



## Original Article

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Ramírez, E. (p. 39)



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# Editorial

With the publication of this new issue of the Le Cordon Bleu University Research Journal, we aim to continue aligning with the standards required by scientific journals in order to achieve the long-anticipated indexation, while simultaneously providing the timely updates expected by the scientific community to which this journal is addressed.

The journal continues to publish articles related to food and nutrition from diverse perspectives, all of them engaging and innovative. This issue includes an insightful update on a recurring topic, the history of pisco, supported by archival documents and high-value interviews that contribute transparency and clarity to the discussion from our journal's standpoint. We also present an analysis of food security issues in Peru, along with policies designed to confront this challenge, one that not only concerns Peru and the Spanish-speaking world but also stands among the most pressing global issues of our time.

Another study explores the impact of climate change on biodiversity, which provides a large portion of the raw materials essential to our food systems. From a technical and industrial viewpoint, we feature research examining the effect of drying on phenolic content—compounds of great importance to human health. The issue also includes an analysis of the use of siglalon in the production of bakery goods, items consumed daily by many, as well as a study on edible films and their potential applications in food packaging.

From a clinical perspective, this issue offers a review of the effects of carboxytherapy on metabolic health, along with a study on aging and its relationship with free radicals and antioxidants. Furthermore, two significant studies are presented: one on the nutritional profile and gastrointestinal alterations in schoolchildren with autism spectrum disorder, and another on the knowledge and attitudes of pregnant women toward anemia, a condition of persistent concern in our region.

With the completion of this issue, we are once again pleased to present such timely and relevant topics authored by both seasoned researchers and emerging scientists. We extend our gratitude to all contributors and invite others to join our ongoing efforts to make this journal increasingly present, relevant, and current.

THE EDITOR

# Effects of Carboxytherapy on Metabolic Health: A Narrative Review

## *Efectos de la Carboxiterapia en la salud metabólica: revisión narrativa*

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### ABSTRACT

Carboxytherapy is a medical technique that uses carbon dioxide for therapeutic purposes. This review aimed to evaluate the scientific evidence regarding the effects of carboxytherapy on metabolic health. The applications of carboxytherapy encompass several areas of medicine. Evidence indicates that carbon dioxide is not only an important regulator of blood pH, but also modulates gene expression, influences growth factors, and stimulates the production of endothelial progenitor cells. These effects are reflected in the increased microcirculation observed in the skin (where collagen production is stimulated), in subcutaneous adipose tissue (where lipolysis and tissue reduction have been documented), in muscle (where mitochondrial biogenesis and muscle fiber differentiation are promoted), and in bone (where reparative processes are stimulated). The activation of microcirculation is mediated by the upregulation of vascular endothelial growth factor expression. Despite the evidence presented, further research is needed on the application of carboxytherapy across different fields of medicine.

**Keywords:** Carbon dioxide, carboxytherapy, CO<sub>2</sub>, CO<sub>2</sub> therapy.

### RESUMEN

La carboxiterapia es una técnica médica que utiliza el dióxido de carbono con fines terapéuticos. El objetivo de esta revisión fue evaluar la evidencia científica sobre los efectos de la carboxiterapia en la salud metabólica. Las aplicaciones de carboxiterapia abarcan varias áreas de la medicina. La evidencia muestra que el dióxido de carbono no sólo es un importante regulador del pH en la sangre, sino que también regula la expresión de genes, factores de crecimiento y estimula la producción de células endoteliales progenitoras. Estos hechos se ven reflejados en el incremento de la microcirculación en piel (donde se estimula producción de colágeno), en el tejido celular subcutáneo (en el que se ha evidenciado lipólisis y reducción del mismo), en el músculo (en el que estimula la biogénesis mitocondrial y la diferenciación de fibras musculares) y hueso



(en el que estimula su reparación). La activación de la microcirculación está mediada por el incremento de la expresión del factor de crecimiento de endotelio vascular. Pese a la evidencia mostrada, se necesitan más estudios de investigación de carboxiterapia aplicada en los distintos campos de la medicina.

