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Post-harvest management and quality evaluation for soursop (*Annona muricata*) in the province of Pastazaza

Manejo poscosecha y evaluación de la calidad de la guanábana (*Annona muricata*) en la provincia de Pastaza

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Abstract

The postharvest handling of *Annona muricata* L. has several critical points in its productive process. This fruit, having a tropical character, tends to ripen quickly and receive damages in its physicochemical and physiological structure, causing a decrease in its quality, so this review aimed to identify quality parameters, such as technological processes in postharvest in order to increase the shelf life, descriptive methodology based on the PRISMA method was used, having as results, that the information has more boom in 2019 and 2022, being America the point where more data have been collected on the postharvest of *A. muricata*, the optimum degree of maturity for harvesting is in ET3, while the evaluation of the organoleptic quality is based on factors such as size, colour, weight and hardness, the physicochemical evaluation with a moisture (81.16%), acidity, pH (4), ash and °brix (17.65), The physiological characteristics are linked to the production of ethylene, and for its preservation several methods can be implemented, such as the application of controlled atmosphere, thermal regulations, etc. In the province of Pastaza there is no record of production, but according to the data obtained, this fruit has a high productive potential. It is concluded that the most recommendable preservation methods are ethylene inhibitors combined with wax emulsion, applied at a concentration of 1-MCP of 1500 NLL-1 for 12 h, combined with candelilla or beeswax diluted in a ratio of 15:85 in H_2O in a storage of 16 °C and modification of atmospheres in flexible polystyrene trays at a temperature of 12 °C alternating with 14 °C in a storage room, leading to an increase of shelf life from 15 to 22 days.

Keywords: *Annona muricata*; soursop; management; postharvest; quality

Resumen

El manejo poscosecha de *Annona muricata* L., tiene varios puntos críticos en su proceso productivo, este fruto al poseer un carácter tropical tiende a madurarse con rapidez y recibir daños en su estructura físico-química y fisiológica, provocando la disminución de su calidad; por lo que, esta revisión tuvo como objetivo identificar parámetros de calidad, como procesos tecnológicos en poscosecha con la finalidad de aumentar su tiempo de vida útil. Se empleó metodología descriptiva basada en el método PRISMA, teniendo como resultados, que la información tuvo mayor auge en el 2019 y en el 2022, siendo América el punto donde más datos se han recopilado sobre la poscosecha de *A. muricata*, el grado de madurez óptimo para su cosecha se encuentra en ET3, mientras que la evaluación de la calidad organoléptica se basa en factores como el tamaño, color, biomasa y dureza, la evaluación físico-química con la humedad (81,16%), acidez, pH (4), cenizas y °brix (17,65), las características fisiológicas se encuentran ligadas a la producción de etileno y para su conservación se pueden implementar varios métodos como la aplicación de atmósferas controladas, regulaciones térmicas, entre otras. En la provincia de Pastaza no se tiene un registro sobre la producción, pero según los datos obtenidos este fruto posee un alto potencial productivo. Se concluye que los métodos de conservación más recomendables son los inhibidores de etileno, combinados con emulsión de ceras, aplicadas a una concentración de 1-MCP de 1500 NLL-1 durante 12 h , combinado con cera de candelilla o de abeja diluida en una relación 15:85 en H_2O, en almacenamiento de 16 ºC y la modificación de atmósferas en bandejas de poliestireno flexible a una temperatura de 12 ºC, alternando con 14ºC en un cuarto de almacenamiento, llevando a un aumento de vida útil de 15 a 22 días.

Palabras clave: *Annona muricata*; guanábana; manejo; poscosecha; calidad.

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Introduction

Soursoup (*Annona muricata* L.) is a tropical fruit from the Anonaceae family. It is know for being climacteric, for having a high respiration rate, and ethylene production, which causes rapid enzymatic activity that weakens the fruit makes the handling more difficult during the postharvest. In addition to its distinctive sensorial characteristics, like its color, smell, and taste, the soursoup has become a promising resource for vrious products, such as beverages, jams, ice cream and seasonings (Mendoza-Méndez et al., 2022).

A. muricata farming is a profitable source of local employment, especially for technologically advanced systems, resulting in yields of more than 3,5 tonnes per hectare per year (Álvarez et al., 2004). Nonethless, there are significant challenges, mainly related to plagues and diseases, such as the *Colletotrichum gloeosporioides* fungi, which causes up to 90% loss (Cambero et al., 2019).

