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# ALLI KAWSAY: EVALUACIÓN DEL OBJETIVO 4, LITERAL A. DE LA LEY ORGÁNICA DE ECONOMÍA POPULAR Y SOLIDARIA Y SUS IMPACTOS EN LA COMUNIDAD SANTA BARBARA

# ALLI KAWSAY: EVALUATION OF OBJECTIVE 4, PARAGRAPH A. OF THE ORGANIC LAW ON POPULAR AND SOLIDARITY ECONOMY AND ITS IMPACT ON THE SANTA BARBARA COMMUNITY

Elizabeth Idania Chicaiza Quiñónez[1], María Belén Bravo Avalos[2]
{elizabeth.chicaiza@uaw.edu.ec1, maria.bravo@espoch.edu2}

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**RESUMEN:** El presente trabajo de investigación estudia la práctica del Objetivo 4, letra a) de la Ley Orgánica de Economía Popular y Solidaria (LOEPS) en la comunidad de Santa Bárbara, cantón Cotacachi, Ecuador, desde el punto de vista de la cosmovisión del *Alli Kawsay* o Buen Vivir. La finalidad esencial es escudriñar la relación que hay entre el ideario jurídico estatal y la praxis socioeconómica territorial, respecto de fenómenos tales como el asociacionismo juvenil o la disolución del tejido social. La metodología utilizada es cualitativa, de carácter descriptivo-explicativo, mediante entrevistas semiestructuradas a la muestra de 28 comuneros y la observación activa en los entornos de trabajo colectivo. Los resultados de esta búsqueda evidencian una notable asimetría: mientras existe un conocimiento universal del *Alli Kawsay* (100%), un 85,2% desconoce la LOEPS, y ello se traduce en distanciamiento entre la política pública estatal y la práctica territorial. A la que, a pesar de ese analfabetismo jurídico institucional, la comunidad presenta una resiliencia basada en la autosuficiencia y el cuidado de la vida (92,9%), manteniendo instituciones ancestrales como la *minka* y la reciprocidad (78,6%). Por otro lado, la falta de conexión con lo normativo y la migración hacia los espacios urbanos representan riesgos para la transmisión intergeneracional de conocimientos y la soberanía alimentaria. Se puede concluir que la práctica de un Buen Vivir no se encuentra supeditada a la ley formal sino a la acción local y la resistencia cultural. Existe la necesidad de diseñar políticas públicas que sean contextualmente válidas y que trasciendan la legalidad mercantil para fortalecer la autogestión comunitaria mediante procesos de acompañamiento que convaliden los conocimientos situados de las culturas kichwas.

***Palabras clave:*** *Alli kawsay, sostenibilidad, transformación social, economía social y solidaria.*

**ABSTRACT:** This research study examines the implementation of Objective 4, letter a) of the Organic Law on Popular and Solidarity Economy (LOEPS) in the community of Santa

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Bárbara, Cotacachi canton, Ecuador, from the perspective of the Alli Kawsay or Good Living worldview. The main purpose is to examine the relationship between the state's legal ideology and territorial socioeconomic practice with regard to phenomena such as youth associations and the dissolution of the social fabric. The methodology used is qualitative, descriptive-explanatory, through semi-structured interviews with a sample of 28 community members and active observation in collective work environments. The results of this research reveal a notable asymmetry: while there is universal knowledge of Alli Kawsay (100%), 85.2% are unaware of the LOEPS, and this translates into a gap between state public policy and territorial practice. Despite this institutional legal illiteracy, the community shows resilience based on self-sufficiency and care for life (92.9%), maintaining ancestral institutions such as minka and reciprocity (78.6%). On the other hand, the lack of connection with regulations and migration to urban areas pose risks to the intergenerational transmission of knowledge and food sovereignty. It can be concluded that the practice of Good Living is not subject to formal law but to local action and cultural resistance. There is a need to design public policies that are contextually valid and transcend commercial legality in order to strengthen community self-management through support processes that validate the situated knowledge of Kichwa cultures.

***Keywords:*** *Alli kawsay, sustainability, social transformation, social and solidarity economy.*

[1]Universidad Intercultural de las Nacionalidades y Pueblos Indígenas "Amawtay Wasi", https://orcid.org/0009-0005-1541-5609.
[2]Escuela Superior Politécnica de Chimborazo (ESPOCH), https://orcid.org/0000-0002-5999-4690.

## INTRODUCTION

In these days of civilizational, environmental, and economic crisis, the debate on the concept of development has shifted from inflationary conceptions centered on linear economic growth to alternative ones linked to an ancestral worldview. At the global level, this search for sustainability has driven, for example, concepts such as the Social and Solidarity Economy (SSE) to become systemic responses to the exclusion of the formal market and the degradation of ecosystems (1). In the Andean region, the focal point of this evolution is the Alli Kawsay or Sumak Kawsay (Good Living), an ontological category that establishes multidimensional harmony between human beings, the community, and nature, and that imposes limits on the advance of material accumulation as the sole indicator of progress (2).

For its part, Ecuador, by constitutionalizing Good Living in 2008, established a legal mandate. Unprecedented, to define the economic system as social and solidarity-based. In this way, the Organic Law on Popular and Solidarity Economy (LOEPS) was also promulgated in 2011 within this normative framework (3). The purpose of the law, particularly in relation to its Objective 4, paragraph a, seeks to open, I would say, the "production process, the consumption process, and the exchange process of goods and services that satisfy needs before recognizing profit" (4). In any case, contemporary academic literature warns of the existence of an "empty institutionalization" of Good

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Living, that is, where state rhetoric or technical regulations have little relation to practice in indigenous territories (2), (5).

**Theoretical and referential bases.** The conceptual base to which this research appeals is identified with a series of three anthropological pillars of Andean reality, and with social economic theory:

**1. The *Alli Kawsay* as a praxis of life:** it is not only a rather abstract philosophical concept; it is a form of community governance that manifests the *minka* (collective work), or the *randi-randi* (reciprocity). Authors consider that Good Living is a type of governance that makes possible the reproduction of life as a form of opposition to modern individuality (5).

**2. Popular and Solidarity Economy (PSE):** Not as a marginal economy, but as an organization of processes oriented toward the satisfaction of needs. What the LOEPS finds as a need to regulate these processes, a previous study indicates that the LOEPS tends to impose bureaucratic structures that can strangle organic communal logic (6).

**3. Sustainability and worldview:** The relationship with nature from communities such as those of Cotacachi is not only utilitarian; respect for "Pacha Mama" is a transversal axis that determines what is produced and how exchange is carried out, an adequate practice of biocentric sustainability (7), (8).

In the locality of Santa Bárbara, Cotacachi canton, the dilemma between norm and reality is clearly observed. Being a community that maintains a cabildo structure and that has achieved a strengthening of its own Kichwa identity, this binomial is threatened by the departure of young people taking on the challenge of seeking new opportunities in other urban centers and the failure to have reterritorialized commonly known public policy (9). The main issue underlying this community is that the mechanisms offered by the LOEPS become the design of the environment of a formal market economy, alien to the dynamics of self-management and food sovereignty that the same Santa Bárbara community promotes.

The justification of this study is social, by reason of the urgency of safeguarding the community fabric and the transmission of knowledge; legal, for the purpose of contrasting the real efficacy of the LOEPS exercised in territories of peoples and nationalities; and territorial, providing situated data on the Andean Zone of Cotacachi (10). Thus, the general objective of this research shares the evaluation of the fulfillment of Objective 4, paragraph a) of the LOEPS, essentially and the determination of its real impacts on the socioeconomic and cultural sustainability of the Santa Bárbara community during the period 2022-2025.

**Table 1. Principles of Alli Kawsay versus the Principles of the LOEPS**

| Principle of Alli Kawsay (Philosophical) | Principle of the LOEPS (Legal) | Comments on Synergy or Discrepancy |
|---|---|---|
| Harmony with Nature and the Social Being | Social and environmental responsibility | Synergy. Both discuss a "balance," although the LOEPS frames it from the sphere of responsibility, not from the holistic notion of nature as a subject of rights. |

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| | | |
|---|---|---|
| Reciprocity and Redistribution | Equitable and solidary distribution of surpluses; Primacy of collective interests over individual ones | Synergy. The law affirms ancestral practices such as the principle of reciprocity (*minka*) and the redistribution proper to the Andean worldview. |
| Self-management and Democracy | Self-management; Democratic organization: "one member, one vote" | Synergy. The law guarantees the autonomy and form of governance that communities were already practicing in a customary manner. |
| Progress not linked to material heritage | Strengthening and dynamization of production, marketing, and financing | Discrepancy. The Alli Kawsay rejects material progress; in contrast, the LOEPS uses language about growth and insertion into the market, which may invert the ideal suspended from the philosophy. |

The research tests the fulfillment of Objective 4, paragraph a) of the Organic Law on Popular and Solidarity Economy (LOEPS) in the community of Santa Bárbara, Cotacachi, contrasting it with the *Alli Kawsay* (11,12). Drawing on qualitative research and interviews with 28 community members, it inserts a critique of the opposition between state normative frameworks and the territorial situation: if knowledge of the Alli Kawsay is universal (100%), the LOEPS is unknown to 85.2%; it is argued that this community sustains its economy and environmental sustainability (92.9%) through the will to self-manage or ancestral practices such as the *minka* (78.6%), and not through the management of public policy. It is only concluded that the mercantilist language of the law is in contradiction with the integral vision of Good Living, for which reason it is urgent to territorialize the laws in order to mitigate risks such as youth migration and to guarantee that the transmission of knowledge is not interrupted (13).

## MATERIALS AND METHODS

The research was founded and sustained on an interpretative paradigm with a qualitative and socio-legal approach, in order to explore the normative content and, in addition, to explore the meanings and perceptions that the citizens of Santa Bárbara give to the Alli Kawsay and to the application of the law. The research combined a descriptive level in order to describe the state of Good Living and an explanatory level in order to explain the consequences of the different changes in the forms of a community fabric. Considering its origin, it is field research, inasmuch as the empirical data were obtained from contact with its social actors directly in the territory.

Likewise, an exhaustive review of documents and legal regulations was carried out (including the 2008 Constitution and the Organic Law on Popular and Solidarity Economy (LOEPS)). This analysis was verified with the scientific literature collected on the basis of criteria of technical relevance and currency, in relation to the topics of Social and Solidarity Economy.

The collection of primary information took place through the application of two main techniques:

**Semi-structured interviews:** They were applied to a sample of 28 informants. The population included young people, adults, and elders of the Santa Bárbara community,

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making it possible to elicit the intergenerational perception relative to the fulfillment of Objective 4 of the LOEPS.

**Participant observation:** The researcher lived with the local actors in the activities and in the mingas. This technique served for the understanding of meanings and emotions that go beyond verbal communication.

**Table 2. Methodological components of the research**

| Component | Technical detail |
|---|---|
| Approach | Qualitative – interpretative |
| Population / sample | 28 community members of Santa Bárbara (Non-probabilistic sampling) |
| Techniques | Semi-structured interview and participant observation |
| Instruments | Interview guide and field diary |
| Data analysis | Content analysis and descriptive statistics of frequencies (14) |

The data recovered in the interviews were systematized for the purpose of identifying response frequencies and percentages of perception in relation to the application of the principles of Good Living. Subsequently, a triangulation of the information was carried out, in which the field findings were crossed with the theoretical principles of the Alli Kawsay together with the normative framework of the LOEPS, with the objective of seeing whether there were synergies or differences between them.

## RESULTS

The results of the research show us the complex socioeconomic and cultural reality of the Santa Bárbara community in the face of the premises put forward by the Organic Law on Popular and Solidarity Economy (LOEPS). From the triangulation of qualitative and quantitative information we evidence that the operationalization of Objective 4, paragraph a) of the law under study has not achieved territorialization, operating in an asynchronous manner with respect to the community practice of the *Alli Kawsay*.

**Cognitive dimension: the distance between the worldview and state regulation.** The first analysis is centered on the level of appropriation of the concept by the inhabitants. The ancestral knowledge bequeathed by their grandparents is abysmally different from the technical knowledge that emanates from the legislation in force (15).

**Table 3. Knowledge and Perception of Alli Kawsay versus the LOEPS**

| Evaluation Variable | Affirmative Responses (n=28) | Percentage (%) | Detail and Observations |
|---|---|---|---|
| Knowledge of the *Alli Kawsay* | 28 | 100% | Universal and lived knowledge of the concept. |

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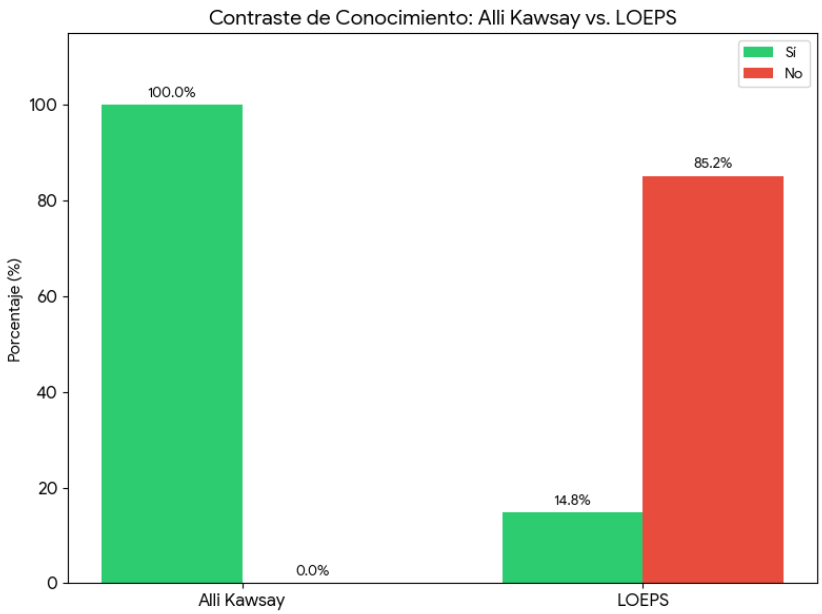
| | | | |
|---|---|---|---|
| Life in accordance with principles (respect, solidarity) | 23 | 82.1% | Perception of majority application of the values of Good Living. |
| Knowledge of the LOEPS | 4 | 14.8% | High institutional legal illiteracy (85.2%). |
| Perception of benefit from the law | 0 | 0% | High uncertainty; no respondent affirms a tangible direct benefit. |

Full knowledge of the culture of the *Alli Kawsay* rises to a total of 100%, which indicates to us that this knowledge is not a simple theoretical construct external to them, but the guiding thread that articulates identity in Santa Bárbara. In contrast, the lack of knowledge of the LOEPS law, which stands at 85.2%, makes evident a deficiency in the dissemination of public policies, inhibiting the community's access to the mechanisms of financing and marketing that the law guarantees in Objective 4.

**Figure 1. Contrast of Knowledge: Alli Kawsay vs. LOEPS**




*Source: Own elaboration based on study data.*

The graphic representation shown in Figure 1 emphasizes the "critical asymmetry" between culture and law. At one extreme the *Alli Kawsay* floods the cognitive framework of the community, while the LOEPS law is rendered invisible. This distance indicates that the "institutionalization of Good Living" in Ecuador is erected as a top-down process that has not been interwoven into the knowledge-power structure of rural communities (16).

**Procedural dimension: sustainability of ancestral practice and territory.** The second dimension evaluates the degree of validity of indigenous social institutions and their correlation with biocentric sustainability.

**Table 4. Validity of traditional practices and environmental awareness**

| Community practice or value | Affirmative Responses (n) | Percentage (%) | Technical-social interpretation |
|---|---|---|---|

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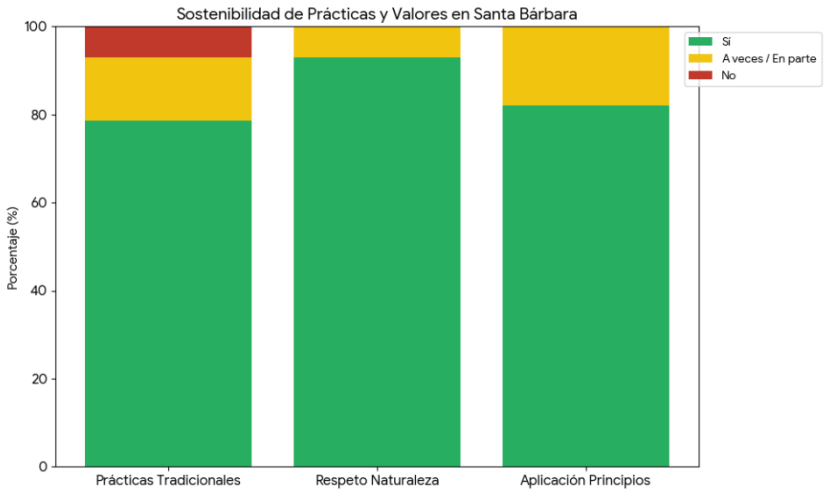
| | | | |
|---|---|---|---|
| Maintenance of the *minka* and mutual aid | 26 | 78.6% | Robust validity of reciprocity as an economic base. |
| Respect for nature and local culture | 25 | 92.9% | Commitment to sustainability above material profit. |
| Work oriented toward the common good | 17 | 59.3% | Moderately high social cohesion, aligned with solidarity. |
| Perception of positive changes in knowledge | 25 | 89.3% | Optimistic vision regarding the cultural resilience of the community. |

The continuity of the *minka* (78.6%) gives us evidence that Santa Bárbara incorporates a system of democratic self-management that is prior and superior to the formalization claimed by the LOEPS. The almost absolute respect for nature (92.9%) indicates that the community does organically fulfill the environmental responsibility required for compliance with legal requirements. However, only 59.3% of respondents perceive that the common good is always prioritized, which signals an incipient tension produced by the irruption of individual logics proper to the external market economy (17).

**Figure 2. Sustainability of practices and values in Santa Bárbara**




*Source: Own elaboration based on study data.*

Figure 2, of the stacked bar chart, reflects that sustainability in Santa Bárbara does not depend on state incentives, but arises from the strength of its cultural values. The prevalence of "yes" regarding respect for nature and the performance of traditional practices indicates a community that, in practice, is a collective not only of the popular economy, but of a popular and solidarity economy that is extremely effective in the reproduction of life, even if it is not so in the sense of capital accumulation (18).

Finally, the perception of transformation and generational challenge and the community's vision of the future in the face of external threats were analyzed.

**Figure 3. Perception of positive changes in unity and knowledge**

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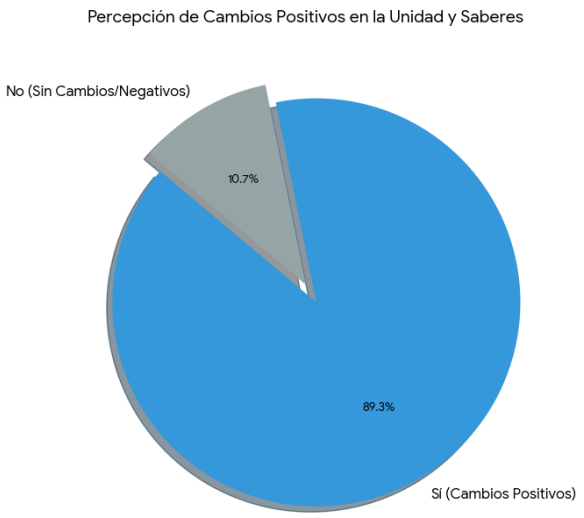


*Source: Own elaboration based on study data.*

Figure 3 of sectors shows a notable optimism regarding the strengthening of the social structure in the absence of the transmission of knowledge, 89.3%. The warning of the result must be made in the face of the situation of youth migration. The interviews evidence that, despite the attempt to conserve unity, the transfer of young people toward urban centers causes a rupture of the everyday exercise of the *Alli Kawsay*, thereby generating a vacuum that the regulations in force do not manage to mitigate, being mercantilist and centered. This analysis of results reaches the point of corroborating that the real exercise of Good Living is not in the laws, but in the resilience and in the local action of living and appropriating the *Alli Kawsay* in the territory.

## DISCUSSION

**The gap between the plurinational State and normative efficacy.** The finding of 100% knowledge of the *Alli Kawsay* versus a scant 14.8% knowledge of the LOEPS makes evident what Luzuriaga Muñoz and Ruiz Castillo (3) describe as the distance between what was established with a plurinational regulation and the existence of a "monocultural State" camouflaged as plurinational. This asymmetry accounts for the fact that, although Good Living has been constitutionalized, its technical implementation carried out through the LOEPS has not managed to permeate the knowledge-power structure of rural communities. As Acosta (1) defends, the institutionalization of Good Living has run the risk of emptying that concept of emancipatory content in order to transform Good Living into an instrumental tool of administrative management that communities such as Santa Bárbara perceive as distant or non-existent.

**Ontology of care versus market logic.** The results indicate to us that 92.9% of the community members place consideration toward nature and local culture above economic benefit. This datum seems to us of the utmost importance when we contrast it with Objective 4, paragraph a) of the LOEPS, which speaks to us of "mercantile dynamization" and of "marketing" (4). At the philosophical level, there is still a

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discrepancy: the law seeks to insert the actors into the market while the community of Santa Bárbara, on the contrary, preaches an "economy of care and of life." Authors such as Inuca Lechón (5) and Dávalos (10) affirm that this resistance to being totally linked to the exchange economy is what makes it possible to maintain Kichwa identity; this implies that the LOEPS presents a productivist bias that hides the non-monetary exchange practices and of reciprocity, which are those that allow sustainability to live in the territory.

**Erosion of the social fabric and the issue of migration.** Although 78.6% of workshop participants maintain that the *minka* is sustained, the perception of work for the common good falls to 59.3%, and this downward spike coincides with the article by Flores Endara et al. (7), (19) on the context of the communities of Cotacachi in the face of globalization. Youth migration, a disruptive factor recognized in the interviews, occasions what we call a "flight of knowledge" that the LOEPS does not contemplate (it points only to the formalization of productive associations) (20). In some way the law leaves aside the social reproduction of the community, given that if the young people are not going to leave the place by force "inheriting" the practice of the *minka*, in the end the structure of the Popular and Solidarity Economy in the community of Santa Bárbara may fall and become a structure of individualist subsistence distant from the *Alli Kawsay* (21).

For which reason it is in the last instance also a synthesis of community resilience. In conclusion, the discussion would lead one to think that a "resilience of fact" in Santa Bárbara contrasts with an "omission of law," that is, that the community does fulfill a series of principles of solidarity and environmental respect not by the force of public policy but by a cultural heritage. Said process, which for Quijano (22) forms part of the coloniality of power, once the laws are elaborated from an urban centrality, ignoring the rhythms and needs of the indigenous periphery, the "dynamization" that the LOEPS proposes constitutes, in practical terms, a category that is absent and that leaves the community in the possibility of reactivating its own autonomy on the basis of self-management, making of the *Alli Kawsay* a mechanism of resistance in the face of a normative framework that does not finish assimilating and understanding them.

## CONCLUSIONS

We arrive at the conclusion that the inoperativeness of the regulation in the face of cultural identity calls attention to the existence of a critical disconnection between the LOEPS and the community of Santa Bárbara, evidenced by an 85.2% lack of knowledge of the law versus a 100% appropriation of the *Alli Kawsay*. Objective 4, paragraph a), which attempts to activate production and marketing, has not been able to be territorialized and has become a nominal legal framework, alien to the dynamics of communication and organization of the Kichwa peoples.

With respect to the resilience of ancestral self-management it is found that Good Living in the community does not depend on the state impulse, but depends on the validity of institutions such as the *minka* and mutual aid (78.6%), as well as on the strong commitment to exercise respect toward nature (92.9%). The community connects an "economy of life" sustained in reciprocity and self-management and organically fills the

principles of solidarity that the law attempts to formalize, but according to its own rhythms and scales of development.

The vulnerability also in the face of the generational gap is, at the least, that the sustainability of the *Alli Kawsay* faces a structural threat, for youth migration toward urban centers tends to break the transmission of knowledge and to weaken the collective networks and of living together, although there exists a dose of optimism due to the strength of social strengthening (89.3%); the lack of public policies that articulate economic development with territorial rootedness makes the community vulnerable before the logics of individuality that go on deforming community life and Good Living.

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# ACTIVIDAD INHIBITORIA DEL EXTRACTO DE BARBASCO (Bonellia sprucei) Y ACEITE ESENCIAL DE ANÍS ESTRELLADO (Illicium verum) COMO DESINFECTANTES PARA SUPERFICIES EN CONTACTO CON ALIMENTOS CRUDOS

# INHIBITORY ACTIVITY OF BARBASCO EXTRACT (Bonellia sprucei) AND STAR ANISE ESSENTIAL OIL (Illicium verum) AS DISINFECTANTS FOR FOOD-CONTACT SURFACES

Evelyn Elizabeth Sánchez Castro[1], Doris Ximena Guilcamaigua Anchatuña[2], Zulema Layanara Zamora Mendoza[3], Edison Fernando González Alberca[4]

{esanchez@uagraria.edu.ec1, dg@uagraria.edu.ec2, zz@uagraria.edu.ec3, edisonga24@uniandes.edu.ec4}

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**RESUMEN:** La contaminación microbiológica de superficies en contacto con alimentos representa un riesgo significativo para la inocuidad alimentaria, especialmente durante la manipulación y procesamiento de productos crudos. Es por ello que, se necesitan otras alternativas de desinfección que sean eficaces y sostenibles para reducir el uso de compuestos químicos convencionales. El objetivo principal fue realizar una evaluación de la actividad inhibitoria del extracto de barbasco (Bonellia sprucei) y del aceite esencial de anís estrellado (Illicium verum) como desinfectantes para superficies que tengan un contacto directo con los alimentos crudos. No obstante, hubo una formulación de tres tratamientos con diferentes concentraciones de extracto y aceite esencial: T1 (0,05 % – 0,95 %), T2 (0,03 % – 0,97 %) y T3 (0,01 % – 0,99 %), y se analizaron mediante pruebas de difusión en disco e hisopado de superficies frente a Escherichia coli y Staphylococcus aureus. Por otro lado, con los análisis de las propiedades físico-químicas del tratamiento con mayor capacidad antimicrobiana se procedió a comparar su eficacia con un desinfectante comercial. El resultado final evidencio que el tratamiento T3 presentó la mayor capacidad inhibitoria frente a ambos microorganismos. Y con el resultado del análisis físico-químico demostró un perfil de tensoactivos totales de 92,2 %, material activo valorable de 8,1 %, alcalinidad libre de NaOH de 0,8 % y un pH de 4,0. En la comparación con el desinfectante comercial, T3 mostró igual eficacia frente a S. aureus y menor eficacia frente a E. coli. Se concluye que la formulación T3 constituye una alternativa viable para la desinfección de superficies en contacto con alimentos, con especial efectividad frente a microorganismos gram positivos.

***Palabras clave:*** *Barbasco, desinfectante, aceite esencial, actividad antimicrobiana, anís estrellado*

**ABSTRACT:** Microbiological contamination of food-contact surfaces represents a significant risk to food safety, particularly during the handling and processing of raw products. Therefore, effective and sustainable disinfection alternatives are needed to reduce the use of conventional chemical compounds. The main objective of this study

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was to evaluate the inhibitory activity of barbasco extract (Bonellia sprucei) and star anise essential oil (Illicium verum) as disinfectants for surfaces in direct contact with raw foods. Three formulations with different concentrations of extract and essential oil were developed: T1 (0.05%–0.95%), T2 (0.03%–0.97%), and T3 (0.01%–0.99%). Antimicrobial activity was assessed using disk diffusion and surface swabbing tests against Escherichia coli and Staphylococcus aureus. Additionally, the physicochemical properties of the formulation with the highest antimicrobial capacity were analyzed and its efficacy was compared with a commercial disinfectant. The results showed that treatment T3 exhibited the highest inhibitory activity against both microorganisms. Physicochemical analysis of T3 revealed a total surfactant content of 92.2%, an active matter content of 8.1%, free NaOH alkalinity of 0.8%, and a pH of 4.0. When compared with the commercial disinfectant, T3 demonstrated equivalent efficacy against S. aureus and lower efficacy against E. coli. It is concluded that formulation T3 constitutes a viable alternative for the disinfection of food-contact surfaces, with particular effectiveness against Gram-positive microorganisms.

***Keywords:*** *Barbasco, disinfectant, essential oil, antimicrobial activity, star anise*

1 Carrera Agroindustria, Facultad de Ciencias Agrarias, Universidad Agraria del Ecuador, Ecuador, https://orcid.org/0009-0001-0502-3901 +593-90737713.
2 Facultad de Ciencias Agrarias, Universidad Agraria del Ecuador, Ecuador, https://orcid.org/0009-0007-6959-3288.
3 Facultad de Ciencias Agrarias, Universidad Agraria del Ecuador, Ecuador, https://orcid.org/0009-0009-2537-9364.
4 Facultad de Sistemas Mercantiles, Universidad Regional Autónoma de los Andes, Ecuador, https://orcid.org/0009-0006-9715-0444.

## INTRODUCTION

Food safety and security remain among the main risk factors for public health and for the sustainability of modern agri-food systems. One of the principal risks associated with the loss of safety is the microbiological contamination of surfaces that come into direct contact with raw foods during the stages of handling, processing, and storage. These surfaces, when not subjected to adequate cleaning and disinfection processes, can act as reservoirs of pathogenic microorganisms, favoring cross-contamination and the transmission of foodborne diseases (1,2).