**Palabras clave:** Dióxido de carbono, carboxiterapia, CO<sub>2</sub>, terapia con CO<sub>2</sub>.

## INTRODUCTION

Carboxytherapy is a medical technique that uses carbon dioxide for therapeutic purposes. The term carboxytherapy, coined by Dr. Parassoni in 1995 during the 16th National Congress of Aesthetic Medicine in Rome (Brandi, 2022), refers to the percutaneous application of carbon dioxide through subcutaneous or intradermal gas injection. Other methods of administering carbon dioxide also exist, such as using the gas dissolved in water or incorporated into gels (Hartmann *et al.*, 1989 and Oe *et al.*, 2011).

The modern history of carboxytherapy began in France with the first experiments in the 1920s, which demonstrated the safety of subcutaneous CO<sub>2</sub> injections. In the 1930s, at the Royat Institute in Clermont-Ferrand, therapeutic applications of carbon dioxide were introduced using thermal waters to treat circulatory disorders. In 1946, the Cardiovascular Research Institute was established at the same site, one of Europe's first centers dedicated to treating cardiovascular and circulatory conditions using CO<sub>2</sub> dissolved in water. The research conducted there laid the foundations for contemporary carboxytherapy (Brandi, 2022). Initially, the medical use of carbon dioxide was indicated for two conditions: peripheral arterial disease and Raynaud's syndrome (Fabry *et al.*, 2006). Subsequent research identified its physiological effects—vasodilation, wound healing, and pain relief—supporting its therapeutic use in pathologies such as erectile dysfunction,

scleroderma, and rheumatologic disorders like arthritis and fibromyalgia (Body, 2014).

Currently, one of the most widely studied and applied uses of carboxytherapy is in the treatment of chronic wounds, with significant clinical outcomes (Prazeres *et al.*, 2025). Nonetheless, carboxytherapy has a broad range of potential applications across various branches of medicine. In dermatology, for instance, it has been successfully used for skin rejuvenation, stretch marks, infraorbital hyperpigmentation, lymphedema, alopecia, morphea, psoriasis, and vitiligo (Bagherani *et al.*, 2023). In plastic surgery, it is applied for body contouring and skin grafts; in pain therapy, for conditions such as epicondylitis, cervicalgia, and tendinitis; in gynecology, for vaginal dryness, vaginal rejuvenation, and dysmenorrhea; and in endocrinology, as an adjunct treatment for localized adiposity and weight reduction, among others (Shtroblia *et al.*, 2023).

The objective of this review was to evaluate the scientific evidence regarding the effects of carboxytherapy on metabolic health.

## MATERIALS AND METHODS

A narrative search was conducted across the PubMed, PMC, and Google Scholar databases, using various combinations of the terms “carboxytherapy,” “carbon dioxide therapy,” “carboxiterapia,” “carbon dioxide,” “CO<sub>2</sub>,” “CO<sub>2</sub> therapy,”

and “transcutaneous CO<sub>2</sub>.” The search specifically focused on the physiological effects pertaining to vasodilation, wound healing, and pain relief in relation to pathologies including erectile dysfunction, scleroderma, and rheumatological conditions. Relevant articles addressing this subject were extracted, their abstracts were systematically reviewed, and the most pertinent articles for this review were identified

## RESULTS AND DISCUSSION

### Carbon Dioxide in Biological Systems

Carbon dioxide is perpetually generated within the body and is involved in a multitude of physiological functions. A portion of this gas is expelled into the alveoli and subsequently eliminated from the body via the process of ventilation. Carbon dioxide exhibits a high diffusion capacity through tissues and cellular membranes, with its diffusion rates at rest significantly exceeding those of oxygen (400 to 450 ml/min/mmHg for CO<sub>2</sub> compared to 21 ml/min/mmHg for O<sub>2</sub>). Elevated concentrations of carbon dioxide induce the Bohr effect, wherein the oxygen-hemoglobin (O<sub>2</sub>:Hb) dissociation curve shifts to the right in response to increased concentrations of carbon dioxide and hydrogen ions within the bloodstream. This physiological response facilitates the release of oxygen from hemoglobin into the tissues. Furthermore, carbon dioxide is integral to the regulation of pH levels. When dissolved in water, carbon dioxide reacts to form carbonic acid (H<sub>2</sub>CO<sub>3</sub>), which subsequently dissociates into bicarbonate (HCO<sub>3</sub><sup>-</sup>) and hydrogen ions (H<sup>+</sup>). The equilibrium established between bicarbonate and carbonic acid is crucial for the maintenance of pH balance in blood and tissues (Hall *et al.*, 2011).

