterioration of the product occurs (Moraes, 2006). Thus, in postharvest, the application of refrigeration technologies is a good option to slow the speed of these changes, increasing the shelf life and consequently the time of commercialization (Teruel, 2008).

Vegetable deterioration occurs naturally in the post-harvest life, by the respiratory process. However, the damage caused by manipulation or microorganisms, mainly with rupture in the tissues promote the acceleration of metabolic activity, which results in physiological alterations and increase in respiration speed (Mello et al., 2003). In this sense, the quality alterations in post-harvest are directly linked to the oxidative chemical and biochemical processes. In the cell wall structure, they affect components of the primary cell wall, such as cellulose, pectin and hemicellulose, compromising the texture. From the sensory point of view, it causes off-flavor formation, discoloration, and browning (Mello et al., 2003).

In addition, aerobic to anaerobic processes contribute to the formation of aldehydes and ketones favoring the appearance of off flavor. The loss of green color is due to the degradation of chlorophyll by chlorophyllase (a native enzyme) (Streit et al., 2005). Enzymatic and non-enzymatic browning accelerates the appearance of pinkish, brownish, or blackish colors, influenced by storage conditions, compromising postharvest visual quality. At this stage, degradation of nutritional compounds also occurs, as well as the growth of pathogenic bacteria (Flores, 2010).

Considering the aforementioned, the present study aimed to measure the yield and postharvest conservation of lettuce (Crisp, Mimosa and Iceberg lettuce) at room

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temperature and refrigerated from conventional and hydroponic growing systems.

MATERIALS AND METHODS

Lettuce samples were used from three cultivars Lucy Brown (Iceberg lettuce), Vera (Crisp lettuce) and Virella (Mimosa lettuce) grown in two different production systems, conventional and hydroponic, in a rural production unit (rural farm company) in the municipality of Francisco Beltrão-PR-Brasil.

Conventional cultivation system

After 25 days of sowing (commercial seeds-trademark with rights reserved), the plantlets were transplanted to the cultivation area. Spacing of 0.30 × 0.30 m was used. Irrigation of its drip was done during the growth cycle according to need. The soil was prepared with recommended fertilizer dosage of 1600 kg/ha of the formulations 04-14-08 (NPK-Nitrogen, Phosphorus and Potassium) and 1000 kg/ha of simple superphosphate. Subsequently, at 20 and 40 days after transplantation, a dose of topdressing fertilization was applied, urea (40 kg/ha N) and potassium chloride (85 kg/ha K) (Mota et al., 2002; Queiroz et al., 2017; Yuri et al., 2004).

Hydroponic cultivation system

The hydroponic system was performed in an Nutrient Film Technique (NFT) in greenhouses covered with 200 μm polyethylene with anti-UV-A and UV-B treatment. The benches inside the structure had the following measurements 1.25 m wide and 6 m long gutters. The spacing of each gutter was 25 cm, totaling 5 gutters. The slope was 2%. To feed the system, a 1.0 hp motor-pump set was used. The flow rate of each channel was 1.5 L/h. The nutrient solution used was commercial with pH corrected to 5.8±0.5 to obtain a conductivity of 1.7 mS cm^{-1}. The system used was intermittence of 10 min between recirculations.

Sample collection

The vegetables were collected 55 days after planting, when they reached the maximum vegetative development, before starting the fixation process. This facilitates standardization of harvesting and comparison. The harvest was performed randomly for both cultivation systems. This procedure was carried out moment of milder temperature (early morning hours). The samples were immediately transported in plastic boxes under refrigeration to the Laboratory of Fruit and Vegetable Technology of the Federal Technological University of Paraná - Campus Francisco Beltrão. The laboratory has a structure for refrigerated storage, conservation simulations and for necessary post-harvest evaluations.

A completely randomized experimental design (CRD) was used, in factorial scheme 2×3×2 with 2 cultivation systems (Conventional and Hydroponic), 3 cultivars (Lucy Brown, Vera and Virella) and 2 types of storage (Ambient temperature and refrigerated) with 4 repetitions, each repetition was composed of 3 plants. The post-harvest preservation conditions are commercial refrigeration conditions (simulation, ±8°C) and at room temperature (±23°C) for 7 days.