The World Health Organization has estimated that foodborne diseases affect hundreds of millions of people annually worldwide, with deficiencies in hygienic-sanitary practices being one of the determining factors in their occurrence (3). In this context, bacteria such as Escherichia coli and Staphylococcus aureus are widely used as indicator microorganisms of contamination on food-contact surfaces. E. coli is mainly associated with fecal contamination and severe gastrointestinal conditions, while S. aureus stands out for its capacity to produce heat-stable toxins responsible for food intoxications, even when the food has been subjected to thermal processes (4–6).

Traditionally, the food industry has resorted to the use of synthetic chemical disinfectants, such as chlorinated compounds, quaternary ammonium compounds, and alcohols, owing to their high antimicrobial efficacy. Nevertheless, the continuous use of these agents has been related to adverse effects, among them the generation of chemical residues, negative environmental impact, corrosion of surfaces and equipment, as well as the development of microbial resistance (7,8). These limitations have driven the search for natural, safe, and sustainable alternatives that allow

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adequate levels of hygiene to be maintained without compromising human health or the environment.

In recent years, various studies have demonstrated that plant extracts and essential oils possess bioactive compounds with antimicrobial properties, among which flavonoids, saponins, phenolic compounds, and terpenes stand out. These secondary metabolites exert their action mainly through the alteration of the bacterial cell membrane, the inhibition of essential enzymes, and interference in metabolic processes fundamental for microbial survival (9–11). Owing to these characteristics, products of plant origin have aroused growing interest as potential disinfectant agents in the food industry.

Barbasco (Bonellia sprucei) is a plant native to tropical regions of South America, traditionally used by local communities for its biological properties. Previous research has reported the presence of saponins and other compounds with surfactant and biocidal activity, which suggests its possible application as an antimicrobial agent (12,13). On the other hand, star anise essential oil (Illicium verum) is widely recognized for its high content of anethole and other aromatic compounds with demonstrated antimicrobial activity against Gram-positive and Gram-negative bacteria (14,15).

Despite the scientific evidence that supports the individual antimicrobial activity of barbasco extract and of star anise essential oil, the information available on their combined use as disinfectants for surfaces in contact with raw foods is limited, especially in the Ecuadorian agro-industrial context. This knowledge gap justifies the need to evaluate alternative formulations that integrate both compounds and allow their real efficacy against indicator microorganisms of contamination to be determined.

In this sense, the general objective of the present research was to evaluate the inhibitory activity of barbasco extract (Bonellia sprucei) and of star anise essential oil (Illicium verum) as disinfectants for surfaces in contact with raw foods. As specific objectives it was proposed: to formulate different treatments with variable concentrations of both compounds, to evaluate their antimicrobial activity against Escherichia coli and Staphylococcus aureus, and to compare the efficacy of the most effective treatment with a commercial disinfectant. The hypothesis of the study establishes that the combination of barbasco extract and star anise essential oil presents significant antimicrobial activity comparable to that of a conventional chemical disinfectant.

## MATERIALS AND METHODS

This study adopts an experimental approach, of quantitative type, with a descriptive and comparative scope. The study was carried out under controlled conditions according to the standards, with the objective of evaluating the antimicrobial activity of barbasco extract (Bonellia sprucei) and of star anise essential oil (Illicium verum) as disinfectants for surfaces in contact with raw foods (1,2).

For this reason, plant material was used: barbasco (Bonellia sprucei), which came from local suppliers. The plant material was subjected to a process of selection, washing with potable water for the elimination of impurities, and drying at room temperature, avoiding direct exposure to sunlight. Subsequently, the barbasco was ground and subjected to a maceration process (3) using an appropriate solvent, with the purpose of

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obtaining the extract. The resulting extract was filtered to eliminate solid residues and stored in sterile containers until its use.

Star anise essential oil (Illicium verum) was acquired from a certified supplier, guaranteeing its purity and quality. This oil was conserved in airtight containers, protected from light and at room temperature, until its employment in the formulation of the treatments (4).

For the preparation of the disinfectant, three experimental treatments were formulated, combining barbasco extract and star anise essential oil at different concentrations. Treatment T1 was formulated with 0.05 % barbasco extract and 0.95 % essential oil; treatment T2 with 0.03 % extract and 0.97 % essential oil; and treatment T3 with 0.01 % extract and 0.99 % essential oil. Each formulation was homogenized by constant agitation until uniform solutions were obtained, which were stored in properly labeled sterile containers.

The evaluation of antimicrobial activity was carried out against strains of Escherichia coli and Staphylococcus aureus, selected for their importance in food safety (5). The disk diffusion method was employed to determine the inhibitory capacity of the treatments. For this purpose, bacterial suspensions adjusted to a concentration equivalent to the McFarland standard were prepared, which were uniformly seeded onto nutrient agar plates. Sterile paper disks impregnated with each treatment were placed on the plates, including a commercial disinfectant as positive control. The plates were incubated at 37 °C for 24 hours and antimicrobial activity was evaluated by measuring the inhibition zones.

Additionally, a microbiological evaluation was performed on food-contact surfaces by the swab method. The surfaces were treated with the developed formulations and subsequently sampled to determine the microbial reduction achieved by each treatment (7). The results were expressed in colony-forming units.

The treatment that presented the highest antimicrobial activity was subjected to physicochemical analyses, evaluating parameters such as pH, free alkalinity expressed as NaOH, titratable active matter, and total surfactant content, following methodologies established in current technical standards.

The data obtained were analyzed by descriptive statistics, using means and standard deviation to compare the efficacy of the treatments and of the commercial disinfectant (8).

## RESULTS

The estimation of the efficacy of the natural barbasco extract in combination with star anise essential oil as an alternative sanitizing agent for surfaces in contact with raw foods was carried out by means of a set of microbiological tests and rigorous statistical analyses. For this purpose, three experimental treatments were formulated, denominated T1, T2, and T3, which varied in the proportions of barbasco extract and star anise essential oil, keeping the remaining components of the formulation constant. This strategy made it possible to evaluate objectively the influence of the relative

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concentration of the active compounds on the antimicrobial capacity of each treatment (1,2).

**Table 1. Microbiological evaluation of the different proposed treatments by disk diffusion.**

| Treatment | Inhibition zone (mm) *S. aureus* | Inhibition zone (mm) *E. coli* |
|---|---|---|
| T3 | 24.80C | 23.00C |
| T2 | 14.00B | 12.00B |
| T1 | 6.60A | 5.11A |
| p-value | 0.0001 | 0.0001 |
| S.E. | 0.730 | 0.841 |

The main evaluation of antimicrobial activity was carried out by means of the disk diffusion test, a technique widely used to determine the sensitivity of microorganisms to antimicrobial agents (3,4). The results obtained evidenced clear and consistent differences among the treatments evaluated. Against Staphylococcus aureus, Treatment 3 presented the highest inhibitory capacity, reaching an average inhibition zone of 24.80 mm. This value reflects a high and sustained antimicrobial action, superior to that observed in the other treatments. Treatment 2 showed an intermediate response, with an average zone of 14.00 mm, while Treatment 1 registered the lowest efficacy, with an average inhibition diameter of 6.60 mm. Analysis of variance confirmed that the differences observed among the treatments were statistically significant, with a p-value lower than 0.0001, which indicates high reliability of the results obtained.

When analyzing the response against Escherichia coli, a behavior similar to that recorded for S. aureus was observed, although with slight variations in the magnitude of the inhibition zones. Treatment 3 again stood out as the most efficacious formulation, reaching an average zone of 23.00 mm, which evidences a notable inhibitory capacity against this Gram-negative bacterium. Treatment 2 presented moderate inhibition, with an average zone of 12.00 mm, while Treatment 1 showed a limited response, with an average value of 5.11 mm. The statistical analysis again yielded a p-value of 0.0001, confirming significant differences among the treatments. The calculated standard error values for both bacteria were low, which suggests adequate experimental precision and good repeatability of the measurements performed.

The joint analysis of the results obtained by the disk diffusion test made it possible to identify a clear trend in the behavior of the formulations evaluated. An inverse relationship was evidenced between the concentration of barbasco extract and the antimicrobial efficacy of the compound disinfectant. As the proportion of barbasco decreased and the concentration of star anise essential oil increased, a significant increase in inhibitory capacity was observed, particularly in Treatment 3. This behavior suggests that the bioactive compounds present in star anise essential oil, such as anethole and other aromatic terpenes, play a predominant role in the biocidal action of the formulation. At the same time, higher concentrations of barbasco extract could be partially interfering with or antagonizing said effect in the system evaluated (6,7).

In addition to the in vitro tests, microbiological evaluations were performed by the swab method on surfaces in contact with raw foods (1), with the objective of analyzing the efficacy of the treatments under conditions closer to a real application. In the case of

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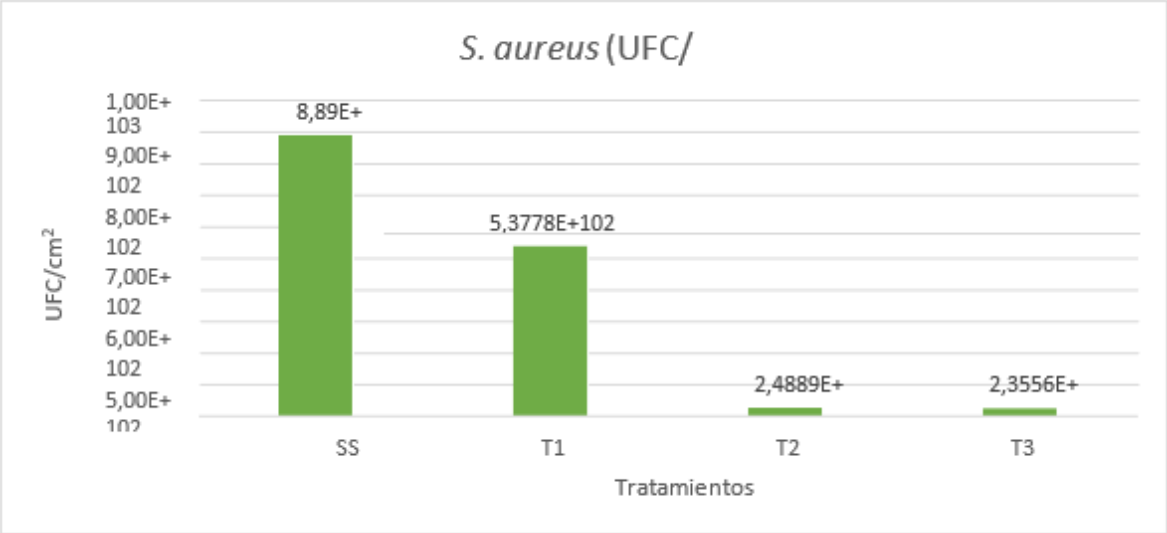
Staphylococcus aureus, the initial count on untreated surfaces was 8.89 × $10^2$ CFU/$cm^2$, a value that reflects a significant microbial load. After application of the disinfectant treatments, a variable reduction was observed according to the formulation used. Treatment 1 managed to reduce the microbial load to 5.37 × $10^2$ CFU/$cm^2$, evidencing limited efficacy. In contrast, Treatments 2 and 3 showed a much more pronounced reduction, reaching final values of 2.48 × $10^1$ and 2.35 × $10^1$ CFU/$cm^2$, respectively. These results confirm the high capacity of Treatment 3 to reduce the presence of S. aureus on surfaces, coinciding with what was observed in the disk diffusion test.

**Figure 1. Swab analysis of the surface prior to the disk diffusion test for S. aureus.**




For Escherichia coli, the initial count on untreated surfaces was 4.67 × $10^2$ CFU/$cm^2$. After application of Treatment 1, the bacterial load was reduced moderately, reaching a value of 3.13 × $10^2$ CFU/$cm^2$. However, Treatments 2 and 3 achieved a practically total elimination of recoverable bacteria, recording final counts of 20 CFU/$cm^2$ in both cases. These results are particularly relevant, since they demonstrate that, although E. coli presents greater intrinsic resistance owing to its outer membrane structure (5), the formulations with higher content of star anise essential oil were capable of reducing the microbial load to minimum detectable levels.

Once the formulation with the best antimicrobial performance had been identified, corresponding to Treatment 3, its physicochemical properties were characterized in order to verify compliance with the criteria established in the INEN 2985 Standard for surface disinfectants (8). The analysis revealed that the total surfactant content reached a value of 92.2 %, which indicates adequate detergent capacity and favors the action of the product on the treated surfaces. Likewise, the biodegradability of the surfactant was greater than 90 %, which suggests a lower environmental impact and greater compatibility with sustainability criteria. The titratable active matter was quantified at 8.1 %, remaining below the maximum permitted limit of 10 %, which guarantees the efficacy of the product without compromising user safety. Free alkalinity, expressed as sodium hydroxide (NaOH), was 0.8 %, a value below the maximum permitted limit, which indicates a low risk of corrosion and safe handling. Finally, the pH of the formulation was determined at 4.0, locating it within the range established by the

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standard and favoring the stability of the active compounds, as well as the antimicrobial activity of the product.

**Table 2. Physicochemical parameters of the disinfectant treatment with the best antimicrobial response.**

| Parameters | Barbasco and star anise disinfectant | Parameters established by NTE INEN 2985 (2015) |
|---|---|---|
| Total surfactants | 92.2 % | ≥ 90 % |
| Titratable active matter | 8.1 % | 10 % |
| Free alkalinity as NaOH | 0.8 % | 1.0 % |
| pH | 4.0 | 3.5 – 10 |

The final phase of the results analysis included a microbiological comparison between Treatment 3 and a commercial disinfectant of common use for food-contact surfaces. Against Staphylococcus aureus, the commercial disinfectant presented an average inhibition zone of 24.20 mm, a value very close to that obtained with the natural formulation. Statistical analysis by Student's t-test did not evidence significant differences between the two products, which indicates that Treatment 3 possesses efficacy comparable to the commercial disinfectant for the control of Gram-positive bacteria. Nevertheless, when evaluating the response against Escherichia coli, the commercial disinfectant showed a superior inhibition zone, reaching 26.60 mm, while Treatment 3 presented a lower value. The statistical analysis confirmed a significant difference in favor of the commercial product, which suggests that the natural formulation might require additional adjustments to enhance its action against Gram-negative bacteria.

**Table 3. Comparative analysis between the commercial disinfectant and the best treatment.**

| | *S. aureus* | *E. coli* |
|---|---|---|
| t-Student | -0.866 | 3.674 |
| p-value | 0.7940 | 0.0003 |

Taken together, the results obtained allow the conclusion that Treatment 3 positions itself as a promising natural disinfectant, with high efficacy against Gram-positive pathogens, adequate physicochemical properties, and competitive performance versus commercial products, which supports its potential application as a sustainable alternative in the disinfection of food-contact surfaces.

## DISCUSSION

The results obtained in the present research evidence that the combination of barbasco extract (Bonellia sprucei) and star anise essential oil (Illicium verum) constitutes a viable alternative for the disinfection of surfaces in contact with raw foods, especially when adequate proportions of both components are employed. The variation in the concentrations of the natural agents evaluated made it possible to demonstrate that antimicrobial efficacy does not depend solely on the presence of both compounds, but on the balance between them, which proves decisive for maximizing their biocidal action.

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In this sense, Treatment 3, characterized by a lower proportion of barbasco extract and a higher concentration of star anise essential oil, showed the highest inhibitory capacity against Staphylococcus aureus and Escherichia coli. This behavior suggests that the bioactive compounds present in the essential oil play a predominant role in the antimicrobial activity of the formulation. Various studies have indicated that metabolites such as anethole, estragole, and limonene possess a marked affinity for bacterial cell membranes owing to their lipophilic nature, which allows them to alter the permeability of the lipid bilayer, provoke the exit of essential intracellular components, and, finally, induce cell death (1–3).

A relevant aspect observed in this study is that the increase in the concentration of barbasco extract, present in Treatments 1 and 2, did not translate into greater antimicrobial activity. On the contrary, the overall efficacy of the formulation decreased. This effect could be associated with a possible antagonistic interaction between the compounds of barbasco and those of star anise essential oil when the former is found at higher concentrations, or else with a dilution effect of the more potent active principles of anise. Similar findings have been reported in investigations where the inadequate combination of plant extracts reduces the expected biocidal activity (4,5).

When contrasting these results with the scientific literature, coherence is observed with studies that report high efficacy of star anise essential oil against Gram-positive bacteria, with inhibition zones comparable to those obtained in this research (6). However, it is particularly relevant that, unlike other works where E. coli showed resistance to anise extracts, Treatment 3 achieved significant inhibition of this Gram-negative bacterium. This effect could be attributed to the high purity of the essential oil employed and to the specific synergy reached in the formulation evaluated, which allowed partial overcoming of the outer membrane barrier characteristic of this bacterial group (7).

From the physicochemical point of view, Treatment 3 presented characteristics that reinforce its potential application in the food industry. The high biodegradability of the surfactant responds to the growing need for more environmentally friendly products, constituting an advantage over conventional synthetic disinfectants, which tend to be persistent and to generate contaminating residues (8). Likewise, the acidic pH of the formulation not only complies with the limits established by current regulations, but also contributes to potentiating antimicrobial activity, given that many pathogens present limited growth under acidic conditions (9). The low free alkalinity, for its part, reduces the risk of corrosion and favors the conservation of work surfaces.

Finally, the comparison with the commercial disinfectant made it possible to contextualize the performance of the developed product. The absence of significant differences in the inhibition of S. aureus positions Treatment 3 as an effective alternative for the control of Gram-positive bacteria. Nevertheless, the greater efficacy of the commercial product against E. coli highlights the structural complexity of Gram-negative bacteria and the need to optimize natural formulations that improve the penetration of their active compounds, while at the same time maintaining an ecological and sustainable approach (10).

## CONCLUSIONS

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The formulation of Treatment 3, composed of 0.01 % barbasco extract and 0.99 % star anise essential oil, proved to be the most efficacious among the alternatives evaluated, achieving significant inhibition zones of 24.80 mm against Staphylococcus aureus and 23.00 mm against Escherichia coli. This superior antimicrobial activity is attributed mainly to the high concentration of star anise essential oil, rich in compounds such as anethole and limonene that destabilize bacterial membranes. It is concluded that there exists an inverse relationship in the interaction of the components, where higher concentrations of barbasco extract, present in the other treatments, negatively affect the biocidal potency of the mixture, suggesting that efficacy rests predominantly on the active principles of star anise.

The analysis of the physicochemical properties of Treatment 3 confirmed its suitability and safety as a disinfectant agent, fully complying with the parameters established by the NTE INEN 2985 standard. The product presents a high biodegradability of 92.2 %, which reinforces its profile as a sustainable and ecological alternative. In addition, its acidic pH of 4.0 and low free alkalinity guarantee not only chemical stability and the potentiation of antimicrobial activity, but also the protection of the treated surfaces against corrosion and safety for the user, validating its potential industrial application.

When comparing the proposed natural disinfectant with a commercial product, it was determined that Treatment 3 possesses statistically equivalent efficacy against Gram-positive bacteria such as S. aureus, positioning itself as a viable and competitive alternative. However, against Gram-negative bacteria such as E. coli, the commercial disinfectant maintained statistical superiority, probably owing to synthetic ingredients designed to penetrate the complex outer membrane of these microorganisms. This indicates that, although Treatment 3 is effective, its formulation might require adjustments or additional natural adjuvants to maximize its spectrum of action against Gram-negative pathogens and to reach levels of efficacy identical to those of traditional chemical disinfectants in this specific bacterial group.

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# ELABORACIÓN Y EVALUACIÓN NUTRICIONAL DE HOJUELAS A BASE DE CÁSCARA DE PLÁTANO ENRIQUECIDAS CON CUSHURO Y CEBADA

# DEVELOPMENT AND NUTRITIONAL EVALUATION OF FLAKES MADE FROM PLANTAIN PEEL ENRICHED WITH CUSHURO AND BARLEY

Jimmy Recalde[1], Shirley Moncayo[2], Liliana Villao[3], Cecibel Alava[4], Jaime Santos[5]
{jimmy.recalde.casquete@uagraria.edu.ec1, smoncayo@uagraria.edu.ec2, lvillao@uagraria.edu.ec3, calava@uagraria.edu.ec4, jsantos@uagraria.edu.ec5}

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**RESUMEN:** El aprovechamiento de residuos agroindustriales de alto valor nutricional constituye una estrategia clave para el desarrollo de alimentos innovadores, sostenibles y funcionales. En este contexto, la cáscara de plátano (*Musa paradisiaca*), generalmente considerada un desecho, presenta un contenido significativo de fibra, carbohidratos y compuestos bioactivos, mientras que el cushuro (*Nostoc sphaericum*) y la cebada (*Hordeum vulgare*) aportan proteínas, minerales y fibra dietética. El objetivo de este estudio fue desarrollar y evaluar hojuelas elaboradas a partir de cáscara de plátano, enriquecidas con cushuro y cebada, como una alternativa alimentaria de mayor valor nutricional y aceptabilidad sensorial. La investigación tuvo un enfoque experimental, en el que se formularon dos mezclas de hojuelas con diferentes concentraciones de cushuro hidratado y deshidratado, harina de cáscara de plátano y harina de cebada, además de un tratamiento testigo. Los tratamientos fueron evaluados mediante análisis bromatológicos para determinar el contenido de proteínas, carbohidratos, grasas, fibra, cenizas y humedad, así como mediante análisis microbiológicos de aerobios mesófilos, mohos, levaduras y *Escherichia coli*, de acuerdo con la normativa vigente de la INEN. Adicionalmente, se realizó una evaluación sensorial con un panel no entrenado para determinar la aceptabilidad del producto. Los resultados evidenciaron que uno de los tratamientos presentó un perfil nutricional superior, destacándose por su mayor contenido de fibra y carbohidratos, la ausencia de microorganismos patógenos y una aceptabilidad sensorial del 87,9 %. Se concluye que la elaboración de hojuelas a base de cáscara de plátano, enriquecidas con cushuro y cebada, constituye una alternativa viable para el aprovechamiento de residuos agroindustriales y el desarrollo de alimentos con valor agregado.

***Palabras clave:*** *residuos agroindustriales, cáscara de plátano, cushuro, cebada, hojuelas*

**ABSTRACT:** The valorization of agroindustrial residues with high nutritional potential represents a key strategy for the development of innovative, sustainable, and functional foods. In this context, plantain peel (*Musa paradisiaca*), commonly regarded as a waste product, contains substantial amounts of dietary fiber, carbohydrates, and bioactive compounds. At the same time, cushuro (*Nostoc sphaericum*) and barley (*Hordeum vulgare*) contribute proteins, minerals, and dietary fiber. The objective of this study was to develop and evaluate flakes made from plantain peel, enriched with cushuro and

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barley, as an alternative food product with improved nutritional value and acceptable sensory attributes. An experimental approach was used in which two flake formulations were developed, differing in the proportions of hydrated and dehydrated cushuro, plantain peel flour, and barley flour, and a control treatment was included. Bromatological analyses were conducted to determine protein, carbohydrate, fat, fiber, ash, and moisture contents, and microbiological analyses were performed for mesophilic aerobic bacteria, molds, yeasts, and *Escherichia coli*, in accordance with current INEN standards. In addition, a sensory evaluation was conducted using an untrained panel to assess product acceptability. The results showed that one treatment exhibited a superior nutritional profile, characterized by higher fiber and carbohydrate contents, absence of pathogenic microorganisms, and a sensory acceptability of 87.9%. It is concluded that the production of flakes based on plantain peel enriched with cushuro and barley is a viable alternative for the utilization of agroindustrial residues and the development of value-added food products.

***Keywords:*** *agroindustrial residues, plantain peel, cushuro, barley, flakes*

[1] Facultad de Ciencias Agrarias, Universidad Agraria del Ecuador, Ecuador, https://orcid.org/0009-0007-2813-953X; +593958845534.
[2] Facultad de Ciencias Agrarias, Universidad Agraria del Ecuador, Ecuador, https://orcid.org/0000-0003-2374-497X; +593987714591.
[3] Facultad de Ciencias Agrarias, Universidad Agraria del Ecuador, Ecuador, https://orcid.org/0000-0002-2677-1415; +593982224534.
[4] Facultad de Ciencias Agrarias, Universidad Agraria del Ecuador, Ecuador, https://orcid.org/0000-0002-8253-2283; +593979359933.
[5] Facultad de Ciencias Agrarias, Universidad Agraria del Ecuador, Ecuador, https://orcid.org/0000-0002-9483-1045; +593994104200.

## INTRODUCTION

During food processing operations, various residues and by-products are generated that, in many cases, could be destined for animal or human consumption or for industrial applications, generating additional economic value (1). Nevertheless, their potential as raw materials is often underestimated owing to the lack of research that allows their chemical and nutritional composition to be characterized, as well as to the scarcity of adequate techniques for their efficient processing and utilization (2). In this context, fruit peels present particular physical, chemical, and biological characteristics that must be evaluated in order to determine their viability as functional ingredients in the food industry (3).

One of the principal applications of these agroindustrial residues is the production of flours, which can be incorporated as ingredients in food products with the purpose of increasing their nutritional value and improving the technological and functional properties of processed foods, such as water-holding capacity, texture, and dietary fiber content (4).

Among these residues, plantain peel stands out for its abundance and nutritional composition. It is estimated that worldwide production of plantain peel reaches approximately 36 million tons, which generate unfavorable environmental impacts when discarded without prior treatment (5).

In some cases, these peels are used as organic fertilizer or as animal feed; however, their potential for human food applications remains underexploited (6). In the Ecuadorian context, this problem acquires relevance owing to the high banana production concentrated in the coastal region. Provinces such as Guayas and Los Ríos contribute a

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significant share to national banana production, which implies a considerable generation of residues associated not only with processing but also with consumption of the fruit (7).

Considering that the peel represents between 30 and 40 % of the total weight of the plantain, the volume of this residue reaches magnitudes that, in the absence of valorization strategies, contribute to the accumulation of organic waste, emission of odors, proliferation of vectors, and higher costs (8,9). In this sense, the utilization of plantain peel as a food ingredient constitutes a viable alternative for mitigating its environmental impact and promoting the circular economy at the regional level.

Despite the wide availability of cereals on the market, the majority of these products are manufactured from traditional cereals such as maize, wheat, or oats, with a high carbohydrate content and a limited contribution of dietary fiber and of proteins of natural origin (10). Various investigations address independently the use of plantain peel as a source of fiber, cushuro as a functional ingredient of high nutritional value, and barley for its β-glucan content; however, these approaches have been developed in isolation and in food matrices different from breakfast cereals (11–13).

In this sense, there exists a knowledge gap regarding the joint integration of these three components in a flake-type product that would make it possible not only to elevate an agroindustrial residue but also to incorporate a non-conventional protein source and a functional cereal in a single formulation. Therefore, the aim is, through the development of flakes based on plantain peel enriched with cushuro and barley, to evaluate in an integral manner their nutritional profile, microbiological safety, and sensory acceptability, as an alternative to conventional cereals.

Among the components of plantain peel are found dietary fiber, carbohydrates, amino acids, polyunsaturated fatty acids such as linoleic acid (Omega-6) and α-linolenic acid (Omega-3), and bioactive compounds associated with health and the prevention of chronic diseases (6). These characteristics make it an innovative raw material for the development of food products.

In the search for non-conventional food sources of high nutritional value, algae and cyanobacteria have acquired special interest. The cyanobacterium Nostoc sphaericum, known as cushuro, is a traditional resource of the Andean region that is characterized by its elevated content of proteins, carbohydrates, fatty acids, and essential minerals such as calcium, iron, phosphorus, sodium, and potassium (14).

In addition, it contains all the essential amino acids and the B-complex vitamins, which positions it as an ingredient with high potential for improving the nutritional status of vulnerable populations, especially children under five years of age, and contributes to the prevention of anemia and malnutrition (15).

On the other hand, among cereals, barley (Hordeum vulgare) has aroused growing interest owing to its capacity to improve the nutritional profile of various foods, especially in bakery and extrusion products (16). Barley is rich in soluble fibers and β-glucans, compounds associated with cholesterol reduction and the improvement of cardiovascular health. Likewise, it constitutes an important source of phytochemicals, such as phenolic compounds, flavonoids, and tocopherols, which present antioxidant activity and contribute to the prevention of diseases related to oxidative stress (17).

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Economic development, population growth, and the growing concern for consumer health have driven new trends in the food industry, oriented toward the development of healthier, more sustainable, and easily consumable products (16). These trends are oriented toward the utilization of industrial residues with nutritional value that, in turn, make it possible to improve the environment. In this context, the present study evaluates the combination of plantain peel flour (Musa paradisiaca), cushuro (Nostoc sphaericum), and barley (Hordeum vulgare) in the elaboration of flakes with an elevated nutritional profile, as a viable food alternative for the utilization of agroindustrial residues through conservation and transformation operations.

The continuous interest in formulating products with an excellent nutritional profile and good sensory acceptability led to the development and evaluation of flakes elaborated from plantain peel (Musa paradisiaca) enriched with cushuro (Nostoc sphaericum) and barley (Hordeum vulgare), with the objective that the incorporation of these ingredients would make it possible to obtain a product with greater nutritional value and superior acceptability relative to a conventional cereal, contributing to the utilization of agroindustrial residues and to the development of value-added foods.