Research conducted in Europe since the early twentieth century has demonstrated that carbon dioxide can induce vasodilation in skin exposed to carbonated water (Diji & Greenfield, 1960; Hartmann *et al.*, 1989). Subsequently, a study examined the effects of immersion in CO<sub>2</sub>-enriched water on angiogenesis within ischemic limbs in murine models. The findings revealed a substantial enhancement in blood perfusion, collateral vessel formation, and capillary density. Increases in vascular endothelial growth factor (VEGF) levels, activation of nitric oxide (NO) synthesis, and mobilization of endothelial progenitor cells were noted. These results suggest that CO<sub>2</sub> therapy can facilitate neovascularization through the activation of growth factors (Irie *et al.*, 2005). Additionally, another investigation indicated that the transcutaneous delivery of CO<sub>2</sub> dissolved in water to patients suffering from diabetes mellitus and obliterative atherosclerosis resulted in a significant elevation in VEGF levels and CD34+CD33+ endothelial progenitor cells, thereby promoting angiogenesis and enhancing blood circulation in the lower extremities, culminating in a reduction of symptoms such as numbness and edema (Saito & Nonomura, 2006).

A variety of cellular sensors capable of detecting minor fluctuations in carbon dioxide concentrations have recently been identified. Through these sensors, carbon dioxide has been observed to activate or inhibit diverse functions, contingent upon its concentration and the duration of exposure (Cummins *et al.*, 2014; Galganska *et al.*, 2021). One particular study demonstrated that carbon dioxide exerts a notable anti-inflammatory effect, modulating extracellular signal-regulated kinases

1 and 2 (ERK1/2) activity in cultured endothelial cells in conditions of elevated CO<sub>2</sub> concentration. However, the effect of carbon dioxide on ERK1/2 activity is concentration-dependent (Galganska *et al.*, 2021). Carbon dioxide has also been associated with a reduction in reactive oxygen species levels and an increase in the presence of antioxidant substances (Bolevich *et al.*, 2016; Dogliotti *et al.*, 2011). Additionally, evidence suggests that carbon dioxide may influence insulin resistance through the inactivation of ERK1/2 and the p38 protein, which regulates various cellular functions and is implicated in inflammatory processes. Such applications may prove beneficial in enhancing insulin sensitivity and promoting the healing of diabetic wounds (Galganska *et al.*, 2023).

### Effects of Carboxytherapy on the Skin

In recent years, carboxytherapy has been regarded as an effective and safe tool for rejuvenation treatments, as subcutaneous administration of CO<sub>2</sub> has been shown to promote wound healing, reduce scar tissue, and enhance collagen renewal—making it a valuable procedure for achieving a wide range of aesthetic benefits. Several studies have demonstrated that the vasodilatory effect of carbon dioxide in the skin enhances microcirculation and oxygen supply, contributing to the aforementioned benefits (Diji & Greenfield, 1960; Minamiyama & Yamamoto, 2010).

An experimental study with histological analysis in rodents demonstrated that subcutaneous and intradermal injections of carbon dioxide increased collagen turnover compared with controls, and that intradermal injections achieved a greater density of collagen bundles (Ferreira *et al.*, 2008). Subsequently, a quasi-experimental study involving nine female volunteers who re-

ceived a single session of carboxytherapy in the infraumbilical region revealed, through histological analysis, a significant increase in collagen synthesis (Oliveira *et al.*, 2020).

A randomized, double-blind clinical trial confirmed the effectiveness of carbon dioxide application in promoting the healing of chronic wounds in diabetic patients. After 20 CO<sub>2</sub> therapy sessions over four weeks, 20 out of 30 wounds achieved complete healing, whereas in the control group, which received 20 placebo sessions with air, none of the wounds healed completely (Macura *et al.*, 2020). A four-year retrospective study evaluated the effects of transcutaneous carbon dioxide application in 86 patients with chronic wounds. The results showed clinical improvement in wound granulation, as well as a reduction in secretions and odor within the first week of treatment (Wollina *et al.*, 2004).

Another study examined the effects of carboxytherapy on venous insufficiency wounds in rats, comparing three groups: a control group, a group treated with silver sulfadiazine, and a group treated with carboxytherapy. The findings demonstrated that carboxytherapy reduced inflammation, improved fibronectin production, and resulted in more organized wound healing compared with the other groups (Brochado *et al.*, 2019). Carboxytherapy has also proven to be safe and effective in reducing recent facial scars, improving skin appearance (Arellano, 2013).