Soursoup production is concentrated in tropical and subtropical areas, and Ecuador is one of the top producing countries. In particular, in the amazonian region, the provinces of Pastaza and Napo are important farming zones, although the exact production numbers are not well documented due to the lack of accurate data and managing techniques (Rochina, 2022).

At the national level, soursoup production has significantly risen, both for national and internationl commerce, reaching an estimated 2000 metric tons. However, the loss caused by inadequate handling during transport and storing may reach 50%,and this affects the quality of the product (Jiménez-Zurita et al., 2017).

This study aims to identify the quality parameters and technological processes in postharvest to increase the shelf life of soursoup in the province of Pastaza, where the available data is limited.

Materials and methods

The study was carried out with mixed, exploratory and non-experimental approach, through a literature review regarding the post-harvest handling of soursoup. The literature was selected from databases such as Google Scholar, Scopus, Scielo. The applied method was second order exploratory; a careful examination of literature from scientific databases.

The data selection was comprised of scientific papers, in english and spanish, published between 2004 and 2023. The selection criteria included the relevant keywords, the consistency of the data with the review, the source of the information, among others. Articles from previous years to analyze the variation of information through time, discarding duplicates and those that did not meet the eligibility requirements, like the lack of definitions, postharvest data management, and quality assessment for soursoup, using keywords such as: “soursoup” “post-harvest management”, “*Annona muricata*” and “quality”, and their combinations.

Results and Discussion

According to the research database, 23 documents were taken into account, including scientific articles and other relevant works on postharvest handling and quality evaluation of *A. muricata*, this compilation of bibliographic material according to the year of publication is shown in Figure 1..

Figure 1. Compilation of scientific articles by year on postharvest handling and quality evaluation of *Annona muricata.*

The information described in Figure 1 showed the number of scientific articles located in the network regarding postharvest handling and quality evaluation for soursop (A. muricata), where it can be seen that between the years 2002 to 2014 the information did not present variation, which determined a scarcity of data, and 2016 to 2018 a rise in the number of articles was noticed, in 2019 a growth of information was appreciated, for 2020-2021 a decrease in the number of articles was evidenced, in 2022 a growth of information was visualized and for the remainder of 2023 an increase in postharvest research and quality of A. muricata was estimated. The fluctuation of the data by region made it possible to determine how important the subject was in other regions of the world and to appreciate how important it could become in the future. Based on the review database, 23 papers were selected from three geographical areas as shown in Figure 2.

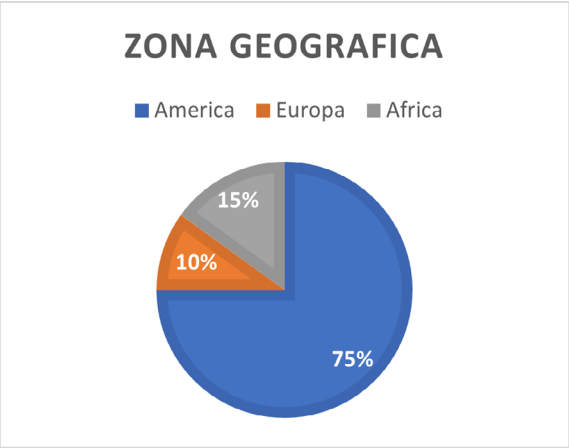

Figura 2. Localización de la información por continente, sobre el manejo poscosecha y evaluación de la calidad de *Annona muricata.*

Seventy-five percent of the articles used were from the Americas, with Mexico and Colombia being the main researchers on this subject, Africa, specifically Tanzania, had 15% of the research, and Europe, specifically Italy, had 10%.

Postharvest is a very important stage in the handling of the fruit, because of its delicate handling; therefore, the postharvest process begins with the selection of the fruit at harvest maturity, followed by cleaning and disinfection, then selection and classification, followed by packing and storage. Table 1 shows the detailed process of fruit selection at harvest maturity and Table 2 shows the physiological ripening stages of A. muricata. Fruit coloration is an important organoleptic factor that can be visually verified at different stages of ripening. As detailed in Table 2.

Tabla 1. Selection of *Annona muricata* fruits at harvest maturity.