## MATERIALS AND METHODS

### Preparation of raw materials

For the elaboration of the flakes, dehydrated cushuro flour (Nostoc sphaericum), plantain peel flour (Musa paradisiaca), and barley flour (Hordeum vulgare) were employed, selected for their availability, nutritional value, and potential for application in the development of functional foods. All raw materials were subjected to cleaning, disinfection, and conditioning processes in order to guarantee their safety and homogeneity before incorporation into the formulations.

The cushuro was washed with water and subsequently disinfected with a sodium hypochlorite solution. Next, it was subjected to a dehydration process in an oven at 50 °C for five days, with the objective of reducing moisture content and facilitating its conservation and milling. Once dehydrated, the material was ground in a manual mill until a flour of homogeneous particle size was obtained, suitable for incorporation into the flake formulation.

The plantain peels were selected manually, discarding those with physical damage or signs of deterioration. Subsequently, they were washed with potable water and disinfected with a sodium hypochlorite solution. With the purpose of inactivating enzymes that could affect the stability of the final product, the peels were subjected to blanching at 95 °C for 5 minutes. Once blanched, they were dehydrated in a food dehydrator at 57 °C for eight hours, until a dry raw material was obtained, which was ground in a mill until a flour of uniform particle size was obtained.

The barley was previously subjected to a cleaning process to eliminate impurities. Subsequently, the grains were disinfected with a sodium hypochlorite solution and dried in a food dehydrator at 50 °C for 10 hours. Once dry, the grains were ground in a roller mill until a fine flour was obtained, suitable for incorporation into the formulations.

### Obtaining hydrated cushuro

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The cushuro used in its hydrated form was previously inspected to verify its quality and physical state. A washing with potable water was performed, followed by a disinfection process with a sodium hypochlorite solution, in order to eliminate possible impurities, residues, or microbiological contaminants. Subsequently, the cushuro was maintained under adequate hydration conditions until its incorporation into the corresponding formulations.

**Elaboration of the flakes**

Four treatments were formulated with different proportions of hydrated and dehydrated cushuro, plantain peel flour, and barley flour (Table 1). The first formulation included 10 % cushuro, 20 % plantain peel flour, and 8 % refined sugar. The second formulation was composed of 5 % cushuro, 8 % barley flour, and 24 % plantain peel flour. In both formulations, common ingredients were incorporated: 4 % powdered milk, 6 % cocoa, 2 % vegetable colorant, and 42 % water, in order to improve the sensory and technological characteristics of the final product.

All ingredients were mixed in an electric mixer until a homogeneous mass of uniform consistency was obtained. The resulting mass was subjected to rolling with rollers to obtain thin and uniform sheets. Subsequently, the sheets were baked at 160 °C for 10 minutes. After cooking, the flakes were allowed to cool until room temperature was reached, which permitted them to develop a characteristic crispy texture. Finally, the flakes were packaged in plastic bags and stored at a temperature between 18 and 24 °C until analysis (Figure 1).

**Figure 1. Flow diagram of the flake elaboration process.**

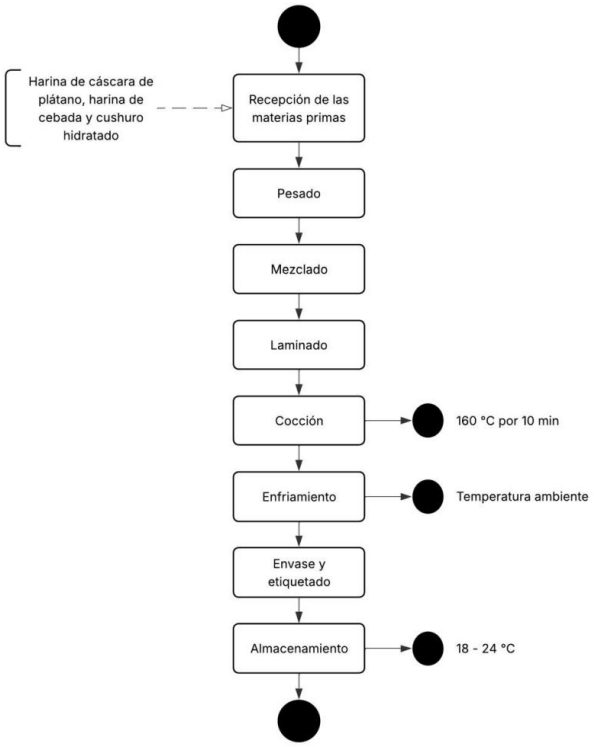

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**Table 1. Formulation of the flakes.**

| Treatment | Cushuro (%) | Plantain peel flour (%) | Barley flour (%) | Sugar (%) | Other ingredients* (%) |
|---|---|---|---|---|---|
| T1 | 10 (dehydrated) | 20 | – | 8 | 62 |
| T2 | 5 (dehydrated) | 24 | 8 | – | 63 |
| T3 | 10 (hydrated) | 20 | – | 8 | 62 |
| T4 | 5 (hydrated) | 24 | 8 | – | 63 |

*Other ingredients: powdered milk (4 %), cocoa (6 %), vegetable colorant (2 %), and water (42 %).

### Bromatological analyses

The bromatological analyses of the flakes were performed in accordance with Ecuadorian standard INEN 2570:2011. Carbohydrate content was determined by the 3,5-dinitrosalicylic acid (DNS) method; protein content by the Bradford spectrophotometric method; and fat content by extraction and spectrophotometric quantification. Ash content was determined according to standard NTE INEN 520:2012, while crude fiber content was evaluated according to standard NTE INEN 522:2013. All analyses were performed in triplicate.

### Microbiological analyses

The microbiological quality of the flakes was evaluated by determination of mesophilic aerobes, molds, yeasts, and Escherichia coli, in accordance with the methods established in standards NTE INEN 1529-5, NTE INEN 1529-10, and NTE INEN 1529-7, respectively, with the objective of verifying the safety of the final product.

### Statistical analysis

The present project was evaluated by means of a statistical analysis of the completely randomized design (CRD), and the data were analyzed by analysis of variance (ANOVA) with the Dunn-Bonferroni test, at a significance level of 5 %. The tests were performed with the statistical program JASP.

### Sensory analysis

The sensory evaluation of the flakes was performed with an untrained panel of 100 persons, evaluating the parameters of color, flavor, odor, and texture, by means of a five-point hedonic scale, where 1 corresponded to “dislike very much”; 2, “dislike moderately”; 3, “neither like nor dislike”; 4, “like moderately”; and 5, “like very much.”

## RESULTS

### Results of the bromatological analysis

The bromatological analyses performed on the flakes elaborated from plantain peel, cushuro, and barley evidenced differences in the nutritional profile among the treatments evaluated, associated mainly with the proportion and form of incorporation of cushuro (hydrated and dehydrated) and of the plant flours used (Table 2). In general, all treatments presented nutritional values consistent with those of cereal-type products, standing out for their content of carbohydrates and dietary fiber.

**Table 2. Bromatological composition of the elaborated flakes (%).**

| Treatment | Carbohydrates (%) | Proteins (%) | Fats (%) | Fiber (%) | Ash (%) | Moisture (%) |
|---|---|---|---|---|---|---|
| T1 | 78.42 ± 0.89a | 1.21 ± 0.18ab | 0.45 ± 0.09a | 13.85 ± 0.42a | 0.18 ± 0.04a | 2.34 ± 0.07a |
| T2 | 74.63 ± 1.12a | 1.08 ± 0.21ab | 0.48 ± 0.11a | 12.46 ± 0.38a | 0.22 ± 0.05a | 2.91 ± 0.10a |
| **T3** | **85.31 ± 11.64a** | **1.94 ± 0.50b** | **0.42 ± 0.10a** | **16.97 ± 0.35b** | **0.13 ± 0.06a** | **1.87 ± 0.06a** |

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|---|---|---|---|---|---|---|
| T4 | 80.15 ± 1.05a | 1.36 ± 0.27a | 0.44 ± 0.08a | 14.62 ± 0.40a | 0.16 ± 0.03a | 2.10 ± 0.08a |

*Values expressed as mean ± standard deviation (n = 3). Different letters indicate significant difference according to the Dunn-Bonferroni test $p < 0.05$.

Carbohydrate content was the majority component in all formulations analyzed. Treatment T3 presented the highest value, reaching 85.31 ± 11.64 %, which is attributed to the combination of plantain peel flour and barley, ingredients recognized for their high contribution of structural and non-structural polysaccharides. The other treatments showed lower values, although within ranges comparable to those of commercial cereals. No significant differences were observed among treatments ($p > 0.05$).

The results evidenced an increase in protein content in the treatments that incorporated cushuro, especially in its dehydrated form. Treatment T3 presented the most favorable nutritional profile (Table 2), standing out for its higher fiber and carbohydrate content. These values are moderate in comparison with those of fortified cereals; however, they represent a nutritional improvement relative to products elaborated exclusively with conventional flours. Analysis of variance indicated significant differences among T3, T4, and the control treatment ($p < 0.05$).

All treatments presented a low fat content, with values that oscillated between 0.42 ± 0.10 % and 0.48 ± 0.11 %, which is favorable from the nutritional point of view and for product stability. Similarly, ash content was reduced, with values close to 0.13 ± 0.06 %, which indicates that the mineral composition does not exceed the limits established for this type of product. The treatments were significantly similar ($p > 0.05$).

Treatment T3 presented the highest crude fiber content, with a value of 16.97 ± 0.35 %, and was the only one that differed significantly from the others ($p < 0.05$). This result is related directly to the use of plantain peel flour, recognized for its elevated dietary fiber content. Moisture content was minimal in all treatments, with treatment T3 standing out with a value of 1.87 ± 0.06 %, which favored microbiological stability and the shelf life of the product. No significant differences were observed among the treatments evaluated ($p > 0.05$).

## Results of the microbiological analysis

The results of the microbiological analysis demonstrated that all flake formulations complied with the requirements of Ecuadorian standard NTE INEN 2570:2011.

**Table 3. Microbiological evaluation of the flakes.**

| Microbiological analysis | Standard applied | Unit | Result | Permitted limit |
|---|---|---|---|---|
| Mesophilic aerobes | NTE INEN 1529-5 | CFU/g | < 10 | $\leq 1 \times 10^5$ |
| Molds and yeasts | NTE INEN 1529-10 | CFU/g | < 10 | $\leq 1 \times 10^3$ |
| *Escherichia coli* | NTE INEN 1529-7 | CFU/g | Absence | Absence |

*Source: Own elaboration based on the microbiological reports according to standards NTE INEN 1529-5, NTE INEN 1529-10, and NTE INEN 1529-7.

The presence of mesophilic aerobes, molds, yeasts, or Escherichia coli was not detected in any of the treatments, which confirms the microbiological safety of the final product and the effectiveness of the cleaning, dehydration, and cooking processes applied during its preparation.

## Results of the sensory evaluation

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In the sensory evaluation, performed by means of a 5-point hedonic scale, differences were observed among the treatments evaluated. Treatment T3 presented the most consistent performance and the highest global acceptance. When analyzing the attributes individually, color was the best valued in T3, followed by T4, while T1 and T2 registered the lowest means, locating themselves between a neutral perception and moderate acceptance. Regarding odor, T3 again stood out with the highest average score, while the other treatments showed intermediate values, which indicates stable, although less marked, acceptance. Texture was the attribute with the greatest contrast among treatments, since T3 reached the highest score, while T1 and, especially, T2 presented the lowest scores, which suggests that this attribute influenced in an important manner the lower acceptability of those treatments. Finally, in the flavor attribute, T3 obtained the highest mean, followed by T4, while T1 and T2 showed lower ratings, which confirms that the sensory differences, particularly in flavor and texture, influenced the observed global preference.

The results indicate that, by means of the incorporation of cushuro, plantain peel, and barley in adequate proportions, flakes with sensory characteristics acceptable to the consumer can be obtained, comparable to commercial cereals but with a better nutritional profile.

## DISCUSSION

The results obtained in the present study confirm the potential of plantain peel, cushuro, and barley as viable raw materials for the development of innovative food products with added nutritional value, as has been reported in previous investigations on the utilization of agroindustrial residues and the development of functional foods (18). The bromatological profile of the elaborated flakes evidenced that the adequate combination of these ingredients makes it possible to obtain a product with characteristics comparable to those of conventional cereals, but with a greater contribution of fiber and of compounds of nutritional interest (19,20).

The elevated carbohydrate content observed in the treatments analyzed, particularly in treatment T3, is in concordance with previous studies that report high levels of polysaccharides in plantain peel and in barley, which contribute to the energy value of the product and to its functionality as a food of everyday consumption (21,22). Investigations carried out by Pilco et al. (2018) and Mohd et al. (2022) have indicated that plantain peel constitutes an important source of structural carbohydrates and of dietary fiber, which supports the results obtained in this study.

Regarding crude fiber content, the highest values recorded in treatment T3 can be attributed mainly to the use of plantain peel flour, an ingredient recognized for its high dietary fiber content. Similar results have been reported in studies in which plantain peel flour has been incorporated into bakery products and cereals, evidencing significant improvements in fiber content and in the functional properties of the final food (23,24). This aspect is relevant from the nutritional point of view, given that adequate consumption of dietary fiber is associated with benefits for gastrointestinal health and the prevention of chronic diseases.

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The protein content observed in the flakes, although moderate, reflects the contribution of cushuro, a cyanobacterium of recognized nutritional value. Various authors have reported elevated protein contents in Nostoc sphaericum, highlighting its potential as an alternative source of protein of non-conventional origin (25,26). Although the protein values obtained in this study are lower than those reported for highly fortified products, their inclusion contributes to diversifying the nutritional profile of the product and to improving its quality relative to cereals elaborated exclusively from refined flours, as has also been evidenced in formulations that incorporate cushuro into food products (27,28).

The low fat content observed in all formulations constitutes a favorable characteristic of the product, since it allows its classification as a food with reduced lipid contribution, in accordance with current consumption trends oriented toward healthier foods. Previous studies have indicated that products elaborated from agroindustrial residues and plant flours tend to present similar fat contents, which coincides with the results obtained in the present investigation (6,29).

From the microbiological point of view, the absence of pathogenic microorganisms in the flakes confirms the efficacy of the cleaning, dehydration, and cooking processes. These results are consistent with investigations in which agroindustrial residues are employed as raw material, demonstrating that, under adequate processing conditions, it is possible to obtain products suitable for human consumption.

The sensory evaluation showed acceptance of the flakes, with treatment T3 standing out as that of greatest preference. This could have been due to the balance reached among the ingredients, which made it possible to obtain adequate sensory characteristics in terms of flavor, texture, and appearance. Results similar to those of the present investigation have been reported in studies that incorporate non-conventional flours into cereal-type products, with formulation and ingredient proportion being determining factors in consumer acceptance (20,28).

The greater sensory acceptance observed in treatment T3 can be explained in function of the concentration and form of incorporation of the ingredients employed. In this treatment, the use of cushuro in its hydrated form and in greater proportion contributed to a more homogeneous matrix, which favored the perception of flavor and texture relative to the treatments with dehydrated cushuro.

Likewise, the balance of plantain peel flour employed in T3 made it possible to increase fiber content without generating negative effects on color or sensory acceptability, in contrast to the formulations with higher proportions of this ingredient. On the other hand, the absence of barley flour in T3 could have favored a lighter and crispier texture, while its inclusion in other treatments was associated with a more compact structure, perceived less favorably by the panelists. Taken together, these results evidence that the trend observed in the sensory data is closely related to the concentration and form of incorporation of each ingredient.

The results of the present study demonstrate the viability of the utilization of residues such as plantain peel, combined with raw materials of high nutritional value such as cushuro and barley, for the development of functional foods, and provide scientific evidence that supports the implementation of the circular economy in the food sector

and open the possibility of carrying out future investigations that seek to optimize the formulations and evaluate their long-term nutritional effect.

## CONCLUSIONS

The elaboration of flakes from plantain peel (Musa paradisiaca) enriched with cushuro (Nostoc sphaericum) and barley (Hordeum vulgare) proved to be a viable alternative for the utilization of agroindustrial residues, making it possible to obtain a product with an adequate nutritional profile and characteristics comparable to those of conventional cereals. The incorporation of these ingredients contributed mainly to the increase in fiber and carbohydrate content, as well as to the nutritional diversification of the product, without negatively affecting its safety or sensory properties.

The bromatological analyses demonstrated that the formulation that combined 20 % plantain peel flour and 10 % hydrated cushuro presented a superior nutritional profile, standing out for its higher fiber content and its low fat content, which makes it a healthy food. Likewise, the microbiological results confirmed that all formulations complied with the limits established in current Ecuadorian regulations, which demonstrates that the cleaning, dehydration, and cooking processes proved effective for guaranteeing a final product suitable for consumption.

The sensory evaluation made it possible to establish that the flakes were well received by consumers. This result demonstrates that the use of non-conventional ingredients, such as cushuro and plantain peel, can be integrated effectively into cereal flakes without compromising their acceptance. Taken together, the results of the present study demonstrate the potential of these ingredients for the development of innovative functional foods and orient future investigations aimed at the optimization of products.

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## DECLARATION OF INTEREST

The authors declare that there exists no financial, academic, or personal conflict of interest that has influenced the development, the analysis of the results, or the writing of the present scientific article.

## AUTHOR CONTRIBUTIONS

The principal author was responsible for the experimental design, for the elaboration of the product, for the execution of the bromatological and microbiological analyses, as well as for the collection and analysis of the data. The academic tutor contributed to the

methodological supervision of the study, to the critical revision of the content, and to the scientific orientation during the development of the research. All authors participated in the writing, the revision, and the final approval of the manuscript.

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# PARASITOSIS INTESTINALES EN CANINOS DE REFUGIOS: EVIDENCIA EPIDEMIOLÓGICA Y PERSPECTIVAS DE CONTROL SANITARIO

# INTESTINAL PARASITES IN SHELTER CANINES: EPIDEMIOLOGICAL EVIDENCE AND HEALTH CONTROL PERSPECTIVES

John H. Velásquez[1], Javier Enrique Camacho Castillo[2], Verónica Elizabeth Llamuca Pineda[3], Carolina Natalia Cruz Chavarrea[4], Melanie Lisseth Cepeda Morales[5]

{j.velasquez@sangabrielriobamba.edu.ec1, jecctms@hotmail.com2, verisofva@gmail.com3, caro2232_@hotmail.com4, melanicepeda27@gmail.com5}

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**RESUMEN:** Las parasitosis intestinales en caninos de refugio representan un problema de relevancia biológica, social y sanitaria debido a las condiciones de hacinamiento, deficiencia en infraestructura y ausencia de programas sistemáticos de control veterinario; estas infecciones, causadas principalmente por helmintos y protozoarios como *Ancylostoma spp*, *Toxocara canis*, *Trichuris vulpis* y *Giardia spp.*, comprometen no solo el bienestar y la salud de los animales, sino que también constituyen un riesgo zoonótico que impacta en la salud pública. El siguiente artículo se propuso revisar la evidencia científica existente sobre la prevalencia de parásitos intestinales en los perros de refugio, determinar factores de riesgo asociados con ello, así como analizar las implicaciones epidemiológicas y sociales de este problema. Se llevó a cabo un estudio documental siguiendo un diseño descriptivo y analítico de revisión bibliográfica, sistematizando artículos de la producción científica publicados en bases de datos internacionales entre los años 2021 y 2025. Los resultados muestran prevalencias que oscilan entre el 25% y el 80%, con cifras más elevadas en América Latina, Asia y África, en contraste con Norteamérica y Europa, donde los valores son menores gracias a protocolos de diagnóstico y control más robusto. Entre los parásitos que se reportaron con mayor frecuencia destacan *Ancylostoma spp.* y *Toxocara canis*, además de la presencia de *Giardia spp.*, relevante por su potencial de transmisión interespecífica. Los principales factores asociados a la persistencia de las infecciones fueron la edad, el estado nutricional, las condiciones ambientales y la falta de acceso a atención veterinaria. Se concluye que la carencia de información sistemática en países andinos como Ecuador limita el diseño de políticas públicas eficaces. Por ello, se recomienda fomentar investigaciones longitudinales y multicéntricas que aporten datos sólidos sobre prevalencia, factores de riesgo y efectividad de intervenciones, integrando el enfoque “One Health” y garantizando el bienestar animal en refugios.

***Palabras clave:*** *Parasitosis intestinal, refugios caninos, zoonosis, salud pública, bienestar animal, epidemiología*

**ABSTRACT:** Intestinal parasitosis in shelter dogs represents a significant biological, social, and public health problem due to overcrowding, inadequate infrastructure, and the absence of systematic veterinary control programs. These infections, primarily

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caused by helminths and protozoa such as Ancylostoma spp., Toxocara canis, Trichuris vulpis, and Giardia spp., compromise not only the animals' well-being and health but also constitute a zoonotic risk that impacts public health. This article aimed to review the available scientific evidence on the prevalence of intestinal parasites in shelter dogs, identify associated risk factors, and analyze the epidemiological and social implications of the problem. A documentary study was conducted using a descriptive and analytical literature review design, systematizing articles published in international databases between 2021 and 2025. The results show prevalence rates ranging from 25% to 80%, with higher figures in Latin America, Asia, and Africa, in contrast to North America and Europe, where rates are lower due to more robust diagnostic and control protocols. Among the most frequently reported parasites were Ancylostoma spp. and Toxocara canis, in addition to the presence of Giardia spp., which is relevant due to its potential for interspecific transmission. The main factors associated with the persistence of infections were age, nutritional status, environmental conditions, and lack of access to veterinary care. It is concluded that the lack of systematic information in Andean countries like Ecuador limits the design of effective public policies. Therefore, it is recommended to promote longitudinal and multicenter research that provides solid data on prevalence, risk factors and effectiveness of interventions, integrating the One Health approach and ensuring animal welfare in shelters.

***Keywords:*** *Intestinal parasitosis, dog shelters, zoonosis, public health, animal welfare, epidemiology*

[1] Instituto Superior Tecnológico San Gabriel, Coordinador de carrera de Tecnología Superior en Cuidado Canino, https://orcid.org/0000-0002-4880-2841.
[2] Instituto Superior Tecnológico San Gabriel, https://orcid.org/0009-0008-3981-2694.
[3] Clínica Veterinaria Dogtor Vet, Auxiliar de Clínica Veterinaria, https://orcid.org/0009-0001-8496-0281, 0967913602.
[4] GADMC PENIPE, Asistente Administrativo 2 / Productivo, https://orcid.org/0009-0004-0987-967X, 0994882976.
[5] Autor Independiente, https://orcid.org/0009-0001-2572-1686, 0985794928.

## INTRODUCTION

Gastrointestinal parasitosis in canines is one of the most common problems for veterinarians, but at the same time it is a potentially endemic problem for public health; these agents are mainly helminths and protozoa of worldwide distribution, which affect dogs in the majority of contexts, but have a higher prevalence in risk situations such as those that occur in shelters and temporary shelters. The condition of these institutions (with overcrowding, limited economic resources, and deficit of sanitary infrastructure) allows the persistence and dissemination of gastrointestinal parasites of veterinary and zoonotic importance (1) (2). Thus, dogs in shelters not only have their physical and physiological well-being compromised, but in addition are a potential means of transmission of pathogens to the human population that cohabits with them or that comes into contact with infected environments (3).

The scientific literature has provided a large amount of information that makes evident that intestinal parasites are one of the most frequent infections in dogs. Different studies carried out in different latitudes have reported prevalences that oscillate between 30% and 80% in canine populations of dog shelters, the most commonly identified infectious agents being *Ancylostoma spp., Toxocara canis, Trichuris vulpis* and *Giardia spp.* (1) (4) (5). These figures are very different from those observed in dogs that live at home or in dogs that receive periodic veterinary care, in whose case the

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prevalence is much lower owing to the application of systematic deworming programs improving the state of the animals and the conditions of hygiene and nutrition (2). The situation is much more critical in Latin American countries where the economic conditions and the low coverage of animal health systems are factors that favor the transmission of this parasitosis and its control.

In Brazil, for example, prevalences higher than 60% have been documented in urban shelters, while in the case of Colombia the data appear around 54%. An investigation carried out in Mexico on stray dogs indicates a positivity of 37%; in Ecuador, for its part, data have been made public that exceed 70% in populations of urban shelters (5) (6) (7). These findings not only make evident the magnitude of the problem, but in addition suggest a close relationship between the socio-environmental context and the dynamics of transmission of intestinal parasites. In regions with high population density, deficiency in waste collection, absence of systematic plans of veterinary control, and exposure to contaminated water sources, the propagation of these agents is practically inevitable (3) (4).

The impact of intestinal parasitosis in canines transcends the veterinary sphere. *Ancylostoma spp.* is capable of producing cutaneous larva migrans in humans, while *Toxocara canis* can occasion visceral and ocular larva migrans, with consequences that range from gastrointestinal symptoms to neurological and visual complications. *Giardia spp.*, for its part, represents a relevant agent of diarrhea in communities with limited conditions of basic sanitation (3) (8). In this sense, canine parasitosis in shelters must be addressed under the perspective of One Health, considering the interdependence between animal health, human health, and the environment (2) (8).

In addition to their zoonotic importance, these infections seriously compromise animal well-being. Affected dogs can present chronic diarrhea, vomiting, weight loss, growth retardation, anemia, and immunosuppression, which in turn increases susceptibility to other diseases (2) (5). From an ethical perspective, it is imperative to guarantee the right to the well-being of shelter animals, framed in the five freedoms of animal welfare, among which are included being free from pain, injuries, and diseases.

The review of the literature reflects, however, that gaps still persist in the epidemiological knowledge of intestinal parasitosis in shelter dogs, especially in Andean countries such as Ecuador, where the studies are scarce and fragmented (6) (7). This absence of systematic information not only limits the design of control programs adapted to the local reality, but in addition hinders the incorporation of the One Health approach, which requires evidence on how animal, human, and environmental health are integrated, in order thereby to establish sustainable public policies. In this sense, the generation and systematization of epidemiological information in the Ecuadorian context is a priority in order to orient sanitary interventions that reduce the zoonotic risk and strengthen the sanitary management of shelters.

In this context, the need arises to compile, analyze, and discuss critically the available evidence with the aim of identifying the most relevant epidemiological patterns and the risk factors associated with the presence of intestinal parasites in shelter canines. Among these factors stand out age, body condition, access to potable water, type of feeding, and conditions of overcrowding, variables that directly influence the parasitic load and community transmission (1) (3) (4).

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This article has as its purpose to synthesize the available information on the prevalence of intestinal parasites in dogs and bitches of shelters; to analyze and extract from the literature the risk factors implicated in a greater parasitic load in dog shelters and, in third place, to address the control strategies that have greater interest and applications in public health and animal welfare, which include the measures in shelters so that they serve as information or inputs at the time of enriching the sanitary management programs and shelters of the region.

Therefore, the specific objectives that will guide the review are, in the first place, to synthesize the information on the prevalence of intestinal parasites in shelter canines at global and regional scale; in the second place, to identify and analyze the risk factors that may be implicated in a greater parasitic load in shelters and, in the third place, to address the strategies that have been applied, as well as their visions taking into account public health and animal welfare.

## MATERIALS AND METHODS

The present work is a documentary-type study that has its base in a descriptive and analytical design of the bibliographic review type. It was developed on the explanatory plane, inasmuch as it was not limited to compiling published data, but rather it was intended to make relations between the prevalence of intestinal parasites in canines in shelters, risk of parasitization associated, and their implications in public health and animal welfare.

Works that offered information of international type were included in its content in order to have a broad and comparative vision of the problem. The process by which the final sample was selected was carried out by means of a systematic process of screening of publications obtained in the international databases, establishing the criterion of prioritizing those articles published as of the year 2021, in such a manner that from a temporal perspective the most recent evidence is made evident.

The search context is defined by the need to analyze the epidemiological situation of intestinal parasitosis in canines in shelter environments where the socioeconomic situation, population density, and sanitary infrastructure represent influencing factors. Priority was given to the inclusion of studies with representative samples, clear diagnostic methodologies, and analysis of risk factors, following the guidelines of the PRISMA statement for literature reviews, which made it possible to organize the process in phases of identification, screening, eligibility, and inclusion of the studies (9).

The procedure of information collection was carried out between the months of June and August of 2025. The search strategy included keywords in English and Spanish, such as “dog shelters”, “canine intestinal parasites”, “zoonotic helminths”, “protozoa in dogs”, “parasitosis intestinal en perros”, “refugios caninos”, and “zoonosis”. Boolean operators (AND, OR, NOT) and specific filters by temporal range (2021-2025), language (English and Spanish), and type of document (original articles, systematic reviews, prevalence studies, and epidemiological reports) were applied. The principal databases consulted were PubMed, Scopus, Web of Science, SciELO, Redalyc, and Google Scholar.

The inclusion criteria contemplated: articles published in peer-reviewed and indexed journals, studies that reported prevalence, risk factors, or zoonotic implications of

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intestinal parasites in dogs, works that included shelter, stray, or vulnerable-condition populations, and publications as of the year 2021. As exclusion criteria were considered those articles for which full text was not available, publications with ambiguous methodologies or with manifest biases in the sampling, clinical reports without epidemiological data, and gray literature not peer-reviewed.

The treatment of the information was carried out through a thematic and comparative analysis. In each publication the following data were collected: author, year, country or region, sample size, type of canine population, diagnostic method, global and by-parasite prevalence, risk factors analyzed, and main conclusions. Subsequently, the articles were classified on the basis of the region and the most frequent parasitic agent. This organization made possible the identification of shared patterns, territorial divergences, and knowledge gaps.