A recent clinical trial comparing the effects of carboxytherapy alone versus in combination with antioxidant and regenerative acids found that while carboxytherapy alone improved skin hydration and elasticity around the eyes, these effects were more pronounced when combined with

lactobionic, ferulic, and ascorbic acids. The combined therapy exhibited greater improvements in skin firmness and biomechanics, suggesting a synergistic relationship between carboxytherapy and these acids (Kołodziejczak *et al.*, 2025).

### Effects of Carboxytherapy on Subcutaneous Adipose Tissue

Over twenty years ago, a publication reported the effects of carboxytherapy on subcutaneous adipose tissue (SAT). Dr. Cesare Brandi and his research team conducted a study involving 48 women with localized fat deposits in the abdomen, thighs, and/or knees, who received subcutaneous carbon dioxide injections. The researchers evaluated microcirculation using laser Doppler imaging and measured tissue oxygen concentration, along with performing biopsies on treated areas before and after treatment. Their findings revealed a significant reduction in the volume of treated areas, increased microcirculation, elevated transcutaneous oxygen pressure, and, under microscopic examination, adipose tissue rupture with the release of triglycerides into intercellular spaces, along with adipocytes showing membrane fracture lines (Brandi *et al.*, 2001).

Another clinical trial, which included a histomorphological study of adipocytes through computed cytometry in 15 female volunteers who received six carboxytherapy sessions on the abdomen, demonstrated a significant reduction in adipocyte count in the abdominal wall, as well as morphological changes in adipocyte area, diameter, perimeter, length, and width following subcutaneous CO<sub>2</sub> administration (Costa *et al.*, 2011).

While studies have confirmed a reduction in subcutaneous fat tissue, the un-

derlying mechanism remains under investigation. Initially, it was hypothesized that the mechanical effect of gas infusion caused adipocyte rupture and subsequent lipolysis (Balik *et al.*, 2011). However, evidence now points toward a metabolic mechanism mediated by vascular endothelial growth factor (VEGF). An experimental study in mice comparing air versus CO<sub>2</sub> injections demonstrated that CO<sub>2</sub> administration (but not air) led to a reduction in adipocyte size within adipose tissue. Additionally, CO<sub>2</sub>-treated fat tissue showed markedly increased expression of the VEGF-1 and FGF-1 (fibroblast growth factor 1) genes, promoting the formation of new blood vessels within the interstitial spaces of treated adipose tissue.

Interestingly, CO<sub>2</sub> administration also increased the expression of the \*Ucp1\* gene by 1.7-fold—this gene encodes a thermogenic protein known as an uncoupling protein. Together with a decrease in lipogenic gene expression, these findings strongly support the hypothesis that carboxytherapy reduces subcutaneous adipose tissue through a **metabolic effect**, rather than by the **mechanical action** of the gas (Park *et al.*, 2018).

Furthermore, evidence suggests that carboxytherapy may contribute to improvements in metabolic parameters such as waist circumference, body mass index, triglyceride levels, and blood pressure when combined with a low-fat diet and high-intensity interval training (HIIT) (Ahmad *et al.*, 2022).

### Effects of Carboxytherapy on the Muscle

A research team from Kobe University in Japan revealed through a clinical trial that transcutaneous application of carbon dioxide produces effects comparable to

those of physical exercise, as it stimulates the expression of genes such as \*PGC-1 $\alpha$ \* (Peroxisome Proliferator-Activated Receptor Gamma Coactivator-1 Alpha), \*Sirt-1\* (Sirtuin-1), and \*VEGF\*, while also increasing mitochondrial number and promoting muscle fiber transformation (Oe *et al.*, 2011).

Akahane *et al.* (2017) investigated whether transcutaneous CO<sub>2</sub> application could enhance muscle injury recovery in rats. Muscle damage was induced in the tibialis anterior muscle using bupivacaine injections, and the rats were randomly assigned to either a treated group receiving transcutaneous CO<sub>2</sub> or an untreated control group. The results showed that CO<sub>2</sub> treatment accelerated the repair of injured muscle fibers. In addition, higher expression levels of genes and proteins associated with muscle protein synthesis were observed, along with greater capillary density in the CO<sub>2</sub>-treated group. The study concluded that transcutaneous CO<sub>2</sub> application may accelerate muscle recovery after injury in rats.