Physical and physicochemical

Head diameter was measured individually with the aid of a pachymeter and expressed in centimeters (cm). Fresh weight determination was performed with the aid of an analytical balance and the weight expressed in grams of fresh matter ($g.plant^{-1}$). Total leaf count was obtained by manually counting the number of leaves of each vegetable ($Unit.planta^{-1}$). Leaf length and stem length were measured using a pachymeter and expressed in centimeters (cm).

Soluble solids was determined in °Brix using a portable refractometer (Vodex - Model RTA-80). pH and titratable acidity (TA) were performed according to Adolfo Lutz Institute (IAL, 2008). The pH was determined using a previously calibrated bench top digital potentiometer. Total titratable acidity (TA) was measured volumetrically by titration of 5 g of pulp, homogenized in 50 mL of distilled water with 0.1 $mol.L^{-1}$ NaOH until the turning point was reached. Acidity was expressed in %.

The crude fiber, moisture and ash content were done according to Association of Official Analytical Chemists (AOAC, 2016) method. Moisture and ash content were carried out gravimetrically. For this, 5 g of each sample was dehydrated in an oven at 105°C until constant weight to obtain the moisture content. After this analysis, the samples were placed in a muffle furnace at 600°C until a light ash was obtained to determine the ash content. Crude fiber was measured by acid digestion of the defatted, desiccated sample (1.25% sulfuric acid) for 30 min, followed by an alkaline digestion (1.25% sodium hydroxide) for another 30 minutes, the total fiber being determined gravimetrically after incineration of the residue. Vitamin C was determined volumetrically by the iodometric method, using starch as an indicator, titrating the solution with potassium iodate (IAL, 2008). Nitrate content was obtained from a nitrite analysis by UV/VIS spectrophotometry at 450 nm where the sodium nitrate concentration (mg/kg) was obtained by multiplying the nitrite by 1.231 (IAL, 2008).

In addition to the objective analyzed in this study, the visual and/or appearance aspects were evaluated. For this analysis, the following parameters were adopted: fresh/wilted product; color change/darkening; and absence/occurrence of intense rot. This evaluation did not aim to establish a scale, but to assist in the description of the results and discussion.

Statistical analysis

The data was submitted to analysis of variance by the -F test ($P<0.05$), (ANOVA) and the means were compared by the Tukey test ($P<0.05$) using Statistical Package's (STATSOFT INC, 2004; Jamovi, 2022).

RESULTS AND DISCUSSION

The yield of vegetables is directly related to the species, cultivar, and cultivation system. The results of the yields of Crisp lettuce (Vera), Virella lettuce (Mimosa) and Iceberg lettuce lucy Brown) grown in conventional and hydroponic systems are presented in Table 1.

Head diameter, according to Martins et al. (2017), is a very important characteristic in the choice and marketing of vegetables. In this study, the highest mean head diameters were observed in the cultivars Vera and Virella ($P>0.05$) with mean values of 28.33 and 26.00 cm, respectively. The cultivar Lucy Brown averaged 18.83 cm, being lower ($P<0.05$) than the others analyzed.

There was no significant difference ($P>0.05$) between conventional and hydroponic environments. When unfolding the interaction, the only cultivar that showed a difference between the environments was Lucy Brown,

Table 1. Morphological characteristics of Crisp lettuce (Vera), Virella lettuce (Mimosa) and Iceberg lettuce (Lucy Brown) grown in conventional and hydroponic systems.