In order to minimize biases and increase the reliability of the synthesis, the methodological quality of the studies was valued attending to whether the study had clearly defined the study population, whether the population size had been representative, whether it had described the sampling procedure, whether the diagnostic techniques used were valid, and whether there was consistency among the objectives, the results, and the conclusions. It was also examined whether the authors manifested eventual limitations or sources of error of their investigations. The articles were evaluated on the basis of these criteria in a qualitative form considering their methodological rigor and priority was given in the discussion to those that showed greater robustness in the design and in the presentation of the results. It was verified that the selected publications had employed recognized diagnostic techniques, such as centrifugal flotation, sedimentation, antigen immunoassays, or molecular tests (PCR). In those cases in which the studies relied on methodologies already validated by the literature, the original sources were cited with the aim of recognizing the standardized procedures.

The management of the references was performed following the Vancouver citation norms. Each source was contrasted with its DOI or link in academic repositories, which ensures the traceability and transparency of the review.

## RESULTS AND DISCUSSION

The systematic review of the literature made it possible to identify 35 articles published between 2021 and 2025 that addressed the prevalence of intestinal parasites in shelter dogs and analogous contexts in different regions of the world. The results showed that intestinal parasitosis continued to be a recurrent problem in these canine populations, with global prevalences that oscillated between 25% and 80%, depending on the region, the sample size, the conditions of the shelter, and the diagnostic methodologies employed (5, 7, 9-12).

The evidence was organized in comparative tables by continents, which made it possible to visualize epidemiological patterns, predominant parasitic species, and differences in the control measures applied (10) (11). Subsequently, the results were analyzed in the light of the risk factors, the diagnostic techniques, and the zoonotic implications.

### Prevalence in Latin America

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The literature showed that Latin America continues to be one of the regions with the highest prevalences of intestinal parasites in shelter dogs. The figures were explained by the limitations in infrastructure, the overcrowding, and the scarce coverage of animal health programs.

**Table 1. Prevalence of gastrointestinal parasites in dogs of Latin America (2021-2025).**

| Country | N (sample) | Main parasites | Prevalence (%) | Source |
|---|---|---|---|---|
| Brazil (urban) | 315 | *Ancylostoma spp., Giardia spp.* | 62.1 | (12) |
| Colombia (Cali) | 187 | *Toxocara canis, Trichuris vulpis* | 54.0 | (13) |
| Mexico (Hidalgo) | 250 | *Ancylostoma caninum, Giardia spp.* | 37.2 | (7) |
| Ecuador | 142 | *Toxocara spp., Trichuris spp.* | 71.4 | (6) |
| Peru (Lima) | 98 | *Toxocara canis, Giardia spp.* | 58.7 | (14) |
| Argentina (Buenos Aires) | 126 | *Toxocara canis, Cystoisospora spp.* | 46.2 | (15) |

*Source: Own elaboration based on the data of the study, 2025.*

The evaluation of the condition of the studies for Latin America reveals an epidemiological state with high rates of infection and a broad spectrum of parasitic species, which indicates that there exists active, maintained, and possibly conferred circulation of the parasites under the conditions of the shelter, whose relation appears taken from the common structural characteristics in the region, the most important of which are the deficiencies in sanitary infrastructure, the high turnover of the animals, and the difficulties for the maintenance of programmed dewormings and the sanitary state of the same. With respect to the biological distribution, the helminths occupy a prominent place starting from the identification in the studies of the genera Ancylostoma and Toxocara, whose persistences would be associated with the environmental resistance triggered by their infective forms and with the management conditions that promote reinfection. Also the detection in the studies of protozoa, such as Giardia spp., reinforces the impact of the hygienic-sanitary conditioners and the conditions of water quality as determinants of the transmission cycle of the considered parasite.

## Prevalence in Europe

The European studies reported lower prevalences in comparison with Latin America, which was related to the application of entry protocols, preventive deworming, and routine diagnostics in shelters.

**Table 2. Prevalence of intestinal parasites in shelter dogs in Europe (2021-2025).**

| Country | N (sample) | Main parasites | Prevalence (%) | Source |
|---|---|---|---|---|
| Spain (shelters) | 204 | *Giardia spp., Ancylostoma spp.* | 28.5 | (16) |
| Italy (Rome) | 112 | *Trichuris vulpis, Giardia spp.* | 22.4 | (17) |
| Germany (Berlin) | 156 | *Giardia spp.* | 19.7 | (18) |

*Source: Own elaboration based on the data of the study, 2025.*

The European studies expose a rather controlled epidemiological scenario and that makes one think that the putting into practice of entry protocols, of preventive deworming, and of diagnostic follow-up would be responsible for the diminution of the parasitic load in the shelters.

In a coherent form, the data also indicate that the protozoa, especially Giardia spp., present a relatively high frequency, suggesting that, even in places where adequate sanitary programs are applied, the parasites with environmentally direct transmission cycles continue to be an obstacle at the time of being able to control the parasitosis. The diversity of parasites in some of the studies makes evident that the origin of the animals,

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the turnover of the animals, and the conditions of the lodgings contribute to the transmission.

In this line, different authors agree that the arrival of diagnostic techniques with greater sensitivity such as is the case of ELISA or PCR has permitted a better detection of subclinical infections, improving the taking of sanitary decisions and the elaboration of better focused ones on the fight against the parasites (16) (17).

### Prevalence in Asia

In Asia, the prevalence was elevated, especially in countries with high canine density and limited access to veterinary services. The studies reported figures that placed the region among those with the highest burdens of intestinal parasites in shelter and free-roaming dog populations, reflecting structural constraints similar to those observed in parts of Latin America and Africa. The combination of high animal turnover, inadequate sanitation, and limited systematic deworming programs contributes to sustained transmission cycles.

### Prevalence in Africa

The studies carried out in Africa find prevalences of intestinal parasitosis in shelter dogs among the highest, which makes evident an epidemiological context that responds to a very intense circulation of the parasitic agents. This behavior can be explained fundamentally by structural and environmental factors, such as: scarce veterinary coverage, difficulties in the application of systematized deworming programs, and sanitary conduction that is habitually very poor in shelter and reception centers.

On the other hand, the intense interaction that is produced between street dogs, sheltered dogs, and the human community increases the environmental contamination by infective forms and, therefore, increments the potential of zoonotic transmission. This situation not only maintains the infections in the canine population, but represents a public health problem, above all in populations very compromised with respect to the norms of basic sanitation.

In addition to that, the information that is presented in Table 4 is sufficiently illustrative about the magnitude of the problem and, in addition, corroborates the exigency of integral control strategies that include sanitary management, community education, and epidemiological surveillance over time.

**Table 4. Prevalence of intestinal parasites in shelter dogs in Africa (2021-2025).**

| Country | N (sample) | Main parasites | Prevalence (%) | Source |
|---|---|---|---|---|
| Ethiopia | 190 | *Toxocara canis, Giardia spp.* | 68.2 | (1) |
| Nigeria | 145 | *Ancylostoma spp., Isospora spp.* | 72.5 | (22) |
| Kenya | 948 | *Strongyloides stercoralis, Ancylostoma braziliense, A. caninum, Toxocara canis* | 39.8 | (23) |

*Source: Own elaboration based on the data of the study, 2025.*

### Prevalence in North America

The set of studies carried out in North America shows us an epidemiological picture where the prevalences observed are sensibly lower than those of other regions, which points to the possibility that the sanitary control systems established in shelters and reception centers are efficacious. This tendency can be related to the application of systematic entry protocols, programs of periodic deworming, long-term clinical follow-up, and routine use of diagnostic tools with greater sensitivity.

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The higher levels of sanitary norms and of the possibilities of management and animal welfare go hand in hand to reduce the circulation and the maintenance of intestinal parasites in these populations. In a complementary form, the education of the adopter and the veterinary follow-up after the adoption are elements that contribute to limiting the reinfection and the environmental distribution of infectant forms.

The data contained in Table 5 allow us to observe the general tendency of the region and, above all, to make evident that the implementation of sanitary control strategies can have an important effect on the reduction of the parasitic load in animals of reception.

**Table 5. Prevalence of intestinal parasites in shelter dogs in North America (2021-2025).**

| Country | N (sample) | Main parasites | Prevalence (%) | Source |
|---|---|---|---|---|
| United States | 210 | *Giardia spp., Ancylostoma spp.* | 24.3 | (2) |
| Canada | 165 | *Giardia spp., Cystoisospora spp.* | 18.6 | (24) |

*Source: Own elaboration based on the data of the study, 2025.*

In these countries, the programs of early diagnosis and the frequent sanitary control reduced the figures to less than 25%.

Beyond the numerical data, the reviewed studies indicated that the age of the animals was a determining factor: the puppies presented higher parasitic loads and with greater diversity of agents, in comparison with the adults, similar data found in studies of Sanhueza et al. and Lopes et al. (3) (4). This was explained by the immunological immaturity and the greater susceptibility to reinfection.

The data showed that, despite the methodological and regional differences, *Ancylostoma spp.* and *Toxocara canis* continued to be the most frequently identified helminths, while *Giardia spp.* consolidated itself as the protozoan of greatest clinical and zoonotic relevance (1-4). This pattern was consistent in the majority of studies, which confirms that these agents constitute the epidemiological nucleus of the parasitosis in shelter dogs.

The interregional comparison made evident a clear epidemiological pattern: countries with a low contribution to the provision of animal care, with shelter systems with structural penuries and a scarce coverage of veterinary attention, had higher prevalences of intestinal parasitosis, coinciding with some studies (2,5,7). This pattern suggests that the persistence of intestinal parasitosis would seem to be more in function of the social and operative characteristics that determine the capacity to implement stable programs of sanitary control. Gruntmeir (25) in his study details that the highest figures were given in developing countries of Latin America, Africa, and Asia, while in Western Europe and North America the prevalences were smaller, which can be explained as a consequence of the systematic application of entry protocols, joint diagnostics, and standardized antiparasitic treatments.

The individual factors of the different animals also intervened, in addition to the geographic differences, in the dynamics of the infection, given that the fact that the malnourished dogs presented a greater risk of parasitosis gives importance to the existing association between the nutritional states and the immune response before the parasitic invasions, similar data found in the studies of Amala (26) and Murnik (27). The degree of age was fully determining, since the puppies showed parasitic loads and diversity of the agents greater than that of the aged animals, similar data found by some

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authors (21) (28) (29). This fact corresponds to the immaturity of the immune system in the earliest stages of life and to the greater predisposition of the animals in the same to processes of reinfection.

The environmental factors also determined the persistence of the infections. According to what was reported by Salnt et al. (30) and Papini et al. (31), the shelters that utilized water from untreated sources or from water stored in an inadequate form showed higher associations of enteric protozoa such as *Giardia spp.* and *Cystoisospora spp.* On the other hand, Vafae et al. (19) indicate that the warm and humid climatic conditions favored, on the other hand, the survival and maturation of the infectant forms of ancylostomids and trichurids in the medium, and thus help to maintain transmission cycles in places with those conditions.

From the optic of public health, the reviewed data corroborate that the shelter dogs infested by intestinal parasitosis possess a potential risk for the human communities. The presence of *Toxocara spp.* on tourist beaches where dogs attend in Ecuador reported by Calvopina et al. (6), permits corroborating the environmental contamination with infective forms in recreation spaces, in addition to incrementing the probability of human exposure. A parallel case is that described by Pal et al. (32) on the identification of coinfections of zoonotic helminths in community dogs in India that suggest that the dog populations could act as active reservoirs capable of maintaining the transmission in the environment.

With respect to the control strategies, the literature concurs (33) (34) that the isolated interventions, such as the sole deworming at entry, are insufficient to detain sustainedly the infection cycles.

Campanale et al. (12) corroborated that, although the initial deworming diminishes in the short term the prevalence, a considerable percentage of said animals maintains infections at egress, which also permits demonstrating the necessity of therapeutic schemes repeated over time and continuous monitoring. In the same line, various studies in Latin America have proposed protocols adjusted to contexts of limited resources, combining the use of broad-spectrum antiparasitics with the progressive improvement of the state of health and infrastructure of the shelters (16).

In environments in which there exists limited access to formal veterinary services, the practice of ethnoveterinary medicine has been utilized throughout history as an empirical strategy of sanitary management. The traditional utilization of medicinal plants and local knowledge, especially in rural and peri-urban populations in Latin America, Africa, and Asia, shows that accessible alternatives have been necessary for the management of the distinct ailments that affect the domestic animals (32) (35). However, from a scientific perspective these practices must be valued as a complementary strategy and not as a substitutive practice of evidence-based veterinary medicine.

Some studies have given account of the practices of use of plant extracts that could possess possible antiparasitic, anthelmintic, or antiprotozoal effects and that could contribute to the reduction of the parasitic load always that they form part of practices of sanitary management, hygiene, and community education (36) (37). However, the evidence that sustains these practices continues being scarce and heterogeneous, above

all with respect to the standardization of the plant species, to dosage and the routes of administration, as well as the evaluation of the adverse effects for their formal incorporation within standardized practices of sanitary management (35) (38).

In this context, ethnoveterinary medicine represents an emerging line of applied research that could contribute low-cost and culturally acceptable alternatives for the control of intestinal parasitosis in canine shelters, always that its practices are subjected to processes of rigorous scientific validation. The integration of this traditional knowledge with modern veterinary epidemiology would permit developing more contextualized sanitary strategies, aligned with the One Health approach, and oriented to improve in a sustainable manner the animal welfare and the protection of public health in environments with limited resources (32).

## CONCLUSIONS

The present study of epidemiological review on opportunistic zoonoses leads us to conclude, in the first place, that the intestinal parasitosis in shelter dogs constitute a biological and social problem of great impact, owing to the conditions in which these animals are sheltered. The compiled data demonstrate a marked preponderance of helminths and protozoa in contexts of overcrowding, deficient sanitary infrastructure, and scarce programs of veterinary control. This situation not only affects the animal welfare, its growth and nutrition, but also compromises in a significant manner the public health.

Despite the fact that the phenomenon under study is of a biological nature, the comparative analysis among countries demonstrates that the differences are related directly to the approach of the clinical epidemiology adopted. In regions such as North America and Europe, the prevalences tend to be low owing to the implementation of control strategies, while in Latin America, Asia, and Africa they surpass 60%, evidencing the lack of veterinary attention in shelters.

These results reinforce the necessity of addressing in an integral manner the problem, considering both the prevention and the control of the intestinal parasitosis in shelter dogs. Finally, it is concluded that the vacuum of systematic information, especially in Andean countries such as Ecuador, constitutes a limitation for the design of effective public policies. For that reason, it is recommended to foster longitudinal and multicentric investigations that permit generating robust data on prevalence, risk factors, and effectiveness of the interventions, adapted to contexts of low resources.

These new lines of investigation must be oriented not only to the epidemiological ambit, but also to the evaluation of the social and ethical impact of guaranteeing the welfare of the animals in situation of shelter.

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## DECLARATION OF INTEREST

The authors declare that there exists no economic, personal, or academic conflict of interest that may have influenced in an inappropriate manner the elaboration of the present manuscript.

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# INFLUENCIA DEL MUCÍLAGO DE SEMILLAS DE LLANTÉN (Plantago major) EN LAS PROPIEDADES FÍSICAS DE HELADO SABOR A MORA (Rubus glaucus)

# INFLUENCE OF PLANTAGO MAJOR SEED MUCILAGE ON THE PHYSICAL PROPERTIES OF BLACKBERRY-FLAVORED ICE CREAM (Rubus glaucus)

Ana Campuzano[1], Leonela Vera Intriago[2], Julio Palmay Paredes[3], Carolina Paz Yépez[4]
{acampuzano@uagraria.edu.ec1, leonela.vera.intriago@uagraria.edu.ec2, jpalmay@uagraria.edu.ec3, cpaz@uagraria.edu.ec4}
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**RESUMEN:** La innovación en la Agroindustria está en aumento, con tendencia hacia el reemplazo de estabilizantes sintéticos por naturales para la obtención de diferentes productos. La presente investigación plantea al mucílago de semillas de psyllium (*Plantago major*) como una alternativa evaluando el impacto en las propiedades físicas del helado sabor a mora. Se procedió a establecer las variables (temperatura y tiempo) que permiten obtener mayor cantidad de mucílago, destacándose la extracción a 80°C por 2.5 horas con 29.10% de rendimiento, demostrando que al incrementar la temperatura y tiempo se favorece la extracción del mucílago. Con el mucílago obtenido con estos parámetros se formularon helados variando la concentración de mucílago y crema de leche, analizando posteriormente de cada tratamiento las propiedades físicas por triplicado y aplicando la prueba de comparación de Duncan. Se evidenció diferencia significativa ($p<0.05$) en la viscosidad de todas las muestras, presentando en el helado con 5% de mucílago de semillas de llantén y 28% de crema de leche, el valor más alto (7666.67 cP). El mismo tratamiento presentó diferencia significativa ($p<0.05$) en el tiempo de caída de primera gota a temperatura ambiente (27°C) con una duración de 19 minutos, y en el porcentaje de derretimiento con 6.44% en 10 minutos. Por consiguiente, en todas las pruebas destacó el helado con 5% de mucílago y 28% de crema, seguido del helado con 3% de mucílago y 30% de crema, y por último el helado con 1% de mucílago y 32% de crema. Se demostró que ha mayor porcentaje de mucílago de semillas de llantén en la formulación de helados es posible obtener mejores propiedades físicas y mayor estabilidad a temperatura ambiente.

***Palabras clave:*** *Estabilizante, helado, llantén, mucílago, propiedades físicas, viscosidad*

**ABSTRACT:** Innovation in the agro-industry is on the rise, with a trend toward replacing synthetic stabilizers with natural ones for the production of various products. This research proposes psyllium seed mucilage (*Plantago major*) as an alternative, evaluating its impact on the physical properties of blackberry-flavored ice cream. The variables (temperature and time) that yield the greatest amount of mucilage were established, with extraction at 80°C for 2.5 hours yielding 29.10%, demonstrating that increasing the temperature and time favors mucilage extraction. Ice creams were formulated using the mucilage obtained under these parameters, varying the concentration of mucilage and cream. The physical properties of each treatment were then analyzed in triplicate, and Duncan's multiple range test was applied. A significant difference ($p<0.05$) was observed

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in the viscosity of all samples, with the ice cream containing 5% plantain seed mucilage and 28% cream exhibiting the highest value (7666.67 cP). The same treatment also showed a significant difference ($p<0.05$) in the time to first drop at room temperature (27°C), with a duration of 19 minutes, and in the percentage of melting, reaching 6.44% in 10 minutes. Consequently, in all tests, the ice cream with 5% mucilage and 28% cream stood out, followed by the ice cream with 3% mucilage and 30% cream, and finally the ice cream with 1% mucilage and 32% cream. This demonstrates that a higher percentage of plantain seed mucilage in ice cream formulations can result in improved physical properties and greater stability at room temperature.

***Keywords:*** *Ice cream, mucilage, physical properties, plantain, stabilizer, viscosity*

[1] Facultad Ciencias Agrarias, Universidad Agraria del Ecuador - Ecuador, https://orcid.org/0000-0003-0010-4267; +593987860647.
[2] Facultad Ciencias Agrarias, Universidad Agraria del Ecuador - Ecuador, https://orcid.org/0009-0001-4953-9133; +593999859312.
[3] Facultad de Ciencias Agrarias, Universidad Agraria del Ecuador, Instituto Superior Tecnológico Superarse - Ecuador, https://orcid.org/0000-0002-7546-5211; +593984794451.
[4] Instituto de Investigación, Universidad Agraria del Ecuador - Ecuador, https://orcid.org/0000-0001-9547-2817; +59395700068.

## INTRODUCTION

The development of food products that, in addition to the contribution of nutritional value, present functional characteristics such as the capacity of bioactive compounds to generate beneficial effects for health, has been driven by the sustained growth of the population and the demand for foods. This scenario has increased the interest in the use of ingredients of natural origin that make it possible to improve the technological and functional quality of foods.

*Plantago major*, commonly known as plantain (llantén), is a plant widely valued for its medicinal properties, which are attributed to the presence of diverse chemical compounds and bioactive nutrients (1). The seeds of this species have been classified as mucilaginous, since, upon hydration, they form a highly viscous layer with characteristics similar to a gum or gel, known as mucilage (2). This type of substances can be obtained from plant, animal, processed, or synthetic sources, and possesses diverse applications in the agri-food industry as emulsifying, stabilizing, suspending, and binding agents, owing mainly to their elevated water-holding capacity (3).

The mucilages extracted from plant seeds correspond to polysaccharides of hydrocolloid nature, which present functional properties and potential benefits for health associated with their physicochemical structure (4). In the specific case of *Plantago major*, the mucilage is composed of monosaccharides such as glucose, xylose, rhamnose, galactose, arabinose, and glucuronic acid, which confers upon it thickening, stabilizing properties and capacity for foam formation (2). Although its use has been widely documented in the pharmaceutical industry, its employment in food matrices is still limited, despite its potential from the technological point of view.

Ice cream presents a simple elaboration process; however, it is considered a complex food system at the physicochemical and structural level. Consequently, how to formulate and process this product has evolved significantly over time, with the objective of improving attributes such as texture, stability, smoothness, and resistance to melting (5). In this context, the stabilizing and emulsifying agents play a fundamental role, since they make it possible to increment the viscosity of the mix, control the

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formation of ice crystals, and maintain a homogeneous distribution of the non-miscible components of the system (6); (7).

Currently, the stabilizers most utilized in the elaboration of ice creams are of synthetic origin or derived from plant gums such as pectins, carboxymethylcellulose, and hemicelluloses (8). However, current consumption trends prioritize minimally processed foods, with natural and easily accessible ingredients, which has motivated the search for functional alternatives of plant origin (9).

A wide variety of plant mucilages has been evaluated for their capacity to improve viscosity, water retention, and stability against ice recrystallization, in the search for stabilizers for ice creams (10); (11). Among the most studied are found the mucilages of chia (*Salvia hispanica L.*) and flaxseed (*Linum usitatissimum L.*), which have demonstrated positive effects on stability and the reduction of melting rate in ice creams. However, their use can present technological limitations, such as excessive increases in viscosity, interference with aeration, and sensory alterations when they are utilized at relatively low concentrations (11); (12). On the other hand, the mucilage of plantain (*Plantago spp.*) is characterized by its high content of highly branched arabinoxylans, which confers upon it a high water-holding capacity, a pseudoplastic rheological behavior, and greater stability against freeze–thaw cycles (13). These properties favor the formation of more homogeneous and stable matrices, with a lower negative impact on the texture and sensory acceptability of the final product, which positions it as a differentiated alternative to other plant mucilages traditionally utilized in the elaboration of ice creams.

For the foregoing reasons, the mucilage of plantain seeds represents a promising option, owing to its hydrocolloid properties and to the scarce information available on its application in foods in comparison with the pharmaceutical ambit (14).

Therefore, the present study has as its objective to evaluate the stabilizing effect of the mucilage of plantain seeds (*Plantago major*) on the physical properties of blackberry-flavored ice cream (*Rubus glaucus*), with the purpose of substituting a commercial stabilizer and promoting the use of this mucilage as a functional additive of natural origin in the food industry.

## MATERIALS AND METHODS

### Materials

The seeds of plantain (*Plantago major*) were used for the extraction of the mucilage and pulp of blackberry (*Rubus glaucus*) for the elaboration of the ice cream. The remaining ingredients employed were whole milk, cream, powdered milk, and sugar, all of food grade acquired from local supermarkets. An analytical balance brand Mettler Toledo with capacity of 120 g (precision of 0.0001 g) was used.

### Experimental design

The present investigation presents a completely randomized design; for the extraction of the mucilage 3 treatments were evaluated considering different parameters (temperature and time) in the process. In the formulation of blackberry ice cream 3

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treatments were elaborated with different concentrations of plantain seed mucilage and cream.

### Extraction of plantain seed mucilage

For the extraction of the mucilage the procedure indicated by (15) was followed, with slight modifications based on (14) and (16). The treatments established were T1 (50 °C during 1.5 h), T2 (75 °C during 2 h), and T3 (80 °C during 2.5 h). The mucilage was precipitated with 80 % ethyl alcohol in a 1:3 ratio (sample:alcohol), filtered, and stored at 4 °C until its use for the obtaining of the ice cream.

### Determination of mucilage yield

The yield of the mucilage was determined by means of a gravimetric method, calculating the percentage in function of the initial weight of the seeds and the weight of the mucilage obtained, in accordance with the method described by (17).

### Formulation and elaboration of the ice cream

**Table 1. Formulation of blackberry-flavored ice cream using plantain seed mucilage.**

| Ingredients | T1 | T2 | T3 |
|---|---|---|---|
| Cream (%) | 32 | 30 | 28 |
| Whole milk (%) | 20 | 20 | 20 |
| Plantain mucilage (%) | 1 | 3 | 5 |
| Sugar (%) | 12 | 12 | 12 |
| Blackberry pulp (%) | 25 | 25 | 25 |
| Powdered milk (%) | 10 | 10 | 10 |
| **Total (%)** | **100** | **100** | **100** |

Three treatments were elaborated varying the concentration of mucilage (1 %, 3 %, and 5 %) and concentration of cream (32 %, 30 %, and 28 %). The mucilage used for the different ice cream treatments corresponded to the extraction treatment with the highest yield.

The elaboration process included mixing, pasteurization (85 °C during 5 min), homogenization, maturation (5 h), whipping, packaging, and storage at −18 °C, in accordance with what is stipulated in the standard (18), as observed in Table 1.

### Determination of viscosity

The viscosity of the ice cream mixes was determined by means of the Brookfield rheometer (model DV-II, spindle #3) at 60 rpm at 4 °C, following the procedure described by (5).

### Determination of melting percentage

The melting percentage was evaluated by gravitational drainage, determining the relation between the mass of melted ice cream and the initial mass of the sample, in accordance with the methodology described by (19).

### Determination of time to first drop

The time to first drop was determined at room temperature, measuring the time elapsed from the exposure of the ice cream until the appearance of the first drop of melting, according to (5).

### Physicochemical analyses

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The total fat content was determined by means of the Weibull-Berntrop gravimetric method, in accordance with (20). The weight/volume relation was determined by means of the pycnometer method according to AOAC 986.14. The total solids content was determined in accordance with (21). The milk protein content was determined by means of the Kjeldahl method, according to (22). The cholesterol content was determined in accordance with (23).

### Microbiological analysis

Microbiological analyses were performed for the detection of indicator and pathogenic microorganisms, including count of mesophilic aerobes, total coliforms, *Escherichia coli, Staphylococcus aureus, Salmonella spp.* and *Listeria monocytogenes*, following the standards (24), (25), and (26), as corresponded.

### Statistical analysis

The data obtained were analyzed by means of analysis of variance (ANOVA) under a completely randomized design. The comparison of means was performed utilizing Duncan's test at 5 % probability.

## RESULTS

### Determination of the best process of extraction of plantain seed mucilage according to yield varying time and temperature for its subsequent use in the elaboration of blackberry-flavored ice cream.

For the obtaining of the mucilage the plantain seeds were received eliminating the presence of branches, impurities, and foreign materials. Next, the seeds were dried during 2 hours at 100 °C, in order to reduce or eliminate microorganisms, in addition to facilitating the process of hydration of the seeds. With distilled water the seeds were hydrated, applying different parameters (temperature and time) for each treatment, with constant agitation. For Treatment 1 a temperature of 50 °C for 1.5 hours was applied, Treatment 2 at 75 °C for 2 hours, and finally Treatment 3 at 80 °C for 2.5 hours. For the extraction of the mucilage 80 % ethyl alcohol was utilized, in 1:3 ratio (sample/alcohol) in each treatment; finally filter paper with the aid of a mesh (2 mm) was utilized to separate the seeds from the mucilage.

The percentage of yield of plantain seed mucilage was calculated with Eq. 1 (%Yield = W1 × W2 / 100) for each treatment; the results obtained are detailed in Table 2. Duncan's test at 5 % probability showed that, according to the results obtained in the analysis of variance, there exists significant difference among the treatments ($p < 0.05$). Treatment 3 presented the highest percentage of yield (29.10 %), followed by Treatment 2 (22.35 %), demonstrating that as the time and temperature increased during the process of extraction of plantain seed mucilage, the greater was the yield.

**Table 2. Percentage of yield of the extraction of mucilage from plantain seeds varying time and temperature.**

| Treatment | Means (%) |
|---|---|
| T1 | 8.40a |
| T2 | 22.35b |
| T3 | 29.10c |
| S.E. | 2.40 |
| C.V. | 28.04 |
| Significance | *** |

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Means with a different letter indicate significant difference (p < 0.05). S.E. = Standard error; C.V. = Coefficient of variation. * = p < 0.05; ** = p < 0.01; *** = p < 0.001 and ns = not significant.

**Evaluation of the physical properties (viscosity, time to first drop, and melting percentage) in the blackberry-flavored ice cream with the addition of different concentrations of plantain seed mucilage with best yield.**

In Table 3 it is evidenced that there existed significant difference (p < 0.05) among the samples of blackberry-flavored ice creams with plantain seed mucilage in relation to the viscosity parameter. Ice cream 3 (5 % of plantain seed mucilage and 28 % of cream) presented the highest mean of viscosity (7666.67 cP), followed by ice cream 2 (3 % of plantain seed mucilage and 30 % of cream) (4583.33 cP). Consequently, the percentage of plantain seed mucilage incorporated, as well as the percentage of cream, influences the result of viscosity obtained in each treatment. According to the formulation employed in the process of ice creams, the greater was the percentage of plantain seed mucilage and of cream incorporated in the mix, the greater was the result of viscosity in the ice cream sample.