The effects of transcutaneous CO<sub>2</sub> on muscle fatigue recovery were also demonstrated in a study involving 15 healthy male volunteers. Muscle fatigue was induced through 300 maximal eccentric contractions of the quadriceps, followed by transcutaneous CO<sub>2</sub> application on the thigh. Parameters such as muscle strength, physical performance (assessed by a single-leg long jump), delayed onset muscle soreness (DOMS) using a visual analog scale, and muscle ATP and ADP concentrations were measured. The results indicated that CO<sub>2</sub> application accelerated the recovery of muscle strength and physical function, reduced DOMS, decreased ADP concentration, and increased ATP levels in

muscle tissue. This ATP synthesis may be related to the accelerated muscle recovery observed (Sakai *et al.*, 2012)

### Effects of Carboxytherapy on Bone

Carboxytherapy is a medical technique with multiple applications, and its metabolic effects (Figure 1) are supported by scientific evidence. Following its use for skin regeneration, the reduction of subcutaneous fat is among its most sought-after treatments. This localized fat reduction is associated with the lipolytic effect of carboxytherapy, demonstrated by the release of triglycerides following CO<sub>2</sub> administration (Brandi *et al.*, 2001). However, this mechanical lipolysis alone does not fully explain adipose tissue reduction, as obese and insulin-resistant patients often exhibit increased basal lipolysis associated with lipoinflammation (Engin, 2017).

Carboxytherapy stimulates microcirculation in subcutaneous adipose tissue (SAT) and improves tissue oxygenation—an effect mediated by the release of \*VEGF-1\* and \*FGF-1\*. Additionally, carbon dioxide has been shown to reduce reactive oxygen species (ROS) and stimulate the production of antioxidant compounds (Dogliotti *et al.*, 2011). These mechanisms may contribute to its fat-reducing effect. Furthermore, as previously discussed, inhibition of adipogenesis and upregulation of the thermogenic gene \*Ucp1\* are key factors in fat reduction (Park *et al.*, 2018).

Moreover, the potential effect of CO<sub>2</sub> on improving insulin resistance reinforces its metabolic impact on subcutaneous adipose tissue. At the muscular level, CO<sub>2</sub> can activate mitochondrial biogenesis (Oe *et al.*, 2011), and these activated mitochondria are responsible for initiating

$\beta$ -oxidation of fatty acids released from adipose tissue to be used as an energy source.

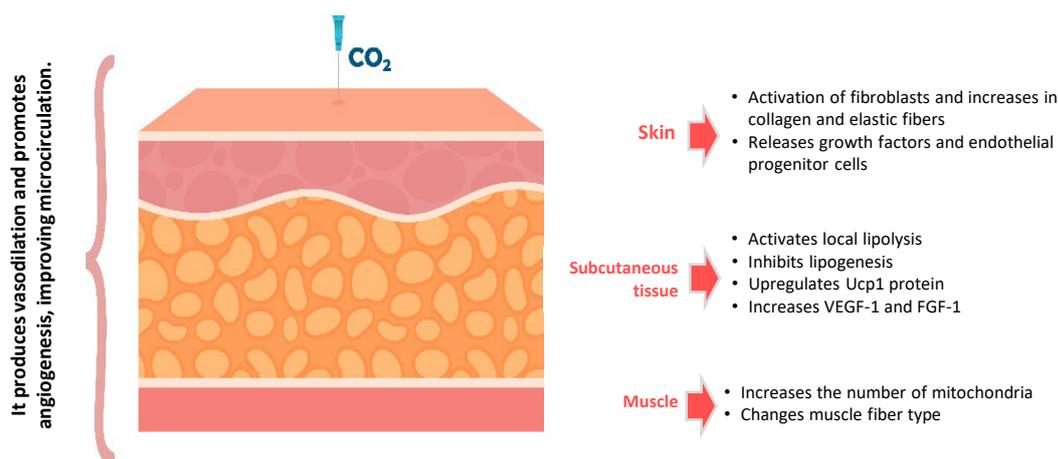
This process completes the full cycle following carboxytherapy treatment for localized adiposity:

1. Activation of microcirculation in the area encompassing gas diffusion, from the skin to the muscle tissue.
2. Enhanced lipolysis in subcutaneous adipose tissue (under non-hypoxic conditions due to the Bohr effect improving oxygenation), accompanied by reduced inflammation in adipose tissue.
3. Transport of free fatty acids through activated microcirculation from the adipose tissue to muscle, where CO<sub>2</sub> stimulates the

release of \*PGC-1 $\alpha$ \* and \*Sirt-1\*, activating mitochondrial biogenesis and  $\beta$ -oxidation of fatty acids.