Variable	Cultivation system (CS)	Cultivars/Groups			Mean (Cultivar)	F Value			CV (%)
		Lucy Brown (Iceberg lettuce)	Vera (Crisp lettuce)	Virella (Mimosa lettuce)		CS	C	CS×C	
DC	HS	21.66^{Ab}	25.66^{Aa}	27.66^{Aa}	25.00^{A}	2.81*	65.58*	9.37^{*}	6.34
	CCS	16.00^{Bb}	26.33^{Aa}	29.00^{Aa}	23.77^{A}				
Mean (Cultivation system)		18.83^{B}	26.00^{A}	28.33^{A}					
PF	HS	191.00^{Ba}	193.33^{Ba}	184.66^{Bb}	189.66^{B}	2.600*	572.00*	398.00*	1.24
	CCS	272.00^{Ab}	296.00^{Aa}	200.66^{Ac}	256.22^{A}				
Mean (Cultivation system)		231.50^{B}	244.66^{A}	192.66^{C}					
NF	HS	17.33^{Ab}	18.33^{Ab}	35.66^{Aa}	23.77^{A}	46.28*	50.96*	41.47*	9.00
	CCS	16.33^{Aa}	18.66^{Aa}	18.33^{Ba}	17.77^{B}				
Mean (Cultivation system)		16.83^{B}	18.50^{B}	27.00^{A}					
CF	HS	21.66^{Aa}	22.00^{Aa}	16.66^{Ab}	20.11^{B}	26.88*	0.61^{ns}	10.64*	8.49
	CCS	21.66^{Aa}	21.33^{Aa}	24.66^{Ba}	21.55^{A}				
Mean (Cultivation system)		21.66^{A}	21.66^{A}	20.66^{A}					
CC	HS	12.00^{Aa}	6.00^{Ac}	10.00^{Bb}	9.33^{B}	20.05*	81.72*	17.05*	2.27
	CCS	12.00^{Ab}	6.33^{Ac}	16.00^{Aa}	11.42^{A}				
Mean (Cultivation system)		12.00^{B}	6.16^{C}	13.00^{A}					

CS: Cultivation system; CCS: conventional system; HS: hydroponic system; C: cultivar; DC: head diameter (cm); PF: fresh weight (g $plant^{-1}$); NF: number of leaves (units $Plant^{-1}$); CF: sheet length (cm): CC: stem length (cm). Uppercase letters in columns and lowercase letters in rows differ from each other by Tukey's test (P<0.05).

with a difference of 35.37% in head diameter, being larger in the hydroponic system than in the conventional. The cultivar Lucy Brown has shown better adaptability for hydroponic system. When unfolding the behavior of cultivars as a function of environments, both cultivars Vera and Virella were superior to Lucy Brown in both systems.

In the hydroponic environment, cultivars Virella and Vera were superior to Lucy Brown at 27.70 and 18.46%, respectively. In the conventional environment, both Virella and Vera were superior to Lucy Brown by 81.25 and 64.56%, respectively. However, with the data presented, it is observed that both cultivars were better adaptable to conventional growing conditions. The hypothesis accepted for the low development of head diameter may be related to the electrical conductivity of the materials. According to Costa et al. (2001) the increase in electrical conductivity in lettuce cultivation results in a lower vegetative development. This increase in the diameter of the head in conventional cultivation is interesting from a commercial point of view because it increases the volume of material sold.

In relation to the fresh weight, a significant independent effect was observed for environment, cultivars and the interaction between both. In relation to the environment, the CCS was superior on average about the environment HS with an increment of 74%. About cultivars, Vera (Crisp lettuce) was superior to Lucy Brown (Iceberg lettuce) and Virella (Mimosa lettuce) with averages of 244.66, 231.50 and 192.66 g $plant^{-1}$, respectively. When unfolding the cultivars within each environment, they were all superior in fresh weight in CCS. In HS, Lucy Brown and Vera were superior to Virella but did not differ (P>0.05). In CCS, the behavior was different among the cultivars with the higher average for the Vera cultivar followed by Lucy Brown and Virella, respectively. This difference between the genotypes and the environmental behavior (salinity, fertility, temperatures, humidity, light intensity, among others) can directly influence the performance of the species (Blind and Silva Filho, 2015).