**Table 3. Viscosity of blackberry-flavored ice creams with plantain seed mucilage.**

| Samples | Means (cP) |
|---|---|
| H1 | 3766.66a |
| H2 | 4583.33b |
| H3 | 7666.67c |
| S.E. | 556.03 |
| C.V. (%) | 7.28 |
| Significance | *** |

Means with a different letter indicate significant difference (p < 0.05). S.E. = Standard error; C.V. = Coefficient of variation. * = p < 0.05; ** = p < 0.01; *** = p < 0.001 and ns = not significant.

Table 4 evidences the significant difference (p < 0.05) among means where it is compared how the percentage of plantain seed mucilage and the percentage of cream added to the ice cream mix influenced in relation to the time to first drop in the ice cream samples. Ice cream 3 (5 % of plantain seed mucilage and 28 % of cream) presented greater stability upon exposing it to room temperature (27 °C), beginning to melt at 19 minutes. While Ice cream 2 (3 % of plantain seed mucilage and 30 % of cream) showed itself relatively stable at room temperature (27 °C) and melted in 13 minutes. However, Ice cream 1 (1 % of plantain seed mucilage and 32 % of cream) was little stable upon being exposed to room temperature (27 °C), beginning to melt in a time of 8 minutes. Therefore, the greater was the percentage of mucilage employed in the ice cream samples, the greater was the stability that it presented upon being exposed to room temperature.

**Table 4. Time to first drop in blackberry-flavored ice creams with plantain seed mucilage.**

| Samples | Means |
|---|---|
| H1 | 8.83a |
| H2 | 13.76b |
| H3 | 19.17c |
| S.E. | 1.04 |
| C.V. | 4.75 |
| Significance | *** |

Means with a different letter indicate significant difference (p < 0.05). S.E. = Standard error; C.V. = Coefficient of variation. * = p < 0.05; ** = p < 0.01; *** = p < 0.001 and ns = not significant.

In order to evidence the difference among means of the melting percentage, a scatter plot was used that shows the behavior of the melting percentage according to time; this was obtained by weighing the quantity of melted ice cream (in grams) every 10 minutes.

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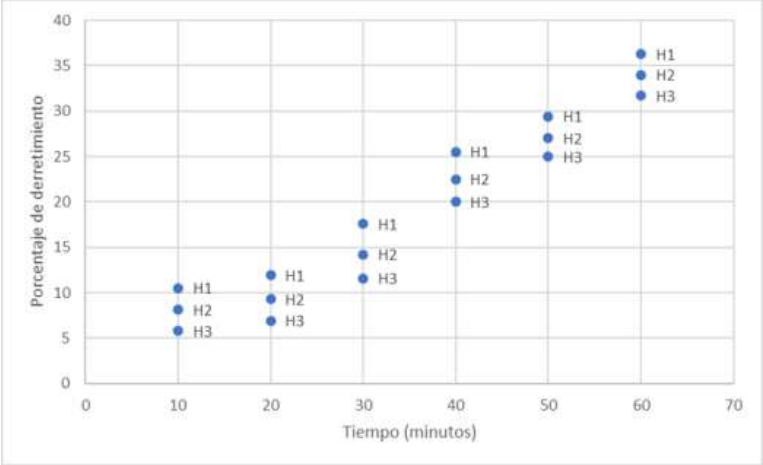
Figure 1 exposes the average value of each treatment on the basis of the melting percentage of the ice cream in relation to the quantity of cream and of plantain seed mucilage. The sample of Ice cream 3 (H3) (5 % of plantain seed mucilage and 28 % of cream) registered a melting percentage of 6.44 % in 10 minutes, a behavior that was maintained constant until 60 minutes that the sample was exposed to room temperature (27 °C). Followed by Ice cream 2 (H2) (3 % of plantain seed mucilage and 30 % of cream) with a melting percentage of 7.44 % in 10 minutes, demonstrating that, the greater is the quantity of mucilage applied, the lower will be the melting percentage at room temperature.

**Figure 1. Scatter diagram among means of ice cream samples in relation to melting percentage. Where: H1: Ice cream 1, H2: Ice cream 2, H3: Ice cream 3.**




**Analysis of physicochemical parameters (total fat, weight/volume, milk protein, total solids, and cholesterol), and microbiological parameters (mesophiles, coliforms, E. coli, Staphylococcus, Salmonella, Listeria monocytogenes), on the basis of NTE INEN 706:2013 of requirements for ice creams to the treatment with best result on the viscosity property.**

## Analysis of physicochemical parameters

Table 5 shows the result of physicochemical analyses performed on the ice cream sample on the basis of (18), where the results obtained are appreciated. It is observed that the treatment of ice cream 3 complies with the requirements established by the standard in each parameter analyzed. With respect to milk protein, fat, and total solids, the values were close to the established limit, while for the cholesterol parameter the analyses reflect the established limit with a value of 0.09 mg/kg of sample, while what is stipulated by the standard is 0.10 mg/kg of sample; in relation to Weight/Volume expressed in g/L of sample a value of 470 g/L was reflected.

**Table 5. Physicochemical parameters of sample of blackberry-flavored ice cream with plantain seed mucilage and what is established by standard NTE INEN 706:2013.**

| Parameters | Unit | Results | Requirement |
|---|---|---|---|
| Milk protein | % | 2.27 | 2.50 |
| Total fat | % | 7.32 | 8 |
| Total solids | % | 28.55 | 32 |
| Cholesterol | mg/Kg | 0.09 | 0.10 |
| Weight/Volume | g/L | 470 | 475 |

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### Analysis of microbiological parameters

In Table 6 it is shown that according to the standard (18) ice cream 3 complies with the requirements stipulated and in force in Ecuadorian legislation. Therefore, absence of pathogenic microorganisms such as Salmonella sp. and Listeria monocytogenes is observed. The counts of the indicator microorganisms are found below the permitted limit in the standard.

**Table 6. Microbiological parameters of sample of blackberry-flavored ice cream with plantain seed mucilage and what is established by standard INEN 706:2013.**

| Parameters | Unit | Results | n | m | M |
|---|---|---|---|---|---|
| Count of mesophilic m.o. | cfu/g | $1\times10^2$ | 5 | 10 000 | 100 000 |
| Count of coliforms | cfu/g | $1\times10^2$ | 5 | 100 | 200 |
| Count of E. coli | cfu/g | <10 | 5 | <10 | <10 |
| Count of Staphylococcus | cfu/g | <10 | 5 | <10 | <10 |
| Detection of Salmonella | /25g | Absence | 5 | Absence | Absence |
| Detection of Listeria monocytogenes | /25g | Absence | 5 | Absence | Absence |

## DISCUSSION

In order to obtain mucilage from plantain seeds (*Plantago major*), a heat-assisted extraction method was utilized with the addition of ethyl alcohol as solvent, following the procedure described by (27). The efficiency of the process was evaluated in function of the yield of mucilage obtained, considering the influence of the time and the temperature of extraction. In this sense, three treatments were established with different combinations of these factors, which made it possible to analyze the variability in the percentage of mucilage extracted.

The results showed that the increase of the time and the temperature of extraction increments significantly the yield of mucilage, a behavior that coincides with what was reported by (14), who indicated that thermal conditions close to 80 °C and prolonged extraction times facilitate the solubilization of the mucilaginous polysaccharides present in the seed. However, differently from these authors, who utilized distilled water as solvent and obtained a yield of approximately 45 g of mucilage, in the present study the use of ethyl alcohol under the same parameters of temperature (80 °C) and time (2.5 h) made it possible to reach a higher yield (75 g). This result highlights the influence of the type of solvent on the efficiency of the extraction process, in accordance with what was indicated by (9), who emphasizes that variables such as temperature, time, seed/solvent ratio, and the nature of the solvent determine the yield of mucilage. The positive effect of the increase of temperature and extraction time on the yield of the mucilage can be explained by the physicochemical changes observed in the polysaccharide matrix of the seed. At temperatures close to 80 °C, the thermal energy favors the rupture of intra- and intermolecular hydrogen bonds, which stabilize the polysaccharide chains, increasing their solubility and facilitating the diffusion of high-molecular-weight macromolecules in the extraction medium (28). In addition, the polarity and the dielectric constant of the system are modified by means of the use of ethyl alcohol as solvent, in contrast with distilled water, which favors a more efficient precipitation of the mucilaginous polysaccharides and reduces the coextraction of low-molecular-weight compounds, which results in a higher general yield of the process (29); (30). In addition, the greater concentration of mucilage in the formulation of the ice cream made it possible to reduce the content of cream without affecting negatively the sensory perception, since the

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polysaccharides with high water-holding capacity contribute to the formation of a continuous and viscous matrix that imitates the rheological functions associated with the fat phase, such as oral lubrication, creaminess, and mouthfeel (31). This behavior has been described widely in natural hydrocolloids utilized as fat mimetics in frozen systems, where the water–air–fat interaction is crucial for the structural stability and the sensory acceptance of the final product.

With respect to the application of mucilage in the formulation of ice creams, the results obtained confirm that upon increasing the concentration of mucilage a significant increment in the viscosity of the system is generated. This behavior has been described previously by (32), where they evaluated the use of mucilage of leaves and seeds of nopal at concentrations of 3 %, 5 %, and 7 %, identifying a progressive increment in the viscosity as the content of hydrocolloid increased. In the present study, the treatment with the highest proportion of plantain seed mucilage (5 %) showed the highest viscosity values, confirming the thickening and stabilizing effect of this biopolymer. Likewise, the observed rheological behavior is characteristic of pseudoplastic systems, in which the viscosity increases with the concentration of the stabilizing agent.

(5) indicate that the emulsifying and thickening agents utilized in the production of ice cream affect directly the quality of the final product by limiting the formation of ice crystals, improving the structural stability, and providing a smoother and more homogeneous texture. In accordance with what was mentioned, the results obtained demonstrate that with the use of plantain seed mucilage it is possible to achieve functions similar to commercial stabilizers, without reaching the point of affecting negatively the physical properties of the product, such as viscosity, time to first drop, and melting percentage.

On the other hand, the obtaining of excessively viscous or gelatinous textures has been warned in diverse studies, mentioning that the high concentrations of mucilage would be the cause, giving as a result a negative affectation on the sensory acceptability of the ice cream. (32) informed that, although the treatment with 7 % of nopal mucilage showed greater viscosity, it was not the most accepted in terms of sensory evaluation, being the treatment with 5 % the most accepted. A similar behavior was observed in this study, where the formulations with greater content of mucilage showed a texture less characteristic of conventional ice cream, while the formulations with 3 % of mucilage presented viscosity and stability values comparable to those reported for commercial ice creams.

With respect to thermal stability, (33) reported melting times superior to 70 minutes in ice creams formulated with 0.8 % of yam mucilage, while lower concentrations showed shorter melting times. In the present study, the ice creams formulated with plantain seed mucilage showed times to first drop and of melting within the ranges established for conventional ice creams. In particular, the treatment with 3 % of mucilage had times to first drop between 12 and 17 minutes and a complete melting time of less than 35 minutes, values close to those reported by (5), who indicate that a quality ice cream presents a time to first drop between 12 and 15 minutes, and an approximate melting time of 30 minutes.

The physicochemical and microbiological results obtained evidenced the compliance with the limits established by (18). The values of milk protein, total fat, total solids, and

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cholesterol were registered within the permitted ranges, and the microbiological analyses confirmed the absence of *Staphylococcus aureus, Salmonella spp.* and *Listeria monocytogenes*. These results support the safety of the product and evidence that the incorporation of plantain seed mucilage as natural stabilizer does not compromise the quality nor the safety of the ice cream.

## CONCLUSIONS

The mucilage obtained from the seeds of plantain (*Plantago major*) by means of heat-assisted extraction showed yields significantly influenced by the time and the temperature of the process. The results confirmed that the more severe extraction conditions favor the liberation of mucilaginous polysaccharides, which makes possible the identification of optimal parameters for maximizing the yield of mucilage, reinforcing the importance of the control of parameters in the process.

The plantain seed mucilage influenced the physical properties of the blackberry-flavored ice cream in a significant manner ($p < 0.05$), since upon increasing the concentration of mucilage a higher viscosity value was evidenced, a decrease in the melting percentage, and a more prolonged time for the fall of the first drop, confirming that the mucilage presents a behavior of functional hydrocolloid, and its potential use in the industry.

From a technological point of view, it was observed that the formulations with intermediate concentrations of mucilage showed an adequate equilibrium between the physical stability and the inherent characteristics of the ice cream, avoiding excessively viscous or gelified textures. This is important for the development of the product, since it highlights the necessity of optimizing the concentration of the natural stabilizer according to the final quality desired and the acceptance of the consumer.

The blackberry-flavored ice cream upon adding plantain seed mucilage complied with the physicochemical analyses such as proteins, total fat, total solids, and cholesterol indicated in the current Ecuadorian regulations. In addition, the microbiological analyses confirmed the safety of the product upon declaring absence of pathogenic microorganisms and counts of indicator microorganisms below the established limit. These results support the viability of the use of plantain seed mucilage from a regulatory and food safety perspective.

The present investigation manifests that the plantain seed mucilage is a viable alternative as natural stabilizer in the production of ice creams, and its potential use in the development of foods that require ingredients of plant origin and a lower dependence on synthetic additives, contributing to innovation and sustainability in the food industry.

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# EVALUACIÓN DEL COMPORTAMIENTO FÍSICO, QUÍMICO, MICROBIOLÓGICO Y SENSORIAL EN RACIMOS Y BAYAS DE UVAS DURANTE DIFERENTES TEMPERATURAS DE ALMACENAMIENTO

# EVALUATION OF THE PHYSICAL, CHEMICAL, MICROBIOLOGICAL AND SENSORY BEHAVIOR OF GRAPE BUSHES AND BERRIES DURING DIFFERENT STORAGE TEMPERATURES

Ronny Quintero Pincay[1], Cecilia Valle Lituma[2], Cecibel Alava Pincay[3], Richard Baque[4]
{ronny.quintero.pincay@uagraria.edu.ec1, cvalle@uagraria.edu.ec2, calava@uagraria.edu.ec3, rbaque@uagraria.edu.ec4}
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**RESUMEN:** La uva de mesa es considerada como un rubro no tradicional en la región litoral del Ecuador donde su fruto es altamente perecedero y cuya calidad post cosecha depende de condiciones de almacenamiento, especialmente de la temperatura. En la provincia de Santa Elena, donde el cultivo de la vid ha aumentado significativamente en los últimos años, aún mantiene limitaciones técnicas en el manejo post cosecha que afectan la vida útil. En este estudio se analizó el comportamiento físico, químico, microbiológico y sensorial de las variedades Red Glove e Ivory, almacenadas en diferentes temperaturas de almacenamiento (0 °C, 4 °C, 10 °C y al ambiente), durante un periodo de 20 días. Las muestras fueron adquiridas un mercado local de Santa Elena empleando un análisis experimental al azar con arreglo factorial. Se evaluaron variables como pérdida de peso de racimos y bayas, pH, sólidos solubles totales (Brix), acidez titulable, índice de madurez, recuento de aerobios mesófilos y análisis sensorial. Los resultaron indicaron que el almacenamiento a 0 °C permitió disminuir la pérdida de peso, ralentizar los procesos de maduración y mejorar su estabilidad microbiológica en ambas variedades. La variedad Red Glove presentó un comportamiento más estable a esta temperatura, mientras que Ivory mostró mayor deshidratación del racimo, aunque con menor pérdida de peso en sus bayas. Se concluye que el manejo adecuado de la temperatura a 0 °C, es crucial para asegurar la vida útil de la uva de mesa de Santa Elena, por lo que es relevante mejorar la cadena de frio para mejorar la calidad e inocuidad del producto.

***Palabras clave:*** *bayas, racimo, uva, postcosecha, temperatura*

**ABSTRACT:** Table grapes are considered a non-traditional crop in the coastal region of Ecuador, where the fruit is highly perishable and its post-harvest quality depends on storage conditions, especially temperature. In the province of Santa Elena, where grape cultivation has increased significantly in recent years, technical limitations in post-harvest handling still affect shelf life. This study analyzed the physical, chemical, microbiological, and sensory behavior of the Red Glove and Ivory varieties, stored at different temperatures (0 °C, 4 °C, 10 °C, and ambient) for 20 days. Samples were acquired from a local market in Santa Elena using a randomized, factorial design. Variables evaluated included bunch and berry weight loss, pH, total soluble solids (Brix),

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titratable acidity, maturity index, mesophilic aerobic count, and sensory analysis. The results indicated that storage at 0°C reduced weight loss, slowed ripening processes, and improved microbiological stability in both varieties. The Red Glove variety exhibited more stable behavior at this temperature, while Ivory showed greater bunch dehydration, although with less berry weight loss. It is concluded that proper temperature management at 0°C is crucial to ensuring the shelf life of Santa Elena table grapes, making it essential to improve the cold chain to enhance product quality and safety.

***Keywords:*** *Berries, bunch, grape, postharvest, temperature*

[1] Facultad de Ciencias Agrarias, Universidad Agraria del Ecuador, Ecuador, https://orcid.org/0009-0009-8627-7417; +593959828117.
[2] Facultad de Ciencias Agrarias, Universidad Agraria del Ecuador, Ecuador, https://orcid.org/0009-0003-0328-3261; +593995940384.
[3] Facultad de Ciencias Agrarias, Universidad Agraria del Ecuador, Ecuador, https://orcid.org/0000-0002-8253-2283; +593979359933.
[4] Facultad de Ciencias Agrarias, Universidad Agraria del Ecuador, Ecuador, https://orcid.org/0009-0002-6771-3956; +593990582501.

## INTRODUCTION

The introduction of the grapevine on the American continent occurred during the period of European colonization, consolidating subsequently in countries with temperate climatic conditions and marked seasonality (1). In this context, Argentina and Chile position themselves as the principal producers of grapes in South America, standing out for their high technological level, efficient management systems, and consolidated value chains that permit them to compete in international markets (2).

Although Ecuador has not been recognized as a wine-producing country, recent studies and productive experiences evidence that the cultivation of the grapevine possesses a high potential, especially in the provinces of Santa Elena and Loja, owing to their favorable edaphoclimatic conditions (3). In the case of the province of Santa Elena it presents climatic conditions that permit obtaining up to two annual harvests, which represents a significant competitive advantage compared with other producing countries of the region (4).

According to data of the Association of Grape Producers of Ecuador (APRUEC), the cultivation of the grapevine has been gaining space within the productive activities of the province of Santa Elena, traditionally dominated by fishing and tourism (5). In the year 2019, the national production of grapes reached approximately 3.93 million kilograms, concentrated principally in two agricultural enterprises, Pura Vida and Dos Hemisferios. Nevertheless, this production proves insufficient to cover the internal demand, which surpasses 28 million kilograms annually, generating a high dependence on importation (6).

Faced with this gap between supply and demand, the producers have posed as strategic vision the expansion of the sowing areas of the grapevine crop. Currently, in the province of Santa Elena around 38 cultivated hectares are registered, with projections of expansion up to 90 hectares, which would permit incrementing the production by approximately 40% (5). However, this productive growth is conditioned by certain technical limitations, especially in what is related to the management of the crop and, in a critical manner, with the postharvest processes (7).

Diverse authors coincide in that one of the principal factors that affect the competitiveness of table grapes in Ecuador is the limited technical training of the small

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and medium producers in the stages of harvest, postharvest, storage, and commercialization (8). Postharvest constitutes a determining phase, since from it depends that the fruit conserve its organoleptic quality, safety, and shelf life until reaching the final consumer (9).

In the provinces of Santa Elena and Loja, where the major production of grapes of the country is concentrated, deficiencies are still evidenced in the application of adequate techniques of manipulation of the bunches, temperature control, conservation, and storage. These techniques, which have been widely studied and developed in traditional producing countries, are still found in phase of adaptation in the Ecuadorian context, which occasions postharvest losses, deterioration of the quality of the fruit, and affectation of its commercial value.

Among the principal postharvest problematics of table grapes are found the rotting of the bunch and the dehydration of the rachis, phenomena associated both to an inadequate management during the phenological development and to inappropriate storage conditions (10). These losses not only affect the profitability of the producer, but also limit the positioning of the national product compared with the imported grape.

Despite these limitations, the cultivation of the grapevine represents a strategic opportunity for the agricultural development of Ecuador. The grape possesses a high nutritional value owing to its content of vitamins, tartaric acid, and polyphenols, compounds with recognized antioxidant capacity and protective effects against damaging cellular processes (11). These characteristics increment its attractiveness in markets that value functional and healthy foods.

The experience of the first vineyard established in the country demonstrates that it is possible to produce table grapes of quality comparable to the imported. The trials realized with varieties such as Red Globe, Ivory, and Arra 15 have generated favorable results, reinforcing the technical viability of the crop (1). In equal manner, the national harvest is realized in months in which countries such as Chile and the United States do not produce, generating strategic commercial opportunities for the Ecuadorian product.

In this context, the present experimental investigation is oriented to broaden the knowledge on the postharvest life of two varieties of table grapes, Red Globe and Ivory, cultivated in the zone of Santa Elena, specifically in the sector San Juan del Morro. The study evaluates the physical, chemical, microbiological, and sensory behavior of these varieties under different storage temperatures, with the aim of generating technical information that contributes to the reduction of postharvest losses and to the improvement of the quality of the product. Finally it is hypothesized that the postharvest storage of the fruits at 0 °C can minimize the degradation of phenolic components, loss of firmness, and variation in the coloration of the berries in relation with those stored at 4 °C.

## MATERIALS AND METHODS

### Characterization of the grapes

The bunches and berries of table grapes of the varieties Red Globe and Ivory were characterized, before and after being stored. In both stages the behavior of the bunches and berries was evaluated during 20 days with three different temperatures, including

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the control with ambient temperature (0 °C, 4 °C, 10 °C, and control), this with the purpose of avoiding that the fruit suffer any physical, chemical, and microbiological damage during its transportation.

The grapes were obtained from the market of the province of Santa Elena, in the proximities of the commune El Azúcar, located to the south of the province. The samples were selected randomly and transferred to the laboratory for their analysis.

**Analytical determinations: physical, chemical, microbiological, sensory**

*Physical determinations*

These determinations were realized with variations of weight for each sample of bunches and berries, and difference of degrees Brix in berries during the days 5, 10, 15, and 20. The weight loss was calculated based on equation 1:

$$\Delta M = ((m0 - mt) / m0) \times 100$$

Where ΔM is variation of weight in grams in a given time; mt is the weight of sample at the end in grams, and m0 is the initial weight of the sample in grams.

The measurement of degrees Brix was through a refractometer of scale 0 to 90% (ATC, Zuzi.HPD010, Vidrafoc, China).

*Coloration of bunches and berries*

The coloration of the bunch was determined visually at the moment of storage, defining four categories: dark red (1), red (2), light red (3), and poor color with presence of green berries (4) for the variety Red Globe; and for Ivory the coloration scale was Green (1), Green to Amber (2), Amber to Green (3), Amber (4).

*Chemical determinations*

The chemical characteristics determined were of pH, titratable acidity, and maturity index, evaluated periodically during 20 days.

For the pH a pH-meter with buffer substances was utilized (PH-02 Lite, Biomed instruments, China). For the acidity a solution of sodium hydroxide was necessary and the data were calculated on the basis of equation 2:

$$Acidity = (V \times C \times F) / M$$

Where V is the volume of the sodium hydroxide consumed during the titration; C is the molarity of the sodium hydroxide; F is the conversion factor of acidity of the tartaric acid; and M is the mass of the grape juice analyzed.

On the other hand, the maturity index was calculated with equation 3 to determine the concentrate of tartaric acid that there is in the fruit.

*Microbiological determinations*

The microorganisms analyzed were mesophilic aerobes, applying the technical standard NTE INEN 1529-5:2006 Microbiological control of foods. Determination of the quantity of mesophilic aerobic microorganisms.

These analyses were realized by a certified food laboratory employing 500 grams of each variety of grape stored at three temperatures (0, 4, 10 °C) and the control (ambient temperature).

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*Sensory analysis*

The sensory evaluation was realized with fifteen untrained individuals, the first and fifteenth days. The surveyed oscillated between 20 to 30 years of age, among men and women, all have been accustomed to tasting the grapes of both varieties. The survey was of five-point hedonic scale, being 5 I like very much, 4 I like a lot, 3 I like, 2 I do not like much, and 1 I do not like. The parameters of the characteristics of the fruit evaluated were: flavor, color, form, size, juiciness, seed, and skin, which were represented with a radial diagram by variety.

**Deduction of the postharvest shelf life**

In order to determine the postharvest shelf life in the two varieties of table grapes the temperature, the relative humidity, the management conditions were evaluated, avoiding mechanical damages and the presence of microorganisms. It was stored at temperatures of 0, 4, and 10 °C.

The present investigation in grapes employed a high relative humidity (90–95 %) to help prevent the dehydration and the wilting of the fruit and loss of shelf life. The grape was monitored avoiding the growth of fungi, especially Botrytis cinerea.

**Statistical analysis**

The data of differences of weight of the bunch and berries and Brix of berries obtained from the first until the twentieth day were analyzed by Tukey (ANOVA) with a level of significance (P-value < 0.05), through the program INFOSTAT student version, taking into account the variables of storage temperature and the two varieties of grapes.

## RESULTS

**Analytical determinations: physical, chemical, microbiological, sensory**

*Physical determinations*

*A. Variations of bunch weight*

In the variations of weights of the grape bunches that surpassed 222 grams of loss, it presented for the variety Ivory at 4 °C; this could be due to the dehydration that is produced at this temperature, as well as to the relative humidity and to the time of storage in which it was exposed (see Table 2).

The analysis of variance of the means of data corresponding to the weight of the bunch on the first day, gave a coefficient of variation (CV) 36.58%; it is necessary to remember that logarithmic transformation technique was applied, therefore the CV changed to 6.85%. Among the means, the highest valuation obtained was Ivory 4 °C 566 g, followed by Red Globe 0 °C 544.33 g, and finally the Ivory Control with a lower mean 262.67 g.

On the fifth day, upon weighing the bunches, a coefficient of variance of C.V 37.35% was obtained; with the transformation of values it arrived at 7.00%. However, no significant differences were found; the highest value of the mean resulted for Red Globe 0 °C 540 g, and Ivory 4 °C 528.67 g, being the lowest mean for Ivory Control 246.33 g.

On the tenth day, the CV was very elevated of the range 38.19%, for which a transformation technique (Log 10) was applied, changing to a normal coefficient 7.19%, without finding significant differences. The variety Red Globe 0 °C obtained higher valuation 529.33 g, and the Ivory Control with lower mean 232.33 g.

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On the fifteenth day, the CV was very high 38.82% for which with the transformation of Log 10 it was managed to lower it until 7.40%, determining that no significant differences were found. The valuations of high mean was for Red Globe 0 °C 519.67 g, contrary to Ivory Control with low mean 222. Arriving at the twentieth day, the CV was of 7.36% being within the established range, for which no significant differences were found. The high mean was for Red Globe 0 °C 500.67 g, and low mean for Ivory Control 210 g.

*B. Variations of berry weight*

With respect to the variations of weight in berries, from the first day its behavior was very similar in both varieties, being the Ivory the one that registered weight a little low. Until the last day, the Red Globe at 0 and 10 °C and Ivory 0 °C lost ≥ 4 grams (see Table 1).

With respect to the analysis of variance, for the first day the CV was 15.75%, without showing significant differences in means. The highest value of mean was for Red Globe 0 °C 10.67 g, and the lowest for Ivory 4 °C 7.33.

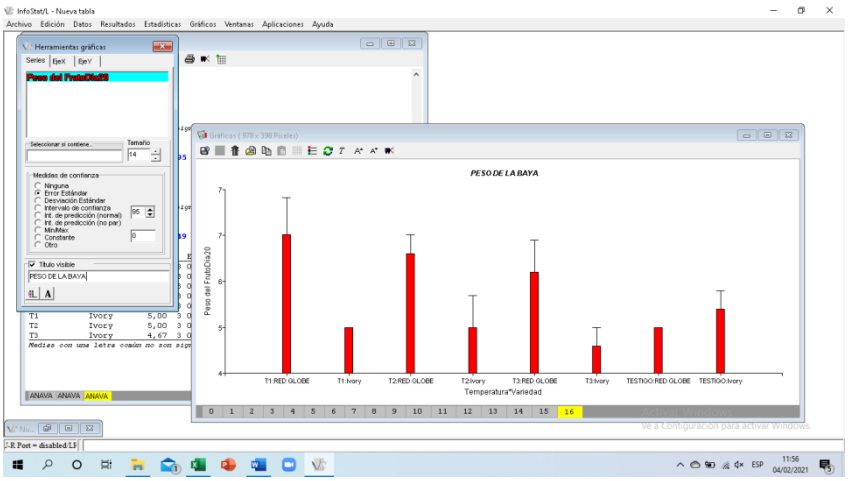
For the fifth day the CV was 9.38%, the data indicate significant differences in the different temperatures, being the highest value of mean for Red Globe 0 °C 10 g, and the lowest value for Ivory 4 °C 6.75 g.

The CV for the tenth day was of 13.93%, being the highest value of mean for Red Globe 0 °C 10 g, and the lowest value for Ivory 4 °C 5.67 g. The fifteenth and twentieth days, the CVs were 15.07% and 13.38% respectively. The values of higher means were for Red Globe 0 °C 7.67 and 6.67 g, and lower for Ivory 5.33 g and Ivory 10 °C 4.67 g respectively.