Authors	Factors	Indicators	Description	Instruments
Moreno (2020)	Physical and physiological	Harvest time	harvest 4 to 5 months harvest soursoup bagging	Register
		detachment	Detachment verification	Recolector
		Ripening stage	Physiological ripening (verde claro)	Coloration table
Leiva (2018)	Composición	Sugar content	Sugar content in a range 13 ºBrix	Refractometer

Table 2. Ripening stages of *Annona muricata.*

Maduration Stage (MS)	Description
EM1	The fruit showed a dark green opaque pigmentation.
EM2	the shades vary from dark green to bright light.
EM3	Light green fruit with separation of stylar terminals.
EM4	Bright light green fruit.

According to Moreno (2017) when the fruit presented a light green coloration it was in the optimal period of physiological maturation, also acquiring brighter shades, its pulp was of white coloration exceeding 100 seeds and being a little sour, while Villarreal-Fuentes et al. (2020) indicated that in the optimal range of physiological maturation it presented a light green coloration, with more than 90 seeds, with white pulp. On the other hand, Leiva (2018) stated that fruit coloration should be light green with very subtle and bright tonality with 130 seed, white and bittersweet pulp. The authors agreed on the coloration, also considering that it can vary according to the variety, region, cultivation technique, among other factors, which alter some physiological aspects.

Organolpetic Quality Assessement

Organoleptic analysis is a method to evaluate the quality of a fruit or product based on sensations that can be perceived with the senses, such as sight, smell and taste. Some of these parameters can also be measured with instruments that provide reference values. Quality assessment values based on organoleptic parameters of *A. muricata* are presented in Table 3.

Table 3. Quality evaluation based on organoleptic parameters of *Annona muricata*.

Autores	Biomass (kg)	Color	Taste	Dureza (N)	Size (cm)
Castillo et al., 2005	2,7<2,12	Green	Bittersweet	-----	29-41 equatorial diameter 18-24 polar diameter
Jiménez et al., 2016	2,513	Green	Semi sweet	8,3	25.3 equatorial diameter 18.8 polar diameter
Codex alimentarium (Cajamarca, 2019)	>1	Darken green	Intense sweet	-----	40 height

According to the *Codex alimentarium* (Cajamarca, 2019), soursoup with a biomass greater than 1 kg presented intense and characteristic aroma, dark green coloration, intensely sweet flavor and length of 40 cm. On the other hand, Castillo et al. (2005) suggested that the ideal biomass was between 2.70 and 2.12 kg, with green color, bittersweet flavor, and equatorial and polar diameters within the mentioned range.. Meanwhile, Jiménez et al. (2016) established that the optimum biomass was 2.51 kg, with green color and semi-sweet flavor, along with the aforementioned diameters.

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The findings from these studies suggest a consistency in the evaluated parameters, which indicated that it can be produced and preserved with good characteristics as long as the indicated organoleptic criteria are met. In addition, the importance of the fruit being intact, without cracks or signs of pests or diseases was emphasized.

Assessement of physical-chemical quality variation

The physicochemical parameters are values that can be measured with certain instruments and allowed to capture internal values that were found in various materials of analysis, this due to their nature can be used as indicators of the quality present in a sample, since these values can be compared with others, to determine whether or not they meet a condition, or if they are between ideal ranges for use. Table 4 shows the physiochemical parameters of *A. muricata* to evaluate its quality.

Tabla 4. Evaluación de calidad en base a parámetros fisicoquímicos de *Anona muricata.*

Autores	Humedad (%)	Acidez valorable (%)	ºBrix	pH	Cenizas
Onimawo, 2002	81	3,43	15	4,56	-----
Othman, 2014	73,1±3,1	0,19 ± 0,02	-----	-----	0,87±0,04
Méndez et al., 2016	81,49± 0,10	0,87± 0,05	14,10± 0,01	3,97± 0,02	0,70± 0,11
Abdul et al., 2018	-----	-----	13,0-17,0	3,00-4,00	-----
Berumen-Varela et al., 2019	-----	0,61-1,04	8,2-24	3,6-5,8	-----
Codex alimentarium (Cajamarca, 2019).	81,16	0,858	17,65	4	0,7

According to Onimawo (2002) the physicochemical parameters that demonstrated the quality of A. muricata were moisture, titratable acidity, ºBrix, pH and ash with values of 81% moisture; 3.43% titratable acidity, 15 ºBrix, pH of 4.56. On the other hand, the *Codex alimentarium* and Cajamarca (2019) showed that the optimum quality values of *A. muricata* were 81.16% moisture; 0.86% titratable acidity; 17.65 ºBrix, pH of 4 and 0.7% ash.