The energy produced through this process manifests as heat, an effect reported in a clinical study (Abramo *et al.*, 2009). Although this temperature increase was initially attributed to vasodilation, it may also result from the metabolic process described above, as clinical practice has shown that the treated area remains warm even after the procedure concludes.

The use of carboxytherapy for muscular and bone injuries is still under investigation and development, yet the current evidence suggests highly promising therapeutic potential.



**Figure 1.** Metabolic effects of carboxytherapy application (original illustration, iCDT001-25). Ucp1: uncoupling protein and thermogenic gene; VEGF-1: vascular endothelial growth factor 1; FGF-1: fibroblast growth factor 1.1.

## CONCLUSIONS

Carboxytherapy is a medical technique with multiple applications in medicine, whose scope and benefits extend from the skin to bone tissue, sharing a common mechanism: the activation of microcirculation through the stimulation of growth factors and endothelial progenitor cells. Its

most widespread uses are in skin regeneration and the reduction of subcutaneous fat tissue. Its application in muscular and bone tissues shows great promise; however, further research across all medical fields is needed to fully understand its potential and optimize its therapeutic applications.

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# Impact of Edible Films as an Alternative for Food Packaging

## *Impacto de las películas comestibles como alternativa de envase de alimentos*

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### ABSTRACT

This study evaluates the impact of edible films as a sustainable and biodegradable alternative for food packaging in response to the growing issue of plastic pollution. The objective is to analyze the effectiveness of these films in terms of sustainability, multifunctionality, and food waste reduction. A systematic literature review (SLR) was conducted using scientific databases, selecting relevant studies published between 2019 and 2024 based on specific criteria and following the PICOC, BIBLIOMETRIX, and PRISMA methodologies. The results reveal that 64.29% of the studies consider edible films to be beneficial, emphasizing not only their biodegradability but also their ability to protect food, extend shelf life, and reduce environmental contamination. In addition, their antimicrobial and antioxidant functionalities are highlighted, with materials such as gelatin, chitosan, and other natural polymers being commonly used. In conclusion, edible films represent a promising solution for reducing plastic pollution and improving food preservation, positioning themselves as an eco-friendly alternative within the packaging industry. However, further research is needed to optimize their production and efficacy across various applications.

**Keywords:** Biodegradable, edible films, environmental pollution, sustainable alternative.

### RESUMEN

Este estudio evalúa el impacto de las películas comestibles como una alternativa sostenible y biodegradable para el envasado de alimentos, en respuesta a la creciente contaminación por plásticos. El objetivo es analizar la eficacia de estas películas en sostenibilidad,



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multifuncionalidad y reducción del desperdicio alimentario. Se llevó a cabo una revisión sistemática de la literatura (RSL) en bases de datos científicas, seleccionando estudios relevantes publicados entre 2019 y 2024 mediante criterios específicos y las metodologías PICOC, BIBLIOMETRIX y PRISMA. Los resultados revelan que el 64,29 de los estudios considera que las películas comestibles son beneficiosas, destacando no solo por ser biodegradables, sino también por su capacidad para proteger los alimentos, prolongar su vida útil y reducir la contaminación ambiental. Además, se resalta su funcionalidad antimicrobiana y antioxidante, utilizando materiales como gelatina, quitosano y otros polímeros naturales. En conclusión, las películas comestibles son una solución prometedora para reducir la contaminación plástica y mejorar la conservación de alimentos, presentándose como una alternativa ecológica en la industria de envases. Sin embargo, es necesaria más investigación para optimizar su producción y eficacia en diversas aplicaciones.

**Palabras clave:** Biodegradable, películas comestibles, contaminación ambiental, alternativa sostenible.

## INTRODUCTION

In recent years, restrictions on the use of plastics have increased due to the growing environmental pollution problem (Suresh, 2021). Consequently, the packaging industry is seeking to achieve sustainable production, and one of the most promising alternatives is the use of edible films as substitutes for plastics, given their biodegradable and multifunctional nature (Athanasopoulou *et al.*, 2024).