The number of leaves is an important attribute from the point of view of consumer presentation and is related to the adaptation of the genetic material in the environment (Diamante et al., 2013). Regarding the number of leaves, there was a significant difference (P<0.05) between environments, cultivars and the interaction between both. Among the environments, the H system showed higher average compared to CA for Virella, while it is not different statistically (P>0.05) for varieties Lucy Brown and Vera. As for cultivars, the highest number of leaves was for Virella (P<0.05), followed by Lucy Brown and Vera, which are not different (P>0.05). Souza et al.

Table 2. Physicochemical characteristics of Lucy Brown (Americana), Vera (Crespa) and Virella (Mimosa) lettuce grown in conventional and hydroponic systems.

Variable	Cultivation System (CS)	Cultivars/groups				F Value			CV (%)
		Lucy Brown (Iceberg lettuce)	Vera (Crisp lettuce)	Virella (Mimosa lettuce)	Mean (Cultivar)	CS	C	CS×C	
pH	HS	6.22	6.11	6.08	6.14	0.02^{ns}	0.86n^{s}	0.49^{ns}	1.95
	CCS	6.15	6.10	6.14	6.13				
Mean (cultivation system)		6.19	6.10	6.11					
TA (%)	HS	1.00	1.00	1.00	1.00	0.05^{ns}	0.05^{ns}	0.05^{ns}	22.33
	CCS	1.00	1.33	1.00	1.11				
Mean (cultivation system)		1.00	1.16	1.00					
SS (ºBrix)	HS	4.00^{Aa}	4.00^{Aa}	4.00^{Aa}	4.00^{A}	0.0001*	0.0001*	0.0001*	0.00
	CCS	4.00^{Aa}	3.00^{Bb}	3.00^{Bb}	3.33^{B}				
Mean (cultivation system)		4.00^{A}	3.50^{B}	3.50^{B}					
Moisture (%)	HS	93.66^{Aa}	93.33 ^{Aa}	93.33^{Aa}	93.44^{A}	1.50^{ns}	2.16^{ns}	0.50^{ns}	0.62
	CCS	93.33^{Aa}	93.66^{Aa}	93.33^{Aa}	93.77^{A}				
Mean (cultivation system)		93.50^{A}	94.00^{A}	93.33^{A}					
Ash ($g.100g^{-1}$)	HS	1.35^{Aa}	0.48^{Bc}	1.03^{ABb}	0.67^{B}	643.08*	288.54*	29.81*	4.30
	CCS	1.08^{Aa}	1.03^{Aa}	0.44^{BCc}	1.13^{A}				
Mean (cultivation system)		1.12^{A}	0.74^{B}	0.75^{B}					

TA: Titratable acidity; SS: soluble solids; CS: cultivation system; CCS: conventional system; HS: hydroponic system; C: cultivar. Uppercase letters in columns and lowercase letters in rows differ from each other by Tukey's test (P<0,05). ns: Not significant.

(2021) did not observe differences in the number of leaves as a function of environments for the cultivar Veronica (Crisp). Possibly the difference observed in this study is related to the temperature factor because in milder regions the development of lettuce is better because high temperatures influence the precocious setting of the leaves, thus reducing the number of leaves.

Regarding the length of the leaves, there was a significant difference (P<0.05) only between the environments for the variety Virella, as well as in the interaction between both. For Virella, the leaf length was greater in the CCS when compared with the HS (Table 1). Among the cultivars evaluated, the interaction was only observed in the cultivar Virella (mimosa). Another interesting factor observed is that Virella has adapted better to open field conditions. This cultivar is influenced by the electrical conductivity of the medium, which interferes with growth and development, thus reducing leaf length.

Stem length differed statistically (P<0.05) among cultivars and for Virella it differed also in the cultivation system, showing larger stem size in the CCS. This same observation was reported by Martins et al. (2017) for Rubra and Cristal cultivars grown in conventional, hydroponic, and organic systems.