Othman (2014) determined that *A. muricata* to be considered of quality must have 73.1±3.1% moisture, 0.19 ± 0.02% titratable acidity and 0.87±0.04% ash; on the other hand, Méndez et al. (2016) considered that *A. muricata* is a rather delicate fruit, which under ideal postharvest storage and subsequent utilization conditions should possess the following values 81.49± 0.10% moisture; 0.87±0.05% titratable acidity; 14.10±0.01 ºBrix, with a pH of 3.97±0.02 and 0.70±0.11% ash; however, Abdul et al. (2018) indicated that the ideal values for a quality A. muricata fruit should be in a range of 13.0-17.0 ºBrix, with a pH of 3.00-4.00 and Berumen-Varela et al. (2019) determined that for *A. muricata* to present ideal characteristics it should have a titratable acidity of 0.61-1.04%, with ºBrix of 8.2-24 and a pH of 3.6-5.8 depending on the industry to which the fruit will be received.

The different authors, when carrying out different tests and evaluations to determine the quality based on the physical-chemical parameters, indicated that the data varied according to time, technology, research, among others; all the authors presented values that were found in similar ranges, which indicated according to their research that A. muricata can be used in postharvest processes, taking into account its physical-chemical factors and the purposes for which it is used, since it varies according to the product or by-product for which it is intended. *A muricata* can be used in postharvest processes, taking into account its physicochemical factors and the purposes ,since this varies according to the product or by-product to which it is destined, this is determined because in certain industries it is necessary a fruit with higher or lower ºBrix, or also with a lower pH or for acidity regulation; that is why the variation of data can contribute to a correct industrialization of *A. muricata*.

Cambios fisiológicos

According to Márquez et al. (2012) the respiration rate of *A. muricata* was from 7 to 24 nmol-h-1 depending on the conditions, with an ethylene production rate of 133.2 mg-kg-1-h-1 and a physiological biomass loss of 21.72%; on the other hand, Jiménez-Zurita et al. (2017) indicated that ethylene production was 150 mg-kg-1-h-1 with a physiological biomass loss of 18%, also Marquez (2019) documented that ethylene production was 162 mg-kg-1-h-1 under normal conditions, but under controlled conditions it can reach up to 298.8 mg-kg-1-h-1 with a biomass loss of 21%, depending on these physiological factors the fruit quality was altered, because these accelerated or decreased physiological maturity, The variation in the coloration of the epicarp (peel) and the decrease in the protuberances of the fruit, according to the amount of ethylene, meso-endocarp (pulp) and the amount of seeds were affected, in the case of the pulp, this softened and released water, which in turn caused the physiological loss of biomass, decreasing postharvest yields and

fruit storage (Table 5).

Tabla 5. Physiological characteristics of *Annona muricata.*

Authors	Respiration rates ($nmol \cdot h^{-1}$)	Ethylene production ($mg \cdot kg^{-1} \cdot h^{-1}$)	Biomass physiological loss (%)
Márquez et al., 2012	7 - 24	133,2	21,72
Jiménez-Zurita et al., 2017	------	150	18
Márquez, 2019	------	162-298,8	21

Post-harvest technologies

Post-harvest management technologies for *A. muricata* are based on the reduction of ethylene production, because this enzyme, when found in high concentrations, accelerates the ripening process of the fruit, modifying its characteristics; some of the most widely used technologies have been modified atmospheres, low temperatures, coatings, among others. The different technologies that can be used to mitigate ethylene production are shown in Table 6.

According to Gavin et al. (2021) exogenous ethylene is a technology that allows stimulating ethylene biosynthesis, its bioactivity and quality, in immature or green fruit, to be applied it is recommended to use 500 µL-L-1in a gas chamber under controlled conditions with fruit that were at the optimum size for commercialization, this fruit in green had a higher shelf life, but after treatment this will have a shelf life of about 5 days under ambient conditions.

On the other hand, López-Velasco et al. (2018) indicated that the hydrothermal technology and use of waxes allowed the stimulation preserving the properties of terpenes, allowing to maintain the quality and color for its application recommended using a temperature of 50 ºC for 20 min and applying beeswax diluted in water, this increased from 6 to 8 days the shelf life time.