The importance of these films lies in the fact that they are produced from natural polymers—such as proteins and polysaccharides—and even from certain food residues like fruit peels, thereby helping to reduce global food waste (Schmoltdt *et al.*, 2024). It is estimated that each year, 121 kilograms of food are lost per person worldwide, with the majority of this waste occurring at the household level (United Nations, 2022).

Global plastic production reaches 400 million tons annually, of which 162 million tons are generated by the packaging industry. This poses a major environmental challenge, as plastic is a non-biodegradable

material that takes centuries to decompose, resulting in solid, non-destructible waste and toxic by-products, while also contributing to food waste (Merino *et al.*, 2024).

In Peru alone, three million plastic bags are used each year. However, a Supreme Decree has been enacted to promote the reduction and replacement of plastics with reusable, biodegradable materials whose degradation does not produce microplastic contamination (MINAM, 2019). For this reason, technology is focusing on the development of antibacterial and biocompatible packaging materials that can extend food shelf life and reduce environmental impact. Research is also exploring new biodegradable ingredients for the production of such materials (Solano *et al.*, 2018).

Edible packaging films act as a protective barrier between food and the packaging material, preventing direct contact, reducing contamination, and improving food safety (Tang *et al.*, 2024). This technology is gaining popularity as a sustainable alternative to traditional packaging, thanks to its ability to reduce plastic waste and enhance

food safety. In recent years, the field has advanced rapidly, with new formulations, manufacturing methods, and applications being developed—many of which have not yet been fully documented in prior reviews.

Therefore, the objective of this review is to determine the impact of edible films as an alternative food packaging solution within the food industry.

## MATERIALS AND METHODS

A total of 124 articles relevant to the topic were identified in the Scopus database. The PICOC model was then applied to break down the research topic into key terms to enable a more comprehensive search within Scopus.

### PICOC Methodology

A Systematic Literature Review (SLR) differs from traditional narrative reviews due to its replicable, scientific, and transparent approach. Its goal is to collect all relevant documents and publications that meet predefined inclusion criteria to address a specific research question. When conducted rigorously and with minimal error, an SLR can provide reliable results and conclusions that guide decision-makers and scientific professionals in their work (Mengist *et al.*, 2020).

### General Research Question

Q1: What is the impact of edible films made from natural sources as a sustainable alternative to replace plastic food packaging?

### Specific Research Questions

SQ1: What are edible films?

SQ2: What natural sources are used in the production of edible films?

SQ3: Why should plastic packaging be replaced?

SQ4: Why are edible films considered sustainable alternatives for food packaging?

Both Spanish and English keywords were used based on the research questions. To refine the search process, keywords were combined with Boolean operators, and the IATE database (Interactive Terminology for Europe) was consulted to standardize terminology and organize the search effectively (Abdul *et al.*, 2024).

Boolean operators are an essential tool in scientific literature searches, as they allow researchers to refine, broaden, or limit results using the terms “AND,” “OR,” and “NOT.” This technique helps exclude irrelevant studies and improves the precision of search results (Abdul *et al.*, 2024). Articles related to the research topic were selected according to each criterion defined within the PICOC matrix.