**Table 1. Averages of weight losses of bunch and berries of two varieties of grapes and three storage temperatures.**

Full numerical data for bunch and berry weight losses across days 1, 5, 10, 15 and 20 for Red Globe and Ivory at 0 °C, 4 °C, 10 °C and ambient control are presented in the original source Table 1. Key observed trends: Red Globe at 0 °C retained the highest bunch weights throughout; Ivory at 4 °C showed the highest initial bunch weight but greater subsequent dehydration; berry weight losses were lowest at 0 °C for both varieties.

**Figure 1. Statistical graphs of averages of weight losses in bunch and berries of two varieties of grapes at different storage temperatures.**




*C. Degrees Brix*

On the other hand, the degrees Brix showed values that increased with temperature and time of storage, reflecting the concentration of sugars associated with progressive

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dehydration of the berries. The highest Brix values were recorded in the Ivory variety at intermediate and higher temperatures.

*Coloration of bunches and berries*

Visual coloration progressed according to the temperature regime. At 0 °C the color changes were slower; at higher temperatures and ambient conditions the appearance of fungal growth (Botrytis cinerea) was observed from day 15 onward.

**Figure 3. Visual coloration of Ivory and Red Globe at 0 and 4 °C. A. First day; B. Fifth day; C. Tenth day; D. Fifteenth day; E. Twentieth day.**


*Chemical determinations*

A. pH – For the evaluation of the pH of the variety Ivory 4 °C a value of 4.26 of pH was given being the highest value of the evaluation; in the variety of the Red Globe 0 °C a pH of 3.92 was given being the highest value of its variety. The variety of Red Globe 10 °C obtained 3.04 of pH being this the lowest value.

B. Titratable acidity – The evaluation of titratable acidity of the variety Ivory 0 °C obtained 1.18% being the highest valuation, followed by the variety Red Globe 4 °C with a titratable acidity of 1.16%. The variety of Red Globe 10 °C and 0 °C with 0.57 and 0.58% obtained lower values of titratable acidity.

C. Maturity – The Brix of the treatments were considered for the data of maturity index; the variety that obtained higher index was the Ivory 10 °C with 34.99%, followed by the Ivory 4 °C with 34.42%. Likewise, the varieties with lower maturity indices were the Red Globe with 15.56% followed by the Ivory 0 °C with 18.60%.

**Table 3. Averages of chemical determinations.**

Key values from Table 3: Red Globe 0 °C – pH 3.92, Brix 15, titratable acidity 0.58, maturity index 26.01; Ivory 0 °C – pH 4.19, Brix 22, titratable acidity 1.18, maturity index 18.60; Ivory 4 °C – pH 4.26, Brix 24, maturity index 34.42; Ivory 10 °C – maturity index 34.99. Full titration data are retained in the original source.

*Microbiological determinations*

The samples of Red Globe 4 and 10 °C presented in the microbiological results values <10 CFU/g which indicated absence of microorganisms in a dilution of 1/10. In the Red Globe and Ivory with the temperature of 0 °C there existed presence of mesophilic

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aerobes 3×10 CFU/g; for the variety Ivory 4 °C a count of mesophilic aerobes of 4×10 was given. The Ivory 10 °C and the Control obtained results of count of mesophilic aerobes superior in comparison with the other samples.

**Table 4. Analysis of Aerobes and Mesophiles.**

Results (CFU/g): Red Globe 0 °C = 3×10; Ivory 0 °C = 3×10; Red Globe 4 °C = <10; Ivory 4 °C = 4×10; Red Globe 10 °C = <10; Ivory 10 °C = $2\times10^2$; Red Globe Control = $3\times10^2$.

*Sensory analysis*

On the first day, the variety Red Globe obtained higher acceptability in the parameters evaluated, of flavor, color, form, size and the juiciness with maximum valuation, followed by the parameters of seed and skin. Likewise the evaluation of parameters of the Ivory resulted to be very acceptable with valuation of 5 (I like very much) in color, flavor, seed and the juiciness, followed by the size, skin and form with qualification of 4 (I like a lot).

On the fifteenth day, the parameter of the seed was the best evaluated, in both varieties, more than 88% of the surveyed decided that they like a lot and to 13% they like very much the Red Globe, and to 100% they like very much the seed of the Ivory.

Other parameters well qualified (≥ 4) especially for the Ivory were the juiciness and flavor, followed by the skin and form. For Red Globe the parameters of skin, juiciness, flavor, size and form remained generally acceptable, while color showed some decline.

**Figure 4. Radial graph of the Red Globe and Ivory on the first and fifteenth day.**

**Deduction of the postharvest shelf life**

Coefficients of variation (CV) superior of 40% were obtained for the variables of the weight of the bunch, Degrees Brix and the weight of the berry. For which the assumptions of normality for the described variables were applied determining that the variables possess a normal distribution and equality of variances of the data evaluated, for which the technique of data transformation according to Log 10 was applied.

## DISCUSSION

The storage temperature demonstrated to be a determining factor in the conservation of the postharvest quality of the table grapes, influencing in a direct manner on the physical, chemical, microbiological, and sensory variables evaluated. These results concur with what was reported in the literature, where it is established that the adequate thermal management is key to prolong the shelf life of the grape and to reduce the postharvest losses (9,12,17).

The greater dehydration of the bunch observed in the variety Ivory stored at 4 °C can be attributed to the susceptibility of the rachis to the loss of water under conditions of inadequate relative humidity, more than by a phenomenon directly associated to the berry. Previous studies indicate that the dehydration of the rachis is the most sensitive tissue to the hydric stress, that is to say one of the principal factors that affect the commercial appearance of the bunch; even they indicate that the loss of turgor of the rachis is closely related with the environmental hydric deficit and with the interruption of the flow of water toward the berries after the harvest; upon interrupting the vascular flow, the rachis acts as a surface highly exposed to the transpiration, especially when parameters such as the relative humidity are little controlled (10,18). In this sense,

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although the variety Ivory presented fragility in the bunch, its berries showed lower loss of weight than those of Red Globe, which suggests structural differences in the cuticle and in the permeability of the epidermis, as has been described by Crisosto and Kader (13). This behavior suggests that the dehydration concentrates in the rachis and not in the fruit, that is to say that the wilted appearance of the rachis can present itself even when the berries conserve their turgor.

Likewise, Keller (18) mentions that there are varietal differences in the body of the rachis, in a particular manner in the diameter of vascular bundles, thickness of parenchymatic tissues and in the capacity of retention of water, for which these structural differences can explain why this variety Ivory has a rachis with greater postharvest dehydration.

As was mentioned, in the case of the Ivory the rachis is the predominant factor and not the stomatal density of the berry; the rachis has a thinner cuticle and a greater exposure to the environment than the berry; thus also the dehydration of this causes a great visual impact on the quality of the bunch even when the berries do not register significant losses of weight; however, the results varied with respect to the variety Red Globe in berries (13,14).

On the contrary, the variety Red Globe evidenced a greater loss of weight in the berries during the storage, especially at temperatures superior to 0 °C. This behavior has been widely associated to the transpiration and respiration of the fruit, processes that intensify as the storage temperature increases (9,19). It is necessary to take into account that the grape berries upon possessing few functional stomata, lose activity as the maturation advances; upon occurring this the loss of water in the berry could be by diffusion through the cuticle or by microfissures in the epidermis. This leaves us open to think that the cuticle of the Ivory could be thicker or less permeable reducing the loss of water. The loss of water in the berries keeps direct relation with the increment of the total soluble solids, reflected in the increase of the degrees Brix, phenomenon that has been reported as an effect of concentration of sugars due to the partial dehydration of the fruit (14).

The increment of the degrees Brix and of the maturity index observed in the variety Ivory stored at 10 °C coincides with what was indicated by Valverde et al. (15), who indicate that intermediate temperatures can accelerate the metabolic processes, promoting the degradation of organic acids and the relative increase of sugars (15). However, although a higher maturity index can improve the sensory perception of the flavor, it can also compromise the shelf life of the product especially if it is accompanied by greater microbial activity. Nevertheless, this process can compromise the stability of the fruit, since an accelerated maturation usually goes accompanied by a greater susceptibility to the physiological and microbiological deterioration (20).

From the microbiological point of view, the storage at 0 °C showed better conditions of stability, upon registering lower counts of mesophilic aerobes in both varieties. This result is consistent with what was reported by Cantín et al. (16), who indicate that the low temperatures inhibit the microbial growth and delay the development of postharvest pathogens such as Botrytis cinerea (16). In addition, the more acid pH registered in the treatments at 0 °C contributed to limit the proliferation of

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microorganisms, since values of low pH generate an environment less favorable for the bacterial and fungal proliferation in the table grape (21).

The appearance of fungi from the fifteenth day of storage confirms that, even under refrigeration, the grape is a highly perishable fruit and susceptible to the microbiological deterioration if a constant cold chain and optimal conditions of relative humidity are not maintained. These findings reinforce the necessity of implementing postharvest management technologies adapted to the local conditions of Ecuador, where the losses by microbial deterioration continue being elevated.

With respect to the sensory evaluation, the results evidenced a general positive acceptability for both varieties, especially in the parameters of flavor and juiciness. However, the deterioration of the color and the external appearance of the bunch, principally in the variety Ivory, influenced negatively in the perception of the consumer toward the end of the period of storage. Diverse authors coincide in that the color, the integrity of the bunch and the absence of visible rots are decisive factors in the commercial acceptance of the table grape (22).

Taken together, the results obtained confirm that the storage at 0 °C constitutes the best alternative to conserve the postharvest quality of the varieties Red Globe and Ivory in the conditions evaluated. These findings contribute relevant information for the strengthening of the productive chain of the grape in the province of Santa Elena, contributing to the reduction of postharvest losses and to the better positioning of the national product compared with the imported grape.

## CONCLUSIONS

The storage temperature influenced as the most determining factor in the postharvest behavior for the conservation of the varieties Ivory and Red Globe, managing to influence directly in the loss of weight, the physicochemical changes such as retarding the processes of maturation, and maintaining the microbiological integrity and the sensory acceptability. The storage at 0 °C permitted reducing significantly the dehydration, retarding the metabolic processes associated to the maturation and limiting the microbial development, which translated into a greater general stability of the fruit during the 20 days of evaluation. These results evidence that the adequate thermal management constitutes a key tool to prolong the shelf life of the table grape produced in the province of Santa Elena.

Relevant varietal differences were identified in the postharvest behavior of the grapes evaluated. The variety Red Globe presented a greater stability of the bunch and of the berries, with lower losses of weight and lower values of pH, which favored its microbiological conservation. In contrast, the variety Ivory showed a greater dehydration of the bunch, particularly at 4 °C, although its berries presented lower loss of weight. This behavior suggests that the dehydration observed in Ivory is principally associated to the structural susceptibility of the rachis and not to a greater loss of water in the berry, which highlights the importance of considering specific anatomical and physiological characteristics of each variety in the design of postharvest management strategies.

The changes in the total soluble solids, the titratable acidity and the maturity index evidenced that temperatures superior to 0 °C favor the concentration of sugars and accelerate the maturation, which can improve temporarily the sensory perception, but compromises the stability of the fruit and its shelf life. Likewise, the appearance of fungi and the increment of the count of mesophilic aerobes in treatments at more elevated temperatures and in the control confirm the high perishability of the table grape and the necessity of strengthening the cold chain. Taken together, the results obtained contribute relevant technical information to optimize the postharvest management of the grape in Santa Elena, contributing to the reduction of losses, to the improvement of the commercial quality and to the strengthening of the national production compared with the imported grape. A bad manipulation accelerates the mechanical damage, the respiratory rate and reduces significantly the shelf life of the fruit. The initial quality of the fruit at the moment of the harvest also influences directly in its conservation.

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## DECLARATION OF INTEREST

The authors confirm the absence of conflicts of interest of financial, academic or personal nature that have affected the design, the results or the writing of this scientific article.

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# EVALUACIÓN DE LA CADENA DE FRÍO EN LA COMERCIALIZACIÓN DE QUESO CRIOLLO EN EL CANTÓN LOMAS DE SARGENTILLO

# EVALUATION OF THE COLD CHAIN IN THE MARKETING OF CREOLE CHEESE IN THE LOMAS DE SARGENTILLO CANTON

Bryan Jesús González Tutiven[1], Alexander Álvarez Martínez[2], Ana Arellano Arcentales[3], Julio Palmay Paredes[4]

{bryan.gonzalez.tutiven@uagraria.edu.ec1, aalvarez@uagraria.edu.ec2, aarellano@uagraria.edu.ec3, jpalmay@uagraria.edu.ec4}

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**RESUMEN:** A nivel mundial el queso gracias a su gran nivel nutritivo se ha convertido en uno de los alimentos más consumidos. Su composición se basa en proteínas, grasas combinado con su sabor y textura lo convierten en alimento de alto consumo, su conservación está estrechamente ligado a la cadena de frío que constituye un factor fundamental en la calidad de los productos lácteos. El objetivo de este estudio fue evaluar la cadena de frío mediante el monitoreo de la temperatura de quesos criollos durante su comercialización en el cantón Lomas de Sargentillo. Se seleccionaron cinco locales comerciales mediante un muestreo aleatorio estratificado, evaluando los productos durante un periodo de 21 días. Se tomaron mediciones de temperatura y pH en los días 1, 7, 14 y 21, con el uso de un datalogger para realizar un registro continuo de la temperatura en equipos de almacenamiento, de igual manera se utilizó un termómetro digital para registrar la temperatura interior del producto, en este caso el queso. Además, se tomaron cinco muestras de queso para analizar los parámetros fisicoquímicos y bromatológicos (humedad, grasa y proteína). Los análisis microbiológicos incluyeron la detección de *Salmonella spp.*, *Enterobacteriaceae* se obtuvo un promedio de 3.9x105UFC, *Escherichia coli* se obtuvo un promedio de 3.16x102UFC, *Staphylococcus aureus* se obtuvo un promedio de 4.6x103 UFC y *Listeria monocytogenes* en ausencia. Los resultados, evaluados conforme a la norma (1), evidenciaron incumplimiento en los parámetros de *Enterobacteriaceae*, *E. coli* y *Staphylococcus aureus*, mientras que se cumplió con los criterios establecidos para *Listeria monocytogenes* y *Salmonella spp.* Se concluye que las deficiencias en la cadena de frío influyen de manera significativa en la calidad microbiológica, fisicoquímica y bromatológica de los quesos criollos durante su comercialización.

***Palabras clave:*** *cadena de frío, microbiológica, queso criollo, temperatura, físico-químicos.*

**ABSTRACT:** Globally, cheese, thanks to its high nutritional value, has become one of the most consumed foods. Its composition, based on proteins and fats, combined with its flavor and texture, makes it a widely consumed food. Its preservation is closely linked to the cold chain, which is a fundamental factor in the quality of dairy products. The objective of this study was to evaluate the cold chain by monitoring the temperature of local cheeses during their sale in the Lomas de Sargentillo canton. Five commercial establishments were selected using stratified random sampling, and the products were

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evaluated over a period of 21 days. Temperature and pH measurements were taken on days 1, 7, 14, and 21, using a data logger to continuously record the temperature in storage equipment. A digital thermometer was also used to record the internal temperature of the product, in this case, the cheese. In addition, five cheese samples were taken to analyze the physicochemical and bromatological parameters (moisture, fat, and protein). Microbiological analyses included the detection of Salmonella spp., Enterobacteriaceae (average of 3.9 x $10^5$ CFU), Escherichia coli (average of 3.16 x $10^2$ CFU), Staphylococcus aureus (average of 4.6 x $10^3$ CFU), and Listeria monocytogenes (absence). The results, evaluated according to standard (1), showed non-compliance with the parameters for Enterobacteriaceae, E. coli, and Staphylococcus aureus, while the established criteria were met for Listeria monocytogenes and Salmonella spp. It is concluded that deficiencies in the cold chain significantly influence the microbiological, physicochemical, and bromatological quality of local cheeses during their commercialization.

***Keywords:*** *cold chain, microbiological, creole cheese, temperature, physical-chemical*

[1] Facultad Ciencias Agrarias, Universidad Agraria del Ecuador - Ecuador, https://orcid.org/0009-0001-8669-0617; +593991414912.
[2] Facultad Ciencias Agrarias, Universidad Agraria del Ecuador - Ecuador, https://orcid.org/0009-0007-1095-0658; +593992638051.
[3] Facultad Ciencias Agrarias, Universidad Agraria del Ecuador - Ecuador, https://orcid.org/0009-0006-5606-411X; +593958850486.
[4] Facultad de Ciencias Agrarias, Universidad Agraria del Ecuador, Instituto Superior Tecnológico Superarse - Ecuador, https://orcid.org/0000-0002-7546-5211; +593984794451.

## INTRODUCTION

Ecuador is a country characterized by its diversity in the elaboration of food products, within which natural and processed foods are included. Both types require adequate methods of preservation that permit maintaining their quality, which is determined by factors such as the degree of freshness, the appearance, the flavor, and the coloration. Throughout history diverse procedures of conservation have been developed, among which refrigeration, the use of salts, nitrites, and other traditional and technological methods stand out. Nevertheless, in the production of foods such as meats, dairy products, and their derivatives, it proves indispensable to maintain an adequate cold chain in order to conserve their properties and guarantee that they are apt for human consumption (2).

The dairy products that present a high risk of food intoxication or that possess a short shelf life must be subjected to a rigorous control of temperature, with the aim of assuring the correct functioning of the cold chain. This control permits preserving the safety and quality of the foods during their elaboration, transport, and storage. Currently, the consumers seek products that contribute greater nutritional benefits, which depends directly on the quality of the raw material, the process of elaboration, the transport, and the conditions of storage. An inadequate management in any of these stages can compromise the integrity of the consumer and generate risks for public health (3).

The market of the cheeses is ample at the worldwide level and represents a great responsibility for the producers, since the principal objective is to offer to the consumer a fresh, nutritious, and quality product. There exist different types of cheeses, among them the fresh or soft cheeses and the mature or hard cheeses, each one with specific characteristics. One of the fundamental aspects in the elaboration of the cheese is the

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adequate management of the coagulation of the casein, principal protein of the milk. The interaction of this protein varies according to the type of cheese, the content of salt, the pH, the chemical composition of the milk, and the environmental conditions during the process of elaboration, factors that influence directly in the texture, the flavor, and the final quality of the product (4).

Cheese is one of the most consumed foods owing to its elevated content of proteins, fats, as well as by its sensory properties such as the flavor and the texture. However, owing to its composition, it is susceptible to suffer alterations in its quality, especially when an adequate cold chain is not maintained. Among the principal changes that can present themselves are found variations in the odor, color, and texture, generally associated to an inadequate management during the production or commercialization. In many cases, the artisanal producers do not count with appropriate norms of hygiene nor with the necessary equipment to guarantee a safe process. In addition, a great part of these producers has not received training on good manufacturing practices, which increments the risk of contamination by pathogenic bacteria and can affect gravely the health of the consumer (5).

The cold chain comprises a set of operations destined to conserve the shelf life and the nutrients of the cheese, avoiding fluctuations of temperature that can affect its quality. This chain must be maintained in a continuous manner during all the stages of the productive process, from the elaboration until the sale of the final product. The adequate control of the temperature is fundamental to guarantee the food safety and the quality of the cheese. Nevertheless, the maintenance of the cold chain does not depend solely on the producers and merchants, but also on the final consumer, who must conserve the product in adequate conditions until its consumption. The rupture of the cold chain in any of these stages provokes the deterioration of the product, loss of nutrients, and alterations in its sensory characteristics (6).

In the artisanal elaboration of the cheese, independently of the canton where it is produced, the raw material utilized frequently does not comply with the standards established by the standard (1), corresponding to fresh non-ripened cheeses. In many cases, these products are elaborated with non-pasteurized milk, coagulants of diverse nature are employed, and variable times of fermentation and maturation are managed. These conditions generate a wide diversity of flavors and textures that, on occasions, result disagreeable for the consumer. Likewise, the bad practices of elaboration and manipulation affect negatively the quality of the product, diminish its acceptance in the market, and increase the risk of infections or food intoxications, which can present themselves in an isolated form or give rise to outbreaks of greater magnitude (7), (8).

Lomas de Sargentillo, being a canton that is found in the central part of the province of Guayas and being a site of passage for many tourists, has become a propitious sector so that its inhabitants dedicate themselves to activities such as commerce and alimentation; from there that currently the commercialization of creole cheese in this cantonal head is found widely diffused; although it is necessary to evaluate if at the moment of the commercialization all the processes of assurance of the quality of the product are complied with, otherwise the product would represent a constant threat for the consumer (9).

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Fresh cheese has elevated percentages of moisture which makes necessary that it be controlled with temperatures between 2 °C and 4 °C, which is not complied with in an adequate manner in the elaboration and management of the artisanal creole cheese, which produces alterations in the same favoring the growth of microorganisms such as Staphylococcus aureus and Escherichia coli, principal responsible for acute food intoxications.

Any food becomes susceptible to different contaminating agents even more so if it does not have a control of the temperature. For which the control of the cold chain becomes indispensable; at the same time the lack of knowledge of Good Manufacturing Practices of places that elaborate and commercialize this product do not count with equipment such as refrigerators, since they are artisanal enterprises, which would help to improve the conservation in the cold chain and the quality, in order to guarantee the health of the consumer because from this will depend the growth of the small and medium enterprises (10).

At the present time there does not exist a statistic that reveals with exactitude everything about the commerce that is dedicated to the sale of artisanal cheese in the canton Lomas de Sargentillo; in addition neither is specific information possessed on how many locales dedicate themselves to these activities and count with an adequate management in the conservation of the foods in cold. This investigation was realized with the purpose of evaluating the cold chain by means of the monitoring of the temperature of the creole cheeses in the commercialization of the canton Lomas de Sargentillo assuring the conservation of the product (11).

## MATERIALS AND METHODS

### Experimental design

For the present investigation the locales where creole cheeses are commercialized located in the cantonal head of the canton Lomas de Sargentillo were taken into account, the same which for effects of the investigation were grouped in the following manner: neighborhood stores, industrial stores, supply centers, stall in the market, and distributors.

Once the strata were defined, the simple random sampling was applied in each group or stratum with the aim of determining the sample (12).

**Table 1. Proportional stratified random sampling.**

| Stratum | Probability | Number of locales | Relative frequency | Number sampled |
|---|---|---|---|---|
| 1 | Industrial stores | 3 | 0.07 | 1* |
| 2 | Supply centers | 7 | 0.16 | 1* |
| 3 | Neighborhood stores | 30 | 0.67 | 2 |
| 4 | Stall in the market | 5 | 0.11 | 1 |
| **Total** | | **45** | **1.00** | **5** |

*0.07 of 5 = 1; 0.16 of 7 = 1

**Table 2. Proportional stratified random sampling in locales of creole cheese.**

| Stratum | Probability | No. locales | Rel. freq. | No. sampled | Selected locales |
|---|---|---|---|---|---|
| 1 | Industrial stores | 3 | 0.07 | 1* | LC05 |
| 2 | Supply centers | 7 | 0.16 | 1* | LC03 |
| 3 | Neighborhood stores | 30 | 0.67 | 2 | LC01, LC04 |
| 4 | Stall in the market | 5 | 0.11 | 1 | LC02 |
| **Total** | | **45** | **1.00** | **5** | |

*0.07 of 5 = 1; 0.16 of 7 = 1

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Considering that dairy products demand care in relation to the cold chain, a data logger was placed in the commercial establishments of the canton Lomas de Sargentillo with the aim of controlling the temperature of the places of storage.

Subsequently the discretionary and non-probabilistic type sampling was realized; before realizing the analysis the asepsis of the place, hands, equipment that were utilized was safeguarded; for the management of the samples 454 grams of cheese were taken into consideration; each sample was coded with the initials of each store; finally the sampling by quartering was realized. An analysis of temperature, pH, and moisture was realized during day 1, day 7, day 14, and day 21, by triplicate, and the determinations of content of fat and protein were realized in a single repetition together with the microbiological analysis (13).

**Control of temperature (data logger and thermometer)**

A control of the sample was realized by the measurement of the temperature with data logger, which measured the temperature in real time in programmed periods of time every 10 min during 21 days in the five locales of sale. The determination of temperature of the cheeses was realized with a thermometer, during the days 7, 14, and 21.

**Determination of moisture**

The analysis of moisture was realized by means of the method of desiccation in the hot-air oven.

**Determination of the hydrogen potential (pH)**

The analysis of the sample of the product was determined by means of the potentiometer method to measure the pH.

**Determination of Enterobacteriaceae**

A microbiological control was realized in the creole cheese by means of the method of count in plate by pour plating; the dilutions were realized in peptone water; dilutions were realized for subsequent plating and incubation; after 24 h the count of colony-forming units was realized.

**Determination of Listeria monocytogenes**

For the count of Listeria monocytogenes a plating on petrifilm in different dilutions was realized and subsequent process of incubation at 37 °C ± 1 °C during 24 h; subsequently the count was realized.

**Determination of Staphylococcus aureus**

A microbiological control of the sample was realized by the method of plate by surface spreading for the detection and count of Staphylococcus aureus.

**Determination of Escherichia coli**

A microbiological control of the sample was effected by plating on Petrifilm for the detection and count of Escherichia coli subsequent to the 24 to 48 hours at 35 °C.

**Determination of Salmonella spp.**

25 grams of sample were incubated with peptone water and sodium chloride at 2% for 24 hours for the enrichment of possible cells of Salmonella; subsequently an aliquot was passed to the culture medium Rappaport and it was incubated at 43 °C during 24 hours; after incubation it was plated on selective medium S-S (Salmonella-Shigella) and

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incubated at 37 °C during 24 hours for identification of typical colonies; subsequently the suspicious colonies were plated on TSI agar incubated from 35 to 37 °C and subsequent confirmation.

**Statistical analysis**

The type of statistics that corresponds to this study is the inferential since estimations of the quality that the creole cheeses taken from 5 locales of stores and commercials of the canton Lomas de Sargentillo have were obtained, which were chosen at random, but taking into consideration as requirement that it be a center of commerce of select taste for all the consumers.

For the comparison of the means of the different analyses (temperature, moisture, pH, and microbiological analyses) an ANOVA with a Tukey test $p \geq 0.05$ was realized to determine significant differences.

## RESULTS

Next, in Table 3 the mean values of temperature of the data logger in the course of 21 days are presented, where the temperatures of the refrigeration equipment of the creole cheeses in 5 locales on day 1, 7, 14, and 21 were taken. Upon comparing on each day the temperature of the samples of the locales, it was observed that the temperatures so that an adequate cold chain can be managed should not surpass from 2 °C to 6 °C as indicates (1). For this a control of the temperature with minimal differences that permit an adequate storage in the conservation of the creole cheese should be established.

**Table 3. Mean values of temperature of the data logger.**

| Samples of Locales | DAY 1 (°C) | Day 7 (°C) | Day 14 (°C) | Day 21 (°C) |
|---|---|---|---|---|
| LC01 | 8.59a | 7.51b | 9.91a | 7.27a |
| LC02 | 1.35c | 2.76c | 7.12bc | 4.54b |
| LC03 | 5.40b | -1.41d | 1.12d | 0.17c |
| LC04 | 5.88ab | 8.34b | 8.10ab | 6.15ab |
| LC05 | 7.16ab | 12.38a | 5.69c | 4.78ab |
| S.E. | 0.75 | 0.55 | 0.78 | 1.16 |

Means with different letter in each column differ significantly ($p < 0.05$). S.E.: Standard error of the mean.

As can be observed, in the 5 establishments there exist different fluctuations of temperature on the day until day 21, observing that in the 5 locales analyzed the cold chain is broken and even temperatures inferior to 0 °C are observed, below the range which could occasion a process of freezing of the product, differing throughout the time fluctuating above the range of temperature recommended for a product, for which it is recommended that it not exceed from 2 °C to 6 °C as indicates (1). The ranges of temperature on day 1 in the different locales fluctuated from 8.59 °C to 1.35 °C; different data were observed on day 7 with fluctuations from −1.41 °C to 12.38 °C; on day 14 the variations of temperature were with a range from 1.12 to 9.91 °C and on day 21 changes of temperature that go from 0.17 °C to 7.27 °C are evidenced, which indicates to us that there exists little control with respect to the variations of temperature of the places of storage of the creole cheeses under study.

If fluctuations in the temperature of the places of storage are evidenced, obligatorily the internal temperature of the creole cheeses will be affected as is evidenced in Table 4. Where the mean values of the internal temperature of the creole cheeses sampled from

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5 locales of sale of this product are presented; on day 1 three locales with temperatures that differ from the recommended range are evidenced; two locales are found above what is permitted and one locale with temperatures inferior to what is exposed in (1). In similar form it happens throughout the time where it can be highlighted that LC03 and LC04 are the locales that present more variations in their internal temperature.

**Table 4. Values on the temperature of the sample with thermometer.**

| SAMPLES OF LOCALES | Thermometer temp. DAY 1 (°C) | Thermometer temp. DAY 7 (°C) | Thermometer temp. DAY 14 (°C) | Thermometer temp. DAY 21 (°C) |
|---|---|---|---|---|
| LC01 | 8.6 °C | 1.5 °C | -1.9 °C | -0.2 °C |
| LC02 | 1.8 °C | 0.9 °C | 3.6 °C | 3.8 °C |
| LC03 | 4.5 °C | 7 °C | 2.9 °C | -2 °C |
| LC04 | 6.6 °C | 5.9 °C | 5 °C | 5.3 °C |
| LC05 | 11.6 °C | 10.9 °C | 5.8 °C | 3.7 °C |

Values compiled on the temperature of the cheeses.