Martinez (2019) indicated that refrigeration retarded ethylene synthesis during storage for this a temperature of 5 ºC was used, extending the shelf life up to 9 days, with the risk of damage to the epicarp of the fruit, Gavin et al. (2021) pointed out the use of abscisic acid and nordihydroguairetic acid, in the conservation of A. muricata, the former stimulated the enzymatic activity of biosynthesis (ACO and ACS), for the application of this acid it was recommended to use 8 mg-L-1 and the latter was responsible for indirectly delaying the biosynthesis of ethylene and can be used in conjunction with abscisic acid.

Table 6. Tecnologías de poscosecha de *Annona muricata.*

Autores	Tecnologías	Efectos sobre el etileno	Tiempo de vida útil
Gavin et al., 2021	Exogene ethylene	stimulates ethylene biosynthesis, bioactivity and quality is used in gas chambers, to apply it use 500 µL-liter-1	5 days
López-Velasco et al., 2018	Hydrothermics and wax	Stimulates the preservation of terpenes, maintaining their quality and color, at a temperature of 50 ºC for 20 min, using beeswax diluted in water.	6-8 days
Martínez González, 2019	Refrigeration	Delays ethylene synthesis when stored in plastic crates at 5 ºC with 85% humidity	9 days
Silva, 2019	Modified atmosphere in cold room storage	Extracts air and replaces it with other gases in a low-density polyethylene film with an oxygen concentration of 97%; carbon dioxide of 3% at a temperature of 13°C.	17 days
Jiménez-Zurita et al., 2017	Ethylene inhibitors combined with oil emulsions	1-methylcyclopropene is applied at a concentration of 1000 nL-L-1 for 12 h combined with an emulsion based on carnauba wax with siliconized oils at a temperature of 13 ±2 ºC.	15 days
Jiménez-Zurita et al., 2017	Ethylene inhibitors combined with emulsion waxes	A concentration of 1-methylcyclopropene (1-MCP) of 1500 NL-L-1 should be applied for 12 h, and then combined with candelilla or beeswax diluted (15:85) in H2O in a storage of 16 ºC (59 °F).	14-15 days
Jiménez-Zurita et al., 2017	Modified Atmospheres	The fruit is packed in flexible polystyrene trays at a temperature of 12 ºC alternating with 14 ºC.	22 days

Silva (2019) indicated that applying a modified atmosphere, replacing air by O2: 97% and CO2: 3% in a low density polyethylene film at a temperature of 13 ºC can extend up to 17 days the shelf life of the whole fruit; on the other hand, Zanin (2020) indicated that extracting the pulp and subjecting it to freezing temperatures (0 ºC) can be preserved from 8 to 12 months.

Jiménez-Zurita et al. (2017) indicated that ethylene inhibitors were based on concentrations of 1-methylcyclopropene for 12 h, it can also be combined with wax emulsions diluted in water at a ratio of 15:85, extending its shelf life up to 15 days. The use of acids, exogenous ethylene and thermal treatments allowed extending the shelf life of the fruit, the most recommendable being abscisic acid and nordihydroguairetic acid, because when used together in a modified atmosphere they regulated the

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ethylene production of *A. muricata*, extending its shelf life.

Conclusion

In this study, a comprehensive review of the available scientific literature on postharvest handling and quality assessment for soursop (*A. muricata*) was conducted. The results obtained revealed a paucity of information in the years prior to 2016, followed by an increase in the number of articles published in recent years. This pattern indicates a growing interest in the subject and suggests future potential for additional research in this area.

The postharvest stage was identified as critical for the proper management of soursop, with fruit selection at harvest maturity being a critical step. Physiological ripening criteria, such as light green coloration and separation of stylar terminals, were consistent among the studies reviewed.

The evaluation of organoleptic and physicochemical quality reveals a number of important parameters, including color, flavor, moisture, acidity, sugar content, pH and ash content. Although there was some variation in the values reported in different studies, there is a general trend toward specific ranges that indicate optimum fruit quality.

Physiological changes, such as respiration rate and ethylene production, were identified as key factors affecting the quality and shelf life of soursop. Several postharvest technologies, such as modified atmospheres, refrigeration and ethylene inhibitors, were shown to be effective in mitigating these changes and prolonging shelf life.

Conflict of interest

The authors declare having no conflict of interest for this publication in any of its stages.

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Author contribution

Santiago Aguiar Novillo: methodology, research, formal analysis, original draft, drafting and editing. **Susy Gómez**: formal analysis, writing. **Luis Arboleda**: conceptualization, formal analysis, methodology. **Edgar Chicaiza**: research, original draft-writing, drafting-review and editing.