In general, it was observed that the variety Virella (mimosa) showed the greater influence on the cultivation system, having greater numbers of leaves, however smaller size. The cultivation system influenced the yield in mass (g) of the vegetables, being lower in the hydroponic system, which reflected in the amount of ash in the samples (Table 2). This lower mass yield may be related to extrinsic and intrinsic factors, such as production factors (climate, soil, water, production system), and genetic characteristics of the vegetable (Blind and Silva Filho, 2015). Crops grown directly in the soil undergo cultural treatments that induce greater nutrient uptake and dry matter production (Zárate et al., 2010). Moreover, the differences between cultivars demonstrate the plants' ability to self-regulate in relation to the interaction genotype and growing medium (Freitas et al., 2007). This behavior is observed in other studies that deal with different cultivation systems (Merlini et al., 2018; Santana et al., 2006). Also, low tunnel-protected soil cultivation favors the growth and yield of American lettuce cultivars more than the open field system (Brzezinski et al., 2017), while other cultivars show similar growth and yield in both growing conditions.

Physicochemical characteristics

The physicochemical variables of lettuce belonging to the cultivars Lucy Brown, Vera and Virella are presented in

Table 3. Fiber, vitamin C and nitrate content of lettuce Lucy Brown (Iceberg lettuce), Vera (Crisp lettuce) and Virella (Mimosa lettuce) cultivated in conventional and hydroponic systems.

Variable	Cultivation system (CS)	Cultivars/Groups				F Value			CV (%)
		***Lucy Brown* (Iceberg lettuce)**	**Vera (Crisp lettuce)**	**Virella (Mimosa lettuce)**	**Mean (Cultivar)**	**CS**	**C**	**CS×C**	
Fiber (g.100 g^{-1})	HS	0.66^{Aa}	0.68^{Aa}	0.64^{Ba}	0.69^{A}	6.37*	7.93*	14.74*	3.84
	CCS	0.63^{Ab}	0.69^{Ab}	0.76^{Aa}	0.66^{B}				
Mean (cultivation system)		0.64^{B}	0.68^{A}	0.70^{A}					
Vit.C (mg.100 g^{-1})	HS	20.66^{Bb}	25.33^{Ba}	27.00^{Ba}	29.66^{A}	65.08^{*}	40.76^{*}	0.76^{ns}	5.19
	CCS	25.00^{Ab}	31.66^{Aa}	32.33^{Aa}	24.33^{B}				
Mean (cultivation system)		22.83^{B}	28.50^{A}	29.66^{A}					
Nitrate (g.100 g^{-1})	HS	0.18^{Aa}	0.16^{Ab}	0.13^{Bc}	0.15^{B}	37.48*	366.59*	714.42*	1.23
	CCS	0.17^{Ba}	0.13^{Bb}	0.18^{Aa}	0.16^{A}				
Mean (cultivation system)		0.17^{A}	0.14^{C}	0.15^{B}					

CS: Cultivation system; CCS: conventional system; HS: hydroponic system; C: cultivar. Uppercase letters in columns and lowercase letters in rows differ from each other by Tukey's test (P<0.05).

Table 2.

The pH, TA, and moisture values were not shown to be influenced by the cultivation systems, which is not different statistically (P>0.05), which is also described by other studies (Fontana et al., 2018; Martins et al., 2017; Ohse et al., 2009). Low acidity levels were observed for the varieties studied, and thus, they may be susceptible to deterioration by microorganisms (Beharielal et al., 2018), in addition to the sensitivity itself promoted by the intense respiratory process of the leaves.

The contents of soluble solids were influenced by the cultivation systems in all cultivars, being higher in hydroponic systems, especially for the Lucy Brown, reflecting the better balance of the nutritional medium. This variable, according to Andriolo et al. (2005) can be influenced, among other factors, by temperature, fertilization, luminosity and planting density. Different results to those found in this study for soluble solids were reported by da Silva et al. (2011) and Fontana et al. (2018).

Contrary to soluble solids (SS), ash contents were higher in the conventional production system, indicating that this type of vegetable tends to accumulate mineral compounds, present in the soil. Ash values intermediate (0.61 - 0.77 g.100 g^{-1}) to those found in the present study were presented by Ohse et al. (2009) in different lettuce cultivars produced by hydroponics. Kurubas et al. (2019), working with other cultivars describes a different behavior, where conventional cultivation showed higher contents of total soluble solids, titratable acidity and total phenolics.