Next, Table 5 is presented. Where the mean values of pH in the course of 21 days, of the five locales on day 1, 7, 14, and 21 are exposed. On day 1, a range between 5.79 to 6.43 with a relatively acid pH was observed, observing the influence of the temperature on the pH of the products, evidencing significant differences among the different locales where LC02 and LC03 reached more acid pH; consequently this tendency was observed until day 21, even cheeses that began with a less acid pH on day 21 presented a drastic decrease, for which it can be mentioned that the incidence of the temperature on this parameter is fundamental.

**Table 5. Mean values of pH.**

| Samples of Locales | DAY 1 | Day 7 | Day 14 | Day 21 |
|---|---|---|---|---|
| LC01 | 6.18b | 6.22b | 6.41b | 5.82a |
| LC02 | 5.79c | 6.03c | 6.12c | 5.43b |
| LC03 | 5.82c | 5.87d | 6.12c | 5.41b |
| LC04 | 6.38a | 6.68a | 6.61a | 5.79a |
| LC05 | 6.43a | 5.98c | 5.43d | 5.02c |
| S.E. | 0.04 | 0.02 | 0.04 | 0.05 |

Means with different letter in each column differ significantly ($p < 0.05$).

In Table 6 the mean values and standard error of the moisture of the samples raised from the 5 locales during the days 1, 7, 14, and 21 are presented; as is evidenced they present different content of moisture existing significant differences among the cheeses in a range of 40.61% and reaching a maximum of moisture of 56.96% with a similar tendency throughout the time but presenting a decrease of content of moisture by processes of loss of water in the storage arriving at a content of moisture minimum of 41.59% and maximum of 53.55% on day 21.

**Table 6. Mean values of moisture of the samples.**

| Samples of Locales | Day 1 (%) | Day 7 (%) | Day 14 (%) | Day 21 (%) |
|---|---|---|---|---|
| LC01 | 48.76ab | 45.52b | 50.38a | 46.46b |
| LC02 | 44.77abc | 42.77bc | 47.05a | 44.32b |
| LC03 | 50.45a | 51.90a | 56.96a | 53.55a |
| LC04 | 40.81c | 40.61c | 54.34a | 41.59c |
| LC05 | 44.15bc | 44.63b | 48.81a | 45.30b |
| S.E. | 1.32 | 0.63 | 16.23 | 0.47 |

Means with different letter in each column differ significantly ($p < 0.05$).

With respect to the content of protein and fat the results are presented in Table 7 evidencing contents that comply with the specifications in Standard (14).

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**Table 7. Percentage of protein.**

| Samples of Locales | % Protein | % Fat in dry extract |
|---|---|---|
| LC01 | 16.72 | 53.54 |
| LC02 | 15.63 | 52.36 |
| LC03 | 20.45 | 52.90 |
| LC04 | 14.43 | 41.14 |
| LC05 | 14.09 | 50.30 |

Next, in Table 8 the results of the microbiological parameters of Salmonella spp., Enterobacteriaceae, Escherichia coli, Staphylococcus aureus, and Listeria monocytogenes are presented. The positive results can be observed where it does not comply for Enterobacteriaceae, Escherichia coli, Staphylococcus aureus, and where it can be observed that it does comply with Listeria monocytogenes (absence) and Salmonella spp. (absence) as indicates (1). These results of the presence of microorganisms are associated to the results presented in the changes of temperature linked to the rupture of the cold chain that favors the microbiological development, accelerating the growth of the same, denoting the importance of the conservation of vulnerable products and recommended to be found in controlled storage, being a critical factor the temperature that affects the microbiological stability and the safety of the food.

**Table 8. Results of microbiological analysis.**

| Samples | Enterobacteriaceae m: $2\times10^2$ CFU/g | E. coli m: <10 CFU/g | S. aureus m: 10 CFU/g | L. monocytogenes m: Absence | Salmonella m: Absence |
|---|---|---|---|---|---|
| LC01 | $1.6 \times 10^4$ | $4.3 \times 10^2$ | $9.0 \times 10^3$ | Absence | Absence |
| LC02 | $3.4 \times 10^5$ | $3.9 \times 10^2$ | $3.0 \times 10^3$ | Absence | Absence |
| LC03 | $8.4 \times 10^5$ | $8.0 \times 10^1$ | $1.5 \times 10^3$ | Absence | Absence |
| LC04 | $1.3 \times 10^5$ | $1.0 \times 10^1$ | $8.4 \times 10^3$ | Absence | Absence |
| LC05 | $6.4 \times 10^5$ | $6.7 \times 10^2$ | $1.0 \times 10^3$ | Absence | Absence |

## DISCUSSION

In this present investigation the identification of the distinct points of sales and distribution of creole cheeses in the canton Lomas de Sargentillo was developed; once the strata were defined they were grouped in neighborhood stores, industrial stores, supply centers, market stalls, and distributors totaling 45 points of sales; then the stratified random sampling was applied which permitted us to identify the total of 5 locales completely at random; in this investigation according to (15), the data found are completely different since they realized this study with the purpose of exploring the factors that influence in the purchase of fresh cheeses of cow and of goat. The population was represented by a proposal according to the selection of the domiciles distributed in seven parishes of the municipality Iribarren of the state Lara, Venezuela. Where a stratified random sample of 598 domiciles was selected; each place was coded and analyzed; obtained the results the consumers have greater preference for the cheeses of cow (80.4%); the average of weekly purchase of cheese of cow is 1 to 1.5 kg (54%), and the cheese of goat is of 0.5 to 1 kg fortnightly. The stores are the preferred places for the purchase of cheese of cow (23.7%), and the specialized cheese dairies in cheese of goat (34.7%). The proximity of these centers of distribution to their homes is the principal reason of their selection. The little salty flavor and the medium texture are the principal attributes of purchase for the cheeses of cow, while the cheeses of goat they prefer without salt and of more loose texture.

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According to (16), it was determined in this investigation how the cold chain and the microbiological quality are altered in the fresh cheeses commercialized in a market of the province of Guayas and artisanal cheese production in the province of Chimborazo; the deficiency in the management of the temperatures that affect considerably their physicochemical, compositional, and microbiological properties was evidenced; it is necessary to maintain an ideal control of the temperature in the cold chain from when the product is created until it arrives at the consumer in order to prevent the propagation of prejudicial microorganisms and the production of toxins in the cheese in order to guarantee the quality of our product during the entire procedure. Thus at a determined moment the aspects of manipulation do not compromise some risk of health upon ingesting the product; for that reason it is crucial to maintain the control of the refrigeration equipment 2 °C to 8 °C, in order to avoid any damage and avoid that the cold chain be broken in any dairy product. The data of this investigation on the cold chain in the creole cheeses of Canton Lomas de Sargentillo are completely different from the data of the previous results; it can be appreciated how there exists a rupture of the temperature in LC02 having a minimum temperature of 1.6 °C as was evidenced on day 1, 7, and 14 continues with the same tendency with respect to the temperature in LC02 in comparison with the temperature of day 21 the temperatures are very low; these are not optimal conditions of temperature that a product should be conserved, and its maximum temperature is of 28.4 °C the LC02 where it presents a greater temperature outside the range established 2 °C to 6 °C as indicates (1), at determined times; LC03 has a minimum temperature of −4.0 °C, presents temperatures inferior to 0 °C, is below the range which could occasion a process of freezing of the product; its maximum temperature is of 32.4 °C the LC03 presents a greater temperature outside the range established.

In this investigation it was determined that the moisture in the cheeses of the canton Lomas de Sargentillo have a range of the minimum 40.61% in LC04 of day 7, reaching a 92.19% of maximum moisture in LC03 of day 14; this is an indicative of when a lower quantity is obtained in several of the locales it means the loss of the cold chain; also the pH was determined with a range of (5.02–6.68), in fat with (41.14%–53.54%) and protein (14.09%–20.45%); the results of the investigation do not concur with those of (17), the ranges for their physicochemical parameters were pH (4.84–6.07), moisture (42.71%–66.66%), fat (12%–32%), protein (16.81%–26.62%). The results of this investigation in the artisanal fresh cheese in the city of Toluca, establish the necessity of improving the policies of hygiene by the authorities, in order to promote a good manipulation of the product causing a great impact on the health of the consumers.

According to (18), it determined a diagnosis about the biological hazards in fresh cheeses elaborated in artisanal form that are offered to the consumer in supermarkets and warehouses in order to carry out this study; initially several visits were made to the different establishments with the aim of observing the greater influence of the product to the public; it was taken of reference for the taking of sample, sanitary registers, operating license; the parameters obtained in the microbiological tests of the results of the count of Staphylococcus aureus (5.07 ± 0.06 Log10 CFU/g) of the plant were superior for Enterobacteria (4.33 ± 0.06 Log10 CFU/g), coliforms (4.27 ± 0.03 Log10 CFU/g) and Escherichia coli (4.03 ± 0.03 Log10 CFU/g), are outside the parameters of quality in the standard demanded by the ministry of health; in Listeria monocytogenes there exists

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(Absence), and Salmonella spp. there exists (Absence); this is due to that it had a rupture in the cold chain. In this investigation different values were obtained with respect to the microbiological results that were realized to 5 locales of creole cheeses; the results of Enterobacteriaceae can be observed that it does not comply with respect to ($8.4 \times 10^5$ CFU/g), Escherichia coli does not comply with respect to ($8.0 \times 10^1$ CFU/g), Staphylococcus aureus does not comply with respect to ($9.0 \times 10^3$ CFU/g), and where it is observed in Listeria monocytogenes it does comply (Absence), and Salmonella spp. it does comply (Absence) with respect to (1); this means that the cold chain is already affecting the microbiological load; in the major part of these establishments they do not count with all the characteristics of quality, since they put at risk the health and the well-being of the community.

According to (19), in its cited study Microbiological analysis of fresh cheeses Guayaquil Listeria and Salmonella the presence of these microorganisms in foods of great consumption such as the cheese represents an alert on the systems of management of safety in these foods. Despite the high demand of this product in the city of Guayaquil, records of incidence by intoxication of fresh cheeses are not available. The results obtained where it is managed to evidence the presence of Salmonella spp., in a 13.71% of the cheeses analyzed; for the case of Listeria, the presence was managed to be detected in a 52.94% of the cheeses analyzed. The results of the author previously cited, have data completely different from this study with respect to microbiological parameters analyzed in the locales of sale of creole cheese in the canton Lomas de Sargentillo, where there exist the absence of Listeria and Salmonella spp. With these studies it is managed to leave in evidence the safety of the fresh cheeses that are of greater demand, which permits discovering the risk to which the consumer is exposed. For that reason, it is fundamental to consider the microbiological parameters established by the alimentary regulations in order to guarantee the quality of the foods in benefit of the persons upon consuming a product.

## CONCLUSIONS

In the present investigation the rupture of the cold chain in 5 locales of sale of creole cheese was evidenced affecting directly the bromatological, sensory, and bromatological quality, where fluctuations of temperature in the 21 days of the study were evidenced registering temperatures outside the permitted range, both above the limits and inferior which influences directly in the parameters such as the pH, moisture, fat, protein and favors the microbiological proliferation.

Although the parameters of fat and protein complied with what is established in the regulations, an elevated load of the microbiological count of Enterobacteriaceae, Escherichia coli, and Staphylococcus aureus was evidenced; these results presented themselves in the 5 locales analyzed from day 1, which confirms that there exists a deficient control of the chain of temperature during the storage and its commercialization. Being able to conclude that the continuous control of the cold chain is important in order to guarantee the safety, stability, and shelf life of the creole cheese.

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# LO MICRO Y LO MACRO, EL PAISAJE Y SU CONTEXTO: TEORÍA, MÉTODOS Y POSIBILIDADES DE APLICACIÓN DE REGISTROS MICROSCÓPICOS EN ESTUDIOS ARQUEOLÓGICOS

# THE MICRO AND THE MACRO, THE LANDSCAPE AND ITS CONTEXT: THEORY, METHODS AND POSSIBILITIES OF APPLICATION OF MICROSCOPIC RECORDS IN ARCHAEOLOGICAL STUDIES

Alex Alves De Barros[1], Lenin Garcés Viteri[2], Ana Gabriela Garcés Berrones[3]
{alex.alves@unach.edu.ec1, lgarces@unach.edu.ec2, anag.garces@unach.edu.ec3}

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**RESUMEN:** La microarqueología emerge ahora al centro del escenario en la arqueología contemporánea al posibilitar una articulación innovadora entre las escalas microscópicas y macroscópicas al estudiar sitios, paisajes y contextos arqueológicos. Esta aproximación amplía de forma significativa el entendimiento del registro arqueológico. El enfoque incorpora pruebas que suelen pasar desapercibidas a ojo, incluyendo rastros moleculares, botánicos y sedimentarios. Estos datos resultan fundamentales a la hora de desentrañar las costumbres diarias, los fenómenos ambientales, y las interacciones socioculturales del pasado. En cuanto metodología, este manuscrito se desarrolla por medio de una sistemática revisión bibliográfica que permite comparar diferentes contextos, problemáticas y estudios de caso latinoamericanos y angloamericanos, profundizándola discusión en cuatro áreas clave de la microarqueología: los análisis moleculares, los estudios de isótopos estables, la microbotánica y la micromorfología de los suelos. Examinando el ADN antiguo, se cuestionan críticamente modelos sobre el poblamiento inicial de América, valorando tanto su potencial interpretativo como las limitaciones inherentes a los procesos tafonómicos, particularmente en entornos tropicales. El análisis isotópico, de por si, habilita la reconstrucción intrincada de patrones dietéticos, la movilidad a través del tiempo, y hasta la estacionalidad, aportando resultados considerables en entornos costeros del sur brasileño, donde se encuentran los sambaquis, por ejemplo. La microarqueobotánica, al mismo tiempo, facilita la reconstrucción de paleoambientes y las diversas prácticas involucradas en el manejo de vegetales, la micromorfología del suelo permite reconocer actividades humanas, los complicados procesos de ocupación, junto a transformaciones postdeposicionales mediante el minucioso análisis microscópico de los sedimentos. En definitiva, se establece que la integración de estos diversos métodos metodológicos impulsa notablemente los estudios arqueológicos regionales, sobre todo en investigaciones de cazadores-recolectores, tecnologías líticas, así como, paisajes culturales. Lo anterior, consolida a la microarqueología como un enfoque absolutamente esencial para la generación de interpretaciones más certeras, contextualizadas, y por supuesto, multiescalares del pasado.

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***Palabras clave:*** *Microarqueología, métodos arqueológicos, análisis microscópico, paleoambientes, registro arqueológico*

**ABSTRACT:** Microarchaeology now emerges at the center of the scene in contemporary archaeology to enable an innovative articulation between microscopic and macroscopic scales to study sites, landscapes and archaeological contexts. This approach significantly expands the understanding of the archaeological record. The approach incorporates tests that go unnoticed by the eye, including molecular, botanical and sedimentary traces. These data are fundamental when it comes to unraveling daily customs, environmental phenomena, and sociocultural interactions of the past. In terms of methodology, this manuscript is developed through a systematic bibliographic review that allows comparing different contexts, issues and Latin American and Anglo-American case studies, deepening the discussion in four key areas of microarchaeology: molecular analysis, stable isotope studies, microbotany and the micromorphology of seeds. Examining ancient DNA, models of the early population of America are critically questioned, valuing both their interpretative potential and the limitations inherent to taphonomic processes, particularly in tropical environments. The isotopic analysis, in itself, enables the intricate reconstruction of dietary patterns, movement over time, and up to seasonality, providing considerable results in coastal areas of the Brazilian countryside, where sambaquis are found, for example. The microarqueobotánica, at the same time, facilitates the reconstruction of paleoenvironments and the diverse practices involved in the management of vegetation, the micromorphology of soil allows the recognition of human activities, the complicated processes of occupation, together with postdepositional transformations through the detailed microscopic analysis of sediments. Ultimately, it is established that the integration of these diverse methodological methods notably drives regional archaeological studies, especially in investigations of hunter-gatherers, lithic technologies, as well as cultural landscapes. The previous one, consolidates microarchaeology as an absolutely essential approach for the generation of more certain, contextualized, and, of course, multiscalar interpretations of the past.

***Keywords:*** *Microarchaeology, archaeological methods, microscopic analysis, paleoenvironments, archaeological record*

[1] Facultad de Ciencias de la Educación, Humanas y Tecnologías, Universidad Nacional de Chimborazo – Ecuador, https://orcid.org/0000-0002-6042-2219; +5930968477423.
[2] Facultad de Ciencias de la Educación, Humanas y Tecnologías, Universidad Nacional de Chimborazo – Ecuador, https://orcid.org/0000-0003-0608-3276; +593 99 281 3105.
[3] Coordinación de Gestión de Relaciones Nacionales e Internacionales, Universidad Nacional de Chimborazo – Ecuador, https://orcid.org/0009-0000-0087-251X; +593 99 281 3105.

## INTRODUCTION

Contemporary archaeology has undergone profound transformations in the field of theory, method, and its respective practice, changes that accompany technological developments, aiming each time more to take advantage of the intrinsic interdisciplinarity of the discipline and of the synergy among schools, premises, and research problems that deal with the archaeological record. In this context, the application of microscopic methods increasingly forms part of the interpretations and enrich both the qualitative and the quantitative analysis, managing to connect different

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scales of analysis with the objective of promoting inferences on the sociocultural, environmental, and symbolic dynamics of the past.

The critiques of the rigid positivism of processual archaeology, together with the arrival of Postprocessual approaches, have led to a profound revision of how archaeological knowledge is generated (1). This movement, which had already been anticipated by the idea of the "loss of innocence" of Clarke (2), underlined the necessity of a more reflexive and contextual archaeology, disposed to integrate diverse lines of evidence. Microarchaeology is key in this debate, insofar as it postulates that for the archaeological record the meticulous analysis of microscopic remains is not a subfield, a technique, or an auxiliary. Interdisciplinarity has become a characteristic seal of archaeological practice, from large international projects such as that of Çatalhöyük, under the charge of Hodder (3), even up to more regional and smaller-scale investigations that are carried out in South America.

In the Brazilian context, several archaeological projects have made manifest the importance of combining traditional field methods with high-resolution laboratory analyses, such as those that have been realized in the southeast and center-west of the country (4; 5; 6), as well as in Amazonian areas (7; 8; 9). These studies evidence that, in order to understand human occupations, technological systems, and their relation with the landscape, it is necessary to adopt approaches that can address diverse temporal, spatial, and material scales.

It is in this context that traditional materialist archaeology encounters the loss of innocence (2), and the basic classifications, seriations, and typologies encounter the interpretative universe in the functional, symbolic, and sociocultural fields of the relation between human beings and material culture.

Even with the advanced state of our techniques, applying microarchaeological methods in a constant form continues being difficult, especially under warm climates. Under those conditions, natural deterioration affects greatly the organic remains, vegetal, and terrestrial deposits. It is known that factors such as acid soil, air charged with vapor, and active microbial life make it difficult to preserve useful samples for fine analyses, such as the molecular or isotopic. In any case, new investigations evidence that, once their ambits are appropriately understood, the microscopic information reveals important indications about ancestral diet, human migrations, past environments, the administration of the territory, and the development of diverse archaeological sites. Under this approach, four principal directions stand out today: the study of molecules, the measurement of isotopes, the exploration of diminutive vegetal particles, and the meticulous observation of the strata of the soil.

In contemporary archaeology, depending on the characteristics of the context and its capacity to preserve the material remainders, especially the molecular analyses that permit characterizing ancient DNA, making it possible to extrapolate basic materialist archaeology toward fields of human relations, resulting in inferences on ancestry, peoplings, and displacements among different regions; especially this discussion makes itself present in the dynamics of American Archaeology, a theme until today discussed and problematized by the different fronts of investigations in research centers of the continent.

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In complement, the data associated with isotopes permit corroborating data on paleo-alimentation, migratory movements, and seasonality, especially when we take into consideration coastal environments and of the nomadic hunter-gatherer societies and their complex archaeological context.

In Brazil, a relevant area of study is microarchaeobotany; by means of the analysis of microscopic residues—seeds, charcoal, pollen, phytoliths—that help to decipher past environments and patterns of utilization of vegetals.

Another valuable resource, emerging with precision from the micromorphology of the soil, employs this technique to decipher, through minimal samples, the presence of fire, human activity, burials, or the subsequent transformations in an archaeological site. Moreover, this approach, separating itself from broad approaches, centers us on how microarchaeology, effectively, increments significantly the reach and the solidity of the conclusions obtained in archaeology.

The interesting comes when one looks at how it unites distinct levels of analysis with what the past leaves under the ground. Paths are opened by showing small but profound methods used today in ancient findings. Uniting distant examples, from Latin America to Anglophone regions, strengths emerge together with weak zones. It surprises to see how these approaches could be woven among themselves in local works. Behind each layer there are social histories, changes of the environment, or technical advances already forgotten. Upon addressing these themes, this article seeks to enrich the methodological and epistemological debate in the field of archaeology, highlighting microarchaeology as a strategic area for constructing more solid, contextualized, and multiscalar interpretations of the archaeological record.

## MATERIALS AND METHODS

The approach that we are utilizing in this study combines different fields and looks at things both at small and large scales, with the objective of mixing the details at small scale with the larger image in order to understand better the ancient sites. The work rests on the premise that the sociocultural and environmental processes of the past manifest themselves in a differential manner in the archaeological record, requiring analytical tools capable of operating at distinct scales of observation and resolution.

In a general manner, this interdisciplinary research project is based on a critical review of specialized literature combined with a comparative systematization of case studies coming from Latin American and Anglo-American archaeological contexts, which is considered an efficacious strategy for evaluating the potential of microarchaeological methods under different conditions of taphonomic, ecological, and cultural type, especially in what is found situated in tropical and subtropical environments (of difficult preservation of the micro remains), permitting connecting common problematics to the different cultural areas of America, as is the case of the shell mounds (Sambaquis) Brazilian and of the most ancient human remainders in the context of the cenotes, as is the case of the finding of Naia in Quintana Roo, Mexico, contexts these that classically have their interpretation limited to what the macro can present and from microarchaeology transform themselves into particular histories of indigenous America.

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The methodological analysis is grouped into four principal axes of modern microarchaeology: molecular analyses, studies of stable isotopes, microarchaeobotany, and micromorphology of soils. Each one of these axes addresses the methods of obtaining and analysis of data, but from the integrating point of view of dialoguing those technical protocols of obtaining and analysis of data with archaeological problematics of greater scale. The investigation with stable isotopes is considered a crucial technique for ascertaining what people ate, where they moved, and in what epochs they lived.

The molecular analyses are considered principally from the study of ancient DNA, making emphasis on their applications for the reconstruction of processes of occupation, dispersion, and even biological affinity of human populations.

On the methodological plane, criteria of selection of samples, conditions of preservation, as well as limits derived from taphonomic processes are discussed, especially in contexts of acid soils.

It is not the fact of only analyzing molecular data, but of crossing these informations with indications of the archaeological environment, avoiding little scientific conclusions or outside of the context.

Stable isotopes result crucial upon attempting to understand the ancestral diet, the migrations, and the chronologies of settlements. Specialized techniques are applied, detecting subtle chemical signals, let us say of carbon, together with traces of nitrogen or oxygen, all from osseous remains, whether human, of animals, even in residues preserved within ancient vessels.

Interpreting those data in isolation would be misleading; they result much more significant if they are integrated with data of the paleoenvironment, of the archaeological context, and of the post-mortem interaction of the remains with the subsoil. Vegetal vestiges, although minimal, also contribute value; their imperceptible footprints, such as the ancient pollen, or microcrystals within seeds, offer a glimpse of the pretérite vegetal landscape. The protocols of sampling, preparation, and analysis, in conjunction with collections of reference and graphic representations are very fundamental.

Thanks to this, one can help to imagine how the ancient environments were, what people ate, how they managed the plants, and how they organized their spaces by effect of their activities. In fourth place, enters the micromorphology of lands, centered on reviewing thin sections obtained by means of ordered extractions during open-air works. Looking at the sediments with a lens gives clues about how the strata found in ancient sites formed, separating what was done by humans from phenomena such as floods, coverings of mud, or accidental burnings. Each observation made at the microscope goes united to information of layers, forms of the terrain, and material findings that deepen the sense of each context found. The methodology exposed is based on the articulation of a set of lines of evidences in which the contextualization of the data and the integrated reading of the social and environmental processes is prioritized, which will permit amplifying the analytical resolution of archaeology and contributing to elucidate more precise and complex reconstructions of the human dynamics in the past.

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## RESULTS

For the proposed discussion, 4 (four) important contexts of the micro and macro archaeology will be presented and discussed, of which we have the molecular analyses, the stable isotopes, the microarchaeobotany, and the micromorphology of soils, their respective contexts of application and their theoretical and methodological problematic adapted to the context of the archaeology of the American continent and its alterity.

### Molecular Analyses

As first practical case, we will present perspectives on the molecular analysis in archaeology. In the microscopic analyses, the analytical method that encompasses the smallest objects of the microarchaeological investigation is, without doubt, the molecular analysis, which works with units of measure that go from millimeters (mm), micrometers (µm), nanometers (nm) up to ångströms (Å). In the field of archaeology, its principal area is the study of ancient DNA.

The study of ancient DNA is present in the investigation that involves ancient contexts with presence of fossil remains; in the case of archaeology, in contexts with human biological remains, which implies the revision and discussion of the occupation, the displacement, the technology, and the human antiquity.

In the ancient contexts of the American continent, the discussions and critiques are constant, with a recurrent turn from the Clovis and Pre-Clovis paradigms, perspective adopted by the principal centers of study of the United States (10; 11; 12; 13) as the first groups that entered the continent through the Bering Strait, and then dispersed following a north-south axis, toward paradigms linked to other ancient sites dispersed throughout the continent and possible other routes of occupation and distinct periods, especially those located in South America.

Outside of the Clovis and Pre-Clovis axis, the findings in Quintana Roo, Mexico, in the decade of 2010, oblige to revise old paradigms, upon evidencing osseous remains in a geological formation called doline or cenote, that is to say, depressions caused by diverse geomorphological events located in karstic zones. In this case, the Mexican region forms extensive interconnected subterranean systems that store the aquiferous reserves of the entire zone, which presents deficiencies in superficial reserves.

In this sense, Naia was identified by means of submarine prospecting and presents herself as a female hominid, dated between 13,000 and 12,000 years before the present. Her remains presented a quality and quantity of material adequate for molecular analyses, especially mitochondrial, that revealed an origin very similar to that found in the American contexts of pre-Clovis cultures, of originating peoples of Asia, and an antiquity that coincides temporally with interglacial periods (14; 15).

Owing to the acidity of the soils present in the tropical contexts (16; 17; 18), few human biological remains, whether remains of soft or hard tissues, or even coprolites (with the possibility of extracting DNA data according to their conservation), resist the natural and anthropogenic weathering. In the Brazilian context, there exist few contexts in which the taphonomic processes permit the adequate preservation of biological remains for the extraction of ancient DNA, highlighting the studies realized by the Laboratory of Human Evolutionary Studies of the Institute of Biosciences of the University of São

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Paulo, under the coordination of Professor Dr. Walter Neves, who realizes an extensive interdisciplinary investigation in archaeological contexts of Lagoa Santa, MG (19; 20).

As Neves (2016) justifies, the studies in this area are scarce in Brazil owing to the difficulty of preservation and extraction of the remains, as well as of their analysis, since we do not count with specialized laboratories on the theme, and we depend principally on the collaboration with international institutions such as the Max Planck Institute in Germany and the University of Copenhagen in Denmark, referents in investigation.

**Analysis of Stable Isotopes**

The analysis of stable isotopes is characterized by the chemical identification of elements and can be applied in diverse fields, such as ecology, agronomy, geology, and archaeology. In archaeology, it is possible to establish the seasonality, the mobility, and the diet in relation with the human and material remains.

In studies realized in Brazilian contexts, the investigations realized in Sambaquis stand out, whose objective is to identify the sociocultural dynamics among the groups of hunter-gatherers, characterizing the use of the malacological fauna as diet, the seasonality of the availability of this resource, and, finally, the operative chain in relation with the obtaining, management, use, and final disposition of this resource (21).

The analyses can be realized from the extraction of collagen of human osseous remains (22) in order to determine the diet and the displacements in search of food, as well as to determine the use of plants by the ceramic populations by means of the extraction of carbonized residues conserved in the bottom of the vessels (23). The stable isotopes permit verifying the presence of chemical elements in diverse types of materials and substrates. They facilitate the diagnosis of their origin, nutrition, and movement from the perspective of a systematic analysis of the biological and taphonomic characteristics.

The collection of materials for analysis at micro and macro scale implies processes of laboratory strictly regulated and general standards (27; 28), as well as specific, as in our case of archaeology (29; 30). In equal manner, several guides of reference have been created that will serve as base for comparing the materials collected (31), as well as specific guides for Brazilian biomes, such as the Cerrado, the first great systematic guide on palynology developed by (32), and the Amazonia, with the work of Colinvaux, De Oliveira, and Moreno Patiño (33).