### Formulation / Selection of Search Equations and Search Engines

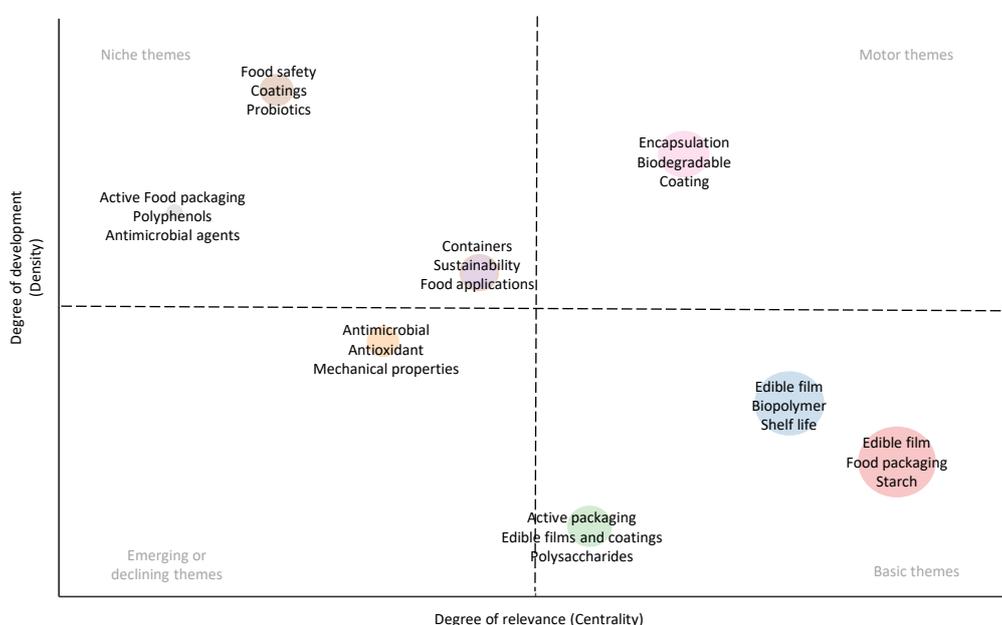
The Scopus database was used, as it is considered the largest existing multidisciplinary database. The keywords were combined with Boolean operators (AND, NOT, and OR) and enclosed in quotation marks to conduct a more systematic, focused, and versatile search.

### Bibliometrix Analysis

Bibliometrix (R language) is recognized as a highly effective tool for analyzing large volumes of data, allowing researchers to organize conceptual and intellectual frameworks through the examination of quantitative data and their visual representations (Campina *et al.*, 2024).

**Table 1.**  
Search strings

Words/Search strings	Number of articles
("Sustainable" or "Packaging" or "Food" or "Environmental Problems" or "Plastic" or "edible film" or "Non-biodegradable" or "Food Industry") AND ("Edible films" OR "Food packaging" OR "Conservation" OR "Environmental viability" OR "Acceptance") AND ("Natural sources" OR "biopolymers" OR "edible films" OR "biodegradable packaging") AND ("Substitution" OR "plastic containers" OR "edible films" "shelf life" OR "waste" OR "foods") AND ("Biodegradable packaging" OR "food industry " OR "food innovation" OR “sustainable production”)	128



**Figure 1.** Thematic Map of Keywords

### Results of the Bibliometrix Analysis in R Studio

The bibliometric analysis performed in R Studio revealed a steady growth in the rate of published articles, which can be expressed as 14.47%. The analysis also allowed for visualization of the relationship between keywords and the years of publication of each study, spanning from 1996 to 2024. The size of each node represents the frequency with which a given keyword appears across the analyzed documents.

### Inclusion and Exclusion Criteria

Inclusion and exclusion criteria are established by authors during the development of a Systematic Literature Review (SLR) to minimize potential bias. These criteria (IC and EC) must be defined a priori and be highly specific—overly broad criteria can make it difficult to draw clear conclusions from the results. Article selection is based on factors such as language, source impact, open access availability, and year of publication (Khan *et al.*, 2022).

For this study, the primary inclusion criterion was the selection of scientific articles published within the last five years (2019–2024) to ensure the use of up-to-date information. Table 2 presents the six inclusion criteria and one exclusion criterion applied to this SLR.

After conducting an exhaustive search in the SCOPUS database and applying the PRISMA flow diagram along with the inclusion and exclusion criteria shown

in Table 3, an initial total of 4690 records was obtained. Since the study used only SCOPUS, there were no duplicate records. After screening, 469 records remained. Applying the PICOC methodology together with the inclusion (IC1, IC2, IC3, IC4, IC5, IC6) and exclusion (EC1) criteria, a total of 42 articles were finally selected for the Systematic Literature Review (SLR), as shown in Figure 2.

**Table 2.**  
*Scientific Article Search Criteria (PRISMA)*

Type	Inclusion criteria	Type	Exclusion criteria
CI1	Articles published within the last five years (2019–2024)	CE1	Articles older than five years
CI2	Subject areas: Chemistry, Biological and Agricultural Sciences, Environmental Sciences, and Engineering		
CI3	Document type: Research article		
CI4	Keywords: edible films, food packaging, chitosan, biopolymers, starch, edible coatings, packaging, shelf life.		
CI5	Language: English		
CI6	Open Access		