The contents of fiber, vitamin C and nitrate present in the lettuce samples grown in conventional and hydroponic systems evaluated in the present study are presented in Table 3.

There was no significant difference (P>0.05) in the fiber content of the lettuce among the cultivars, except for the Virella cultivar which presented a higher amount for the conventional cultivation system. Fiber values lower than those observed in the present study (0.25 - 0.48 g.100 g^{-1}) were presented by Ohse et al. (2009) in different lettuce cultivars. According to these authors, a lower fiber content may be due to the cycle and growing conditions, and time of year.

Vitamin C content varied among cultivars, which is possibly due to the influence of physiology and antioxidant capacity of each species, as well as plant nutrition (Pereira et al., 2015). The lowest indices of vitamin C were presented by hydroponic cultivation (P<0.05), which may be related to the fact that Nitrogen (N) is readily available in the aqueous solution, which facilitates its absorption by the plant decreasing the accumulation of ascorbic acid in vegetables (Lee and Kader, 2000). Physiologically, plants are induced to increase proteins and carbohydrates at the expense of secondary metabolism compounds, such as ascorbic acid (Lee and Kader, 2000; Da Silva et al., 2007).

Nitrate indices showed variation among cultivars and different behavior in the cropping system. Previous studies (Beninni et al., 2002; Ohse et al., 2009; Rezende et al., 2017) with different lettuce cultivars, described similar values (0.13 to 0.18 g.100 g^{-1}) to those found in the present study. The hydroponic system tends to provide increases in nitrate indices, because the nitrogen fertilizer is supplied mainly in the form of nitrate dissolved in water, facilitating its absorption, which did not occur with the cultivar Virella in this study.

The recommended limit of daily intake of nitrate, without health risk, is 3.65 mg.day^{-1} per kg of body

A - Storage at ambient temperature for 4 days B - Refrigerated storage for 4 days

Figure 1. Visual of the lettuces stored at 4 days of post-harvest storage.

weight. FAO (2002) considering a person weighing 70 kg, the safe intake limit would be 255 mg. In our study, the NO_3^{-1} contents (Table 3) were significant for 100 g, and exceed the limits if we consider the fresh mass of the whole head (Table 1). Nitrate levels in lettuce vary with the season. The indexes considered acceptable for human consumption are not yet established in the Brazilian legislation, as occurs in Europe (Luz et al., 2008).

The application of nitrogen in pre-harvest was able to aid in the retention of color, ascorbic acid content and extended the shelf life of lettuce by up to 6 days (Mampholo et al., 2019; Peng and Simko, 2023; Simko, 2020). The higher ascorbic acid concentration coincided with a reduction in the onset of browning in the leaves of fresh cuts. In another study (Lei et al., 2018), it was observed that in hydroponic cultivation the application of exogenous Selenium (Se) increased the photosynthetic capacity of lettuce. The assimilation and transport of NO_3^{-1} were markedly increased, but decreased accumulation in leaves, as increased the activity of nitrate reductase (NR), nitrite reductase (NiR), glutamine synthase (GS), and glutamate synthase enzyme (GOGAT) (Bian et al., 2020a, b). In other words, exogenous Se shows a positive effect on reducing NO_3^- accumulation by regulating transport and increasing nitrogen metabolism enzyme activities in lettuce.

Post-harvest preservation

Appearance and shape are among the main quality attributes, denoting fresh appearance, acceptable color, and is free of defects. In lettuce, appearance is greatly influenced by defects arising from enzymatic browning, which is initiated by the oxidation of phenolic compounds, via polyphenol-oxidase (Mampholo et al., 2019; Peng and Simko, 2023). These reactions produce insoluble, brown-colored polymers, melanins, thus affecting visual quality and consequently reflecting on product quality.