The interdisciplinary archaeological work that utilizes archaeobotanical data offers the possibility of integrating data that go from data of the landscape (macro), such as the paleoenvironmental characterization of a context or region, up to the identification of seeds or grains that served as food (micro), which can reconstruct the diet and therefore the organization and sociocultural relations of groups or populations throughout time, within a characteristic specific landscape (space), which can be chosen owing to alimentary deficiencies or cultural phenomena (34; 35; 36; 37; 38).

**Micromorphology of the Soil**

In the field of archaeology, the microscopic analyses that utilize samples of soil as principal material of study generally are framed in the area of geoarchaeology.

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In archaeology, the micromorphology of the soil is characterized by the analysis centered on the solution of preestablished problems related with the soil and its occupation, as well as its subsequent abandonment, etc.

In this sense, it is possible to characterize the layers of occupation and the respective social activities that interfered in them, identifying exogenous actions to the human activities, such as burials, inundations, fires, and others that alter the natural composition of the layers and that become taphonomically recognizable through changes visible only at the microscope, activities related with the domestication of plants, among others (39; 40; 41; 42).

The micromorphology of the soil is also present in studies that characterize paleoenvironments and chronological studies, with the identification and interpretation of the records that model soils and sediments in relation with the context of the different processes involved in the dynamics of the soil at anthropogenic and natural level (43).

The analyses are configured from the systematic collection of field samples, with the objective of a better identification and characterization of the contexts to analyze, and their subsequent treatment and laboratory analysis, which consists of the preparation of thin sections. Its microscopic analysis seeks the interpretation in the ambit of the chemical, physical, and mineralogical analyses.

In the south of Brazil, micromorphological analyses are realized in order to characterize the sociocultural dynamics in relation with the “Sambaquis” (shell mounds), verifying and validating their natural or anthropogenic formation, their human use as social space for the cultural relations and their function in relation with the landscape.

Another example is the characterization of combustion structures realized in controversial contexts, such as the sites located in Serra da Capivara in Piauí and in Lagoa Santa, Minas Gerais, which involve important contexts with respect to the occupation, displacement, and interaction with the first human groups that interacted on the American continent, aiming at the identification and verification of the contexts of combustion as of anthropogenic or natural origin, as well as the movements in the contexts marked by possible continuities and structural and organizational changes registered in the archaeological contexts.

## DISCUSSION

The theories, methods, and tools presented offer numerous foundations for the characterization of archaeological contexts, validating or refuting previous hypothetical premises, which permits a greater refinement of the sociocultural and environmental reconstructions for the analysis of the material culture and their respective places of activity and interaction.

In the context of American archaeology, we believe that many of the techniques and methods presented could be applied in any archaeological investigation realized by professionals with the due formation, especially in the contexts that have materiality that permits realizing these types of analyses, presenting themselves as an important complement to the studies of technology, of the operative chain, and the technological

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system employed by the groups of hunter-gatherers or those associated to the contexts occupied by agricultural ceramic groups.

In the case of the lithic materials, it would be susceptible of microscopic analyses with emphasis on the traceology (44), and in addition to presenting the technological and utilitarian characteristics of the materials, it could in exceptional cases present botanical evidence related with its daily use. For the ceramic material culture, it could reveal the technological and cultural data related to the processes of pottery production, taking into consideration that the elections with respect to raw materials and manufactures are resulting from a cultural tradition (6). This type of interpretation is strategic for an archaeology that surpasses the basic interpretations of the material culture, transforming objects into active agents of the human activities and relations. Taking into consideration its technicity and the capacity to generate both quantitative and qualitative data, microarchaeology together with the material culture permits elevating the basic discourses toward the scientific and objective inference.

When we speak of microarchaeobotany, it calls attention how the study of the pollen helps to imagine ancient landscapes. Although it depends on the type of site, what is found under the ground many times recounts details about the climate when those persons lived. The interesting appears upon noting changes among layers: some voids are not accidents, but clues guarded for centuries. From there arises a distinct form of understanding past cultures, not only by their objects, but by the environment that surrounded them. Unfortunately, taking into consideration the contexts with neotropical soils so common to the archaeological findings on the American continent, where it becomes difficult, if not impossible, the preservation of organic materials or ecofacts, surely the contexts will occur in which any analysis directed to the identification and interpretation of said materials is discarded.

Finally, the geomorphology is present in the characterization of sites at the level of their archaeological landscape (De Barros, 45) and their use in the human manufacture, whether as carved objects or even as the elements utilized as temper for the ceramic pastes.

In the approach of the study, we speak of how to choose samples, maintain them secure, and establish limits based on how they decompose with time. This method prefers to look at the molecular findings in conversation with other archaeological clues in order to maintain itself distant from unilateral or independent conclusions.

The investigation with stable isotopes is considered a crucial technique for ascertaining what people ate, where they moved, and in what epochs they lived.

Highlighting the standardized protocols for the sampling, treatment, and analysis, throughout the use of collections of reference and the method of atlas. This helps us to assemble ancient environments, how people utilized foods, administered vegetal resources, and organized spaces based on their activities.

The micromorphology of the soil is the fourth method of which we speak, and it treats of studying these thin layers that we obtain from the careful collection of samples from the field.

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In its context of application, a great part of the archaeological studies are realized under the dynamics of the universities or of the contract archaeology, making necessary the search for space where the equipment and consecutively experienced professionals can offer the services or the investigative collaboration. It is necessary to highlight the importance of the interdisciplinary work, so valued by the Processual and Postprocessual archaeology. The case studies presented in this article could go beyond the interpretation of contexts previously present in the archaeological record and surely ignored owing to the lack of precision or even of knowledge of said methods and tools.

## CONCLUSIONS

In the first place, this work makes manifest the role of microarchaeology as one of the strategic fields from which contemporary archaeology can operate in the effective integration between micro and macro scales in the interpretation of the archaeological record. The continuous introduction of molecular, isotopic, botanical, and sedimentary microscopic records opens in a significant form the analytical possibilities of the discipline, and offers more faithful reconstructions in the field of the sociocultural, technological, and environmental dynamics of the past. From this perspective, microarchaeology is not to be considered as a set of auxiliary techniques, but as a methodical and epistemological strategy that in a direct form contributes to the process of construction of the archaeological knowledge.

In the second place, the distinct approximations of microarchaeological character evidence both the high interpretative potential of the same and their limitations in neotropical contexts, characterized by intense taphonomic processes, in which the adverse environmental conditions, the acidity of the substrate, elevated humidity, limit the preservation of organic remains and for this reason the applicability of certain analyses. However, the cases that are studied give account that, when these analyses are contextualized and integrated to the other types of archaeological evidences, they are capable of partially overcoming the limitations and generating key information on diet, mobility, paleoenvironments, practices of management of resources, and the processes of formation of the archaeological sites.

Finally, we can conclude that the strengthening of microarchaeology is directly related with the consolidation of interdisciplinary approaches and with the necessary interrelation between the academic investigation, the laboratory infrastructure, and the specialized formation of the persons who dedicate themselves to the study of problematics of archaeological type. The joint application of the microscopic analyses applied to the regional studies—linked both to the academic archaeology and to the contract archaeology—potentiates a more nuanced reading of the technological systems and of the operative chains, all of this in interrelation with the human societies and the landscapes. Within this framework microarchaeology profiles itself as a tool that shall be key in the construction of multiscalar, contextualized, and critical interpretations that are capable of giving response to the theoretical-methodological exigencies that the archaeology of the 21st century poses itself.

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# INCIDENCIA DE LA PROGRAMACIÓN PRESUPUESTARIA EN EL CUMPLIMIENTO DE LOS PLANES DE DESARROLLO Y ORDENAMIENTO TERRITORIAL (PDOT) EN LOS GAD'S DEL ECUADOR

# IMPACT OF BUDGET PLANNING ON COMPLIANCE WITH TERRITORIAL DEVELOPMENT AND PLANNING PLANS (PDOT) IN ECUADOR'S LOCAL GOVERNMENT UNITS

Lizeth Katherine Ortega Huilcapi[1], Angelica Selena Mendoza Intriago[2]
{lortegah2@unemi.edu.ec1, amendozai6@unemi.edu.ec2}

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**RESUMEN:** Las previsiones y la gestión del presupuesto constituyen los soportes básicos para el desarrollo local. En el Ecuador, los Gobiernos Autónomos Descentralizados (GADs) redactan sus Planes de Desarrollo y Ordenamiento Territorial (PDOT) como su ruta de navegación. No obstante, la falta de conexión que existe entre la planificación estratégica y la programación financiera anual representa uno de los problemas que persiste y que resquebraja la actuación del PDOT. Por lo tanto, el objetivo de este estudio es analizar, mediante una revisión sistemática de la literatura científica indexada, la evidencia existente sobre la incidencia de los procesos de programación presupuestaria en el grado de cumplimiento de los objetivos establecidos en los PDOT de los GADs municipales del Ecuador. Se llevó a cabo una revisión sistemática, siguiendo la declaración PRISMA. Se hizo la búsqueda en las bases de datos Scopus, Web of Science, SciELO y Redalyc, contemplándose artículos publicados desde el periodo 2015 hasta el 2024. Se aplicaron ecuaciones de búsqueda con términos como "public budgeting", "local government", "development planning", "Ecuador" así como sus equivalentes en español. El total de los estudios incluidos en la selección final fue de 34 estudios que cumplieron los criterios de inclusión. Para el análisis se optó por tres dimensiones críticas de incidencia: alineación estratégica, capacidad institucional, marco normativo e institucional, y participación y transparencia. Se establece una relación positiva y directa entre la calidad de la programación presupuestaria y el cumplimiento del PDOT.

***Palabras clave:*** *Planificación del desarrollo, ordenamiento territorial, programación presupuestaria, gobiernos locales, GAD, Ecuador*

**ABSTRACT:** Forecasting and budget management are the basic pillars of local development. In Ecuador, decentralized autonomous governments (GADs) draw up their Development and Land Use Plans (PDOTs) as their roadmap. However, the lack of connection between strategic planning and annual financial programming is one of the persistent problems that undermines the effectiveness of the PDOT. Therefore, the objective of this study is to analyze, through a systematic review of the indexed scientific literature, the existing evidence on the impact of budget programming processes on the degree of compliance with the objectives established in the PDOTs of Ecuador's municipal GADs. A systematic review was carried out, following the PRISMA statement.

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The search was conducted in the Scopus, Web of Science, SciELO, and Redalyc databases, covering articles published from 2015 to 2024. Search equations were applied with terms such as “public budgeting,” “local government,” “development planning,” “Ecuador,” and their equivalents in Spanish. A total of 34 studies that met the inclusion criteria were included in the final selection. Three critical dimensions of impact were chosen for the analysis: strategic alignment, institutional capacity, regulatory and institutional framework, and participation and transparency. A positive and direct relationship is established between the quality of budget programming and compliance with the PDOT.

***Keywords:*** *Development planning, land use planning, budget programming, local governments, GAD, Ecuador*

[1] Facultad de Posgrados, Universidad Estatal de Milagro, Maestría en Administración Pública mención desarrollo institucional, Ecuador, ORCID; https://orcid.org/0000-0001-6887-6795, +593987280232.
[2] Facultad de Posgrados, Universidad Estatal de Milagro, Maestría en Administración Pública mención desarrollo institucional, Ecuador, ORCID; https://orcid.org/0000-0003-0568-7473, +593987809760.

## INTRODUCTION

The realization of development planning and public financial management are the same, but different forms of realizing contemporary public administration. At the global level, the adequacy and type of subnational governments, the efficiency of these depends on their ability to transfer the development goals that remain embodied in the planning instruments into the actions that are accompanied by financial resources and that are executed with great efficiency (1). And the theory of results-oriented public management (ROP M) indicates that the explicit relation of planning–budgeting–execution–evaluation is the axis to improve in order to obtain the improvement of the effectiveness of public policies and accountability (2,3).

In the context of Latin America, and above all in Ecuador, this challenge acquires a special dimension after the approval of a decentralized State; it is thus that the Constitution of 2008, as well as the Organic Code of Planning and Public Finances (COPLAFIP), granted to the Decentralized Autonomous Governments (GADs) municipal the competencies and the responsibility of managing their local development with the correct formulation of the Territorial Development and Planning Plans (PDOT) and the administration of their financial resources (4,5). It is thus that the PDOT becomes the instrument that becomes the axis of local public policy, where the vision, the objectives, and the goals up to a period of ten to fifteen years are established (6).

But, as the reviewed authors observe, the simple planning does not result sufficient to make real the aspirations that this generates, given that the literature indicates expressly the existence of an “implementation gap,” that is, “a very detailed program, oriented toward the products, that is not correlated by a flexible budget and that must deal, even with the resources liberated, with a plethora of assignment practices, derived from institutional pressures of every type, that do not always foster the guidelines established in a strategic plan” (7,8). This lack of coincidence planning–budget gives as result a phenomenon that some authors describe as “institutional isomorphism,” where the GADs reproduce the legal procedures, but not thus the practices that permit the coordination between both processes and that propitiate the transformation of the PDOT into figures very little operative with budgets little linked to these (9,10).

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Previous investigations from the Ecuadorian perspective have made emphasis on the aspects by separate, such as the quality of the programming (11,12) or the problem of the challenges of local financial management (13,14). Other authors have indicated the precariousness of the systems of monitoring and evaluation (15). Nevertheless, there continues existing a vacuum in the knowledge about the systematic investigation that determines how and in what measure the particular mechanisms of the budgetary programming impact on the level of compliance of the goals marked in the PDOT. The problem results of cardinal importance, since at the end it treats of the capacity of the State to close gaps of territorial inequality and the capacity of promoting a balanced and sustainable local development (16).

This inquiry on the relation of the planning in where the citizenship is a fundamental social factor for the development of the public policy and the formulation of the public budget has sense, in the first place, since it is possible to detect the bottlenecks that make that the public policy not be efficacious and impede that the investment orient itself to the real necessities of the cities. In the second place, it reinforces the transparency and the accountability upon determining if the modern rules of the bureaucracy articulate the circumstances of the citizenship so that the resources be executed according to what is planned and promised. At the same time it consolidates the link between authorities and citizens. Finally, it serves of sufficient evidence for the public managers of the GAD and the governing entities, such as the SENPLADES and the Secretariat of Public Finance Management, so that instruments, trainings, and legal reforms be designed that procure a better and more effective integration between planning and budget.

Therefore, the objective of this study is to analyze, by means of a systematic review of the indexed scientific literature, the existing evidence on the incidence of the processes of budgetary programming on the degree of compliance of the objectives established in the PDOT of the municipal GADs of Ecuador.

## MATERIALS AND METHODS

This study was framed in an approach of investigation of bibliographic or documentary type, specifically by means of the realization of a systematic review (SR). The protocol of review was designed following the guidelines of the PRISMA statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), guaranteeing the exhaustiveness and minimizing the selection bias.

**Table 1. Methodological Strategy of the systematic review.**

| Component | Description |
|---|---|
| Type of review | Systematic Review (SR) with narrative synthesis. |
| Search strategy | Systematic search in 4 bibliographic databases: Scopus, Web of Science (WoS), SciELO and Redalyc. |
| Inclusion criteria | • Primary or review studies. • Published between January 2015 and May 2024. • In Spanish or English. • That address explicitly the planning–budget relation in municipal GADs of Ecuador, or that analyze separately PDOT or budgets with elements that permit inferring said relation. |
| Exclusion criteria | • Opinion articles, editorials or brief notes without methodology. • Studies that center exclusively on provincial or parish GADs. • Investigations whose context is not Ecuador. |
| Search equation | Adapted by database. Example for Scopus: (TITLE-ABS-KEY (“public budgeting” OR “budget programming” OR “budget execution”) AND TITLE-ABS-KEY (“local government” OR “municipal” OR “GAD”) AND TITLE-ABS-KEY (“development planning” OR “PDOT” OR “land use planning”) AND TITLE-ABS-KEY (“Ecuador”)) |

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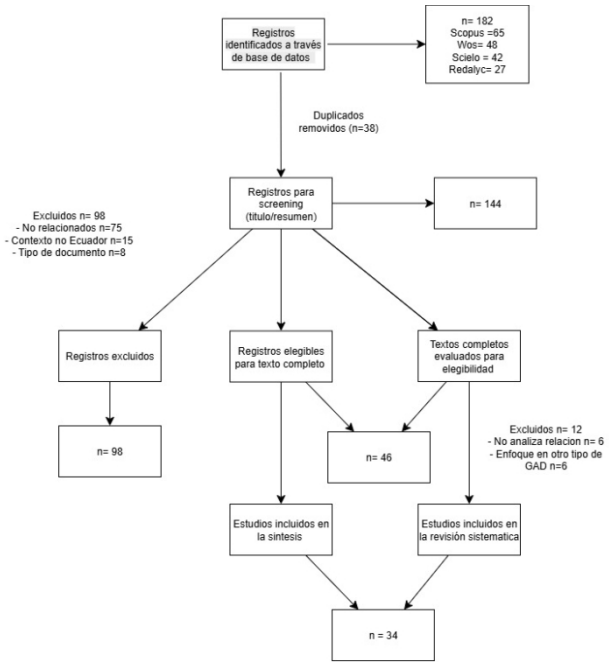
|---|---|
| Selection process | 1. Elimination of duplicates. 2. Screening of titles and abstracts by two reviewers independently. 3. Evaluation of full text against inclusion/exclusion criteria. 4. Resolution of discrepancies by consensus or by a third reviewer. |
| Data extraction | A standardized form was developed in Excel to extract: author, year, title, objective, methodology, population/sample, principal variables, key findings and relevant conclusions for the research question. |
| Data analysis | Narrative synthesis and thematic analysis. The extracted findings were grouped into emerging thematic categories (e.g. alignment, institutional capacity, regulatory framework) to identify patterns, consensuses and discrepancies in the literature. |

The multi-system search strategy (Scopus/WoS + SciELO/Redalyc) assured the coverage both of the international literature of high impact and of the regional and local scientific production more relevant for the Ecuadorian context.

The initial search yielded a total of 182 records. After the elimination of duplicates and the application of the inclusion/exclusion criteria in the screening of titles, abstracts and full texts, the final review was based on 34 scientific articles. The PRISMA flow diagram detailing this process is presented in Figure 1.

**Figure 1. The PRISMA flow diagram.**




The thematic analysis of the 34 studies permitted identifying three principal dimensions that explain the incidence of the budgetary programming on the compliance of the PDOT.

## RESULTS

Within the following table the dimensions of PDOT for the municipal GADs of Ecuador are shown.

**Table 2. Dimensions of Incidence of the Budgetary Programming on the PDOT**

| Dimension | Principal Findings (Synthesis of the Literature) | References |
|---|---|---|
| 1. Strategic Alignment | • Prioritization of operative expenditure: Between 60-75% of the budget is destined to current expenditure (payroll, administration), which limits the real investment in strategic projects of the PDOT. • Incrementalist assignment: The annual budgets are constructed on the basis of previous exercises, with slight adjustments, without a profound revision of the goals of the plan. • Weakness in project formulation: A great part of the projects lacks preinvestment studies, solid technical and financial | (6), (9), (10), (12), (13), (17), (18) |

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|---|---|---|
| | profiles, which impedes their adequate budgeting. • Weak connection between diagnosis–territory and assignment of resources, generating imbalances between local priorities and executed expenditure. | |
| 2. Institutional Capacity | • Gap of technical competencies: The planning teams do not count with interdisciplinary formation in economics, public finances and territorial management. • Fragmented information systems: The lack of interoperability between platforms such as SIGPLAN and SICOIN hinders the follow-up of the budgetary cycle. • Limited organizational culture: The budget is perceived as an accounting requirement more than as a management tool for development. • High turnover of technical personnel, which affects the continuity in the budgetary programming. | (5), (8), (14), (15), (19), (20) |
| 3. Regulatory and Institutional Framework | • Budgetary rigidity: The regulations (COPLAFIP) restrict the flexibility of reassignment of items, reducing the capacity of response to changes in the local priorities. • Late approval processes: In several GADs the budgets are approved in the last months of the fiscal year, which delays the start of the execution of projects. • Instability of incomes: The high dependence on transfers from the central government exposes the GADs to the macroeconomic volatility. • Scarce regulatory articulation among levels of government (central, provincial and cantonal), which generates overlaps or duplicities in investment projects. | (4), (13), (21), (22) |
| 4. Participation and Transparency | • Limited citizen participation: The spaces of participatory budgets are formal, but do not impact in a real manner on the assignment of resources. • Low accountability: The budgetary reports lack indicators of territorial impact linked to the PDOT. • Deficiencies in digital transparency: The information portals are not updated nor permit a friendly access for the citizenship. • Scarce social oversight on the programming and budgetary execution. | (7), (16), (23), (24), (25) |

The thematic analysis of the 34 studies that are included in the review has permitted identifying four key dimensions that explain how the budgetary programming impacts on the compliance of the PDOT in the municipal GADs of Ecuador: strategic alignment, institutional capacity, regulatory and institutional framework, and participation and transparency.

**Strategic alignment between the PDOT and the budget**

The reviewed studies coincide in that between 60% and 75% of the municipal budget is destined to current expenditure, which has as destination principally administrative and personnel items, for which the structure of the budget limits in an important form the investment in strategic projects contemplated in the PDOT.

An interpretative reading of this situation explains that it responds to budgetary practices of incrementalist character, insofar as the annual budgets are realized taking as reference previous fiscal exercises, in which marginal adjustments have been realized, but that do not include a substantive revision of the orientations of the planning of the territorial objectives and goals that have been defined in a first moment.

As consequence, a weak letter of connection between the territorial diagnosis, the strategic prioritization that marks the PDOT and the efficacious assignment of resources to the same is put of manifest, which generates imbalances in the local public investment and its diminution at its time in the capacity that the GADs have to realize their development plans. With respect to the institutional capacity, the gaps of technical competencies and the turnover of the personnel make that the continuity of the management be reduced. The fragmentation in the information systems hinders the follow-up and control of the budgetary cycle. To this is added an organizational culture that understands the budget as an administrative requirement and not as a tool of strategic character that mobilizes the actors of the local development.

**Institutional capacity of the municipal GAD to realize budgetary programming**

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The different reviewed works pose that the municipal GADs present serious limitations with respect to the institutional capacity, in specific the technical formation of the teams responsible for the planning and the administration of the financial management, given that there do not exist profiles of professionals formed in an interdisciplinary mode, that is to say, that incorporate elements of public economy, territorial planning and formulation of projects.

These weaknesses are seen allied to the poverty of the institutional information system, with it the difficulty of following the budgetary cycle in an integral manner, evaluating the compliance of objectives of the PDOT. In equal manner, the loss of the technical personnel contributes to an excessive change of personnel, which hinders that processes of programming and of execution of the budget be produced.

In definitive, it can be affirmed that these institutional limitations back the lesser capacity of the GADs to translate the strategic vision of the PDOT into programs and projects foreseeable from the administration of the GAD, deauthorizing in this mode the importance of the budget as management tool for the local development.

**Regulatory and institutional framework**

With respect to the regulatory framework, the reviewed works reveal that the current regulations present rigidities that hinder the exercise of the flexibility on the part of the GADs to reassign resources in function of the changes that may arise in the priorities of the territory, to which it is necessary to add the delays in the start of the execution of projects provoked by the regulations on the processes of approval of the budget.

In addition, the elevated dependence on transfers from the central government tends to expose the municipal GADs to the volatility of the macroeconomy and to induce uncertainties on their financial plannings of medium term, owing to the scarce regulatory coordination among the distinct levels of government, which also provokes overlaps and duplicities for investing in the projects related with the public investment.

These normative institutional conditions confect a medium that restricts the capacity of the local governments to articulate in an efficacious manner the budget and the reached by means of their strategic objectives embodied in the PDOT.

**Citizen participation and transparency**

The reviewed evidence shows that the mechanisms of citizen participation in the budgetary processes have a clear tendency to be of merely formal character, with a limited incidence for the real decision of assignment of public resources, where the spaces of participatory budget do not always lead to decisions that are binding.

At the same time account is given of weaknesses in the processes of accountability and in the transparency of accountability. The reports to which one accesses on many occasions do not contain information that permits evaluating indicators of territorial impact linked to the compliance of the PDOT and, at the same time, the portals do not guarantee in the first approximation neither the updating of the information nor its accessibility.

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For these traits the capacity for the exercise of the social oversight and the confidence of the citizenship in the local public administration is restricted, weakening this the links that all the parties have among planning, budget and democratic control.

## DISCUSSION

Beyond validating the trends already explained by means of the international literature around the planning and the public budget, authorized by this systematic review, there exists supply of specific evidences for the Ecuadorian case given that the major obstacle to the compliance of the Territorial Development and Planning Plans (PDOT) in the municipal GADs is not and does not consist or reside in the existence of a normative formulation of the PDOT but rather in the structural weakness of the mechanisms of articulation of the PDOT and its employment for a process of annual budgetary programming. This finding permits diverting the center of the debate from the concrete normative formulation of the PDOT to its form of real financial execution, insofar as previously it had been treated in a very fragmentary form.

In contrast with investigations that analyze in an isolated form the territorial planning or address the process of execution of the budget, as well as its times and the actors involved, the added value of the present work is to put at the disposition of the discussion and of the reflection the systematization of the empirical foundation that gives place to an image of the processes of territorial planning and budgetary execution from their conjunction.

The fact that the common dimensions identified—strategic alignment, institutional capacity, regulatory and institutional framework, and participation and transparency—permit understanding the non-compliance of the PDOT as a multidimensional phenomenon, result of concurrent failures not derived from a unique administrative weakness. This approach had not been consolidated until the moment in the case of the Ecuadorian municipal GADs from a systematic review.

The analyzed evidence puts of manifest that the PDOT and the budgetary programming are an essential node for the effectiveness of the local public policy, given that when the budget is structured under logics of incremental type or strictly accounting, the PDOT loses all its potential with respect to generating effect, limiting itself to being a merely declarative device. In this sense and in contrapposition to the rest of the analyzed studies, it is verified that those GADs that strengthen the technical formulation of the projection of projects, articulate information systems and incline themselves for approaches oriented to results obtain greater levels of budgetary execution and of territorial coherences. In this sense, the budgetary programming appears not as a sphere of the financial component, but as a formal and explicit mechanism, a strategic device of the management, governance of the local development.

The findings of this systematic review also evidence that the budgetary programming is a determining tool, although precarious, for the implementation of the PDOT in the Ecuadorian municipal GADs; in fact, these results align with the international literature on the “budgetary ritualism” in the sense that the processes are complied with, but in a ritual and superficial form, evaluating more the dimensionality of the normative management than that of the real results (24), (26).

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And in this sense the findings also evidence a weak strategic alignment between the PDOT and the budgetary programming, characterized by the dominion of the current expenditure of the GADs over the size of the investment in the activities of development through the project of development. Such behavior is congruent with the theory of the budgetary incrementalism, which describes how the administrative inertia and the search for political stability mediate in the taking of decisions of the public sector. An incremental logic is such that in the context of the Ecuadorian municipal GADs the budget cannot be considered an efficacious instrument for the putting into march of the PDOT (22), (27).

The second critical dimension that has been arrived at identifying is the one referring to the limited institutional capacity. The lack of specific technicians provokes a "cognitive bottleneck" that impedes the translation of the long-term vision of the PDOT into programs and budgetable projects. This finding is found linked to the visions on dynamic capacities existing in the ambit of the public sector, which emphasize the importance of counting with an organizational learning that be at the same time adaptive before complex environments (34). To this must be added the fragmentation of the information systems, problematic that also has been registered in the process of applying electronic governments in the local ambit (29).

Finally, the regulatory and institutional framework gives form to an environment that promotes or brakes the linking of the planning and the budget. The possibility that there exist rigidities in the Ecuadorian budget processes is in line with the critiques to models of centralist control that preponderate the transparency, but limit the efficiency and the capacity of local adaptation, however critical the process of planning by which the PDOT has passed may be (30). However, the literature shows that, even in this context some GADs achieve better results thanks to more proactive and technical practices, which means that the regulations are an important variable, but not excluding (31), (32).

Taken together, this review permits sustaining that the lack of compliance of the PDOT does not represent an intrinsic limitation to the process of planning, but that it responds in good part to the weaknesses of the budgetary implementation. Confronting such problem requires a global approach that proposes strengthening institutional capacities, improving the internal processes and transitioning toward normative reforms oriented to a budget by results (PbR), where the assignment of expenditure is linked with the compliance of development goals established at the level of territorial planning (33), (34).

## CONCLUSIONS

The elaboration of the budget has a significant and diverse impact on the correct execution of the PDOT. The analyzed data reveal that this influence is not casual, but that it presents itself in a consistent form by means of three related pathways: the strategic mismatch (giving priority to the daily expenditures instead of investing in the long term in the plan), the deficiencies in the institutional competence (scarcity of experts and unified platforms) and the limitations of the legal framework (slow procedures and scarce adaptability), which in their set function as barriers that alter or block the conversion of the goals traced into real economic resources.

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A clear and beneficial relation is observed: the better is the technical part upon making the budget, the better the territorial development and planning plans (PDOT) are complied with. The results suggest that those decentralized autonomous governments (GADs) that leave behind the custom of simply increasing the budget year after year, and in its place use more modern methods such as planning very well the investment projects, connecting different information systems and managing the money in a more strategic and adaptable form succeed in executing more projects and following more closely the development objectives marked in their plans.

Future investigations could deepen empirically in the measurement of the degree of budgetary alignment of the PDOT at the cantonal level, incorporating indicators of territorial performance. Likewise, it is recommended that the GADs strengthen the formulation of investment projects linked to the PDOT by means of schemes of budget by results.

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