Application of exogenous Selenium (Se) increased the photosynthetic capacity of lettuce. The assimilation and transport of NO_3^{-1} were markedly increased, but decreased accumulation in leaves, as Se increasing the activity of nitrate reductase (NR), nitrite reductase (NiR), glutamine synthase (GS), and glutamate synthase enzyme (GOGAT) (Bian et al., 2020a, b). Se shows a positive effect on reducing NO_3^{-1} accumulation by regulating transport and increasing nitrogen metabolism enzyme activities in lettuce. In the follow-up performed in our study, it was verified that the most effective losses of quality in the lettuce started at 4 days postharvest (Figure 1). In the experimental conditions tested, the lettuces in the hydroponic system presented better conservation of the characteristics of color, freshness, and lower leaf wilting index, both in storage at room temperature and in refrigerated conditions, even at 4 days of storage.

However, all samples submitted to refrigeration presented greater leaf wilting, considering that the refrigerated environment provided (commercial simulation), maintains lower relative humidity indexes. It is known that if we maintained adequate temperature and humidity levels, this effect would decrease (Yuri et al., 2005).

In the case of the lettuce that was left at room temperature, there was a greater yellowing of the leaves and the appearance of brownish pigments, described as russet spoting. This is a postharvest disorder that can develop during the transportation and storage of lettuce. This disorder is characterized by the appearance of numerous brown spots around the central vein of the leaves as a result of enzymatic browning.

At 7 days of storage (Figure 2), all lettuce had qualitative defects in coloration, freshness, and the

A - Storage at ambient temperature for 7 days B - Refrigerated storage for 7 days

Figure 2. Visual of the lettuces stored at 7 days of post-harvest storage.

occurrence of rotting, as expected.

The lettuces that were at room temperature stood out negatively for the appearance of browning and unpleasant flavor. The senescence of plant tissues is influenced by ethylene, which can increase membrane permeability. In lettuce, ethylene induces the activity of the enzyme phenylamine ammonia-lyase, which when associated with phenolic compounds can develop russet spotting. Another important enzyme is lipoxygenase, which catalyzes peroxidation reactions, causing the formation of foreign odors.

Besides the general quality of the product, these injuries or deteriorations can cause loss of commercial value and lead to public health risk, since the contaminating microbiota tend to increase at high temperatures, being a potential risk to consumers.

The conventional cultivated plants presented an almost complete deterioration, mainly for the Lucy Brown and Vera cultivars. On the other hand, it was found that lettuce grown in the hydroponic system showed less damage in conservation, with less deterioration mainly of the leaves of the inner parts, with bright colors and less degree of wilting. So, refrigerated storage was the determinant in the conservation of lettuce from both cultivation systems. The lettuce of both cultivars from hydroponic system maintained better quality until 4 days of storage, at a temperature of 23 and 23°C. At 7 days of storage in refrigeration, the lettuce from hydroponic system showed greater capacity to maintain quality. Freire Júnior et al. (2002) described results in hydroponic lettuces stored under refrigeration and at a temperature of 10°C, where on the third day of treatment the cultivars did not show significant differences in their structure, but after the seventh day the differences between the lettuces stored under refrigeration showed better results. The hydroponic cultivation system, as well as refrigerated storage systems, has been shown to have an important positive effect on the preservation of lettuce (Freire Júnior et al., 2002; da Silva Nascimento et al., 2017). So also, the organic production system is shown to have a positive effect, being more effective in extending the postharvest life and protects the quality of lettuce heads stored in modified atmosphere packaging (Kurubas et al., 2019).

Conclusions

The yield and physicochemical characteristics showed different behaviors related to the cultivars and the lettuce growing systems. Conventional cultivation resulted in higher rates of mineral content (ashes), vitamin C, and fresh mass. On the other hand, lettuce from hydroponic cultivation had a better performance than lettuce from conventional cultivation in terms of postharvest conservation. In a refrigerated environment, they had a better plant structure and a more satisfactory overall appearance, while at room temperature, the degree of deterioration was similar among the lettuces from both growing systems.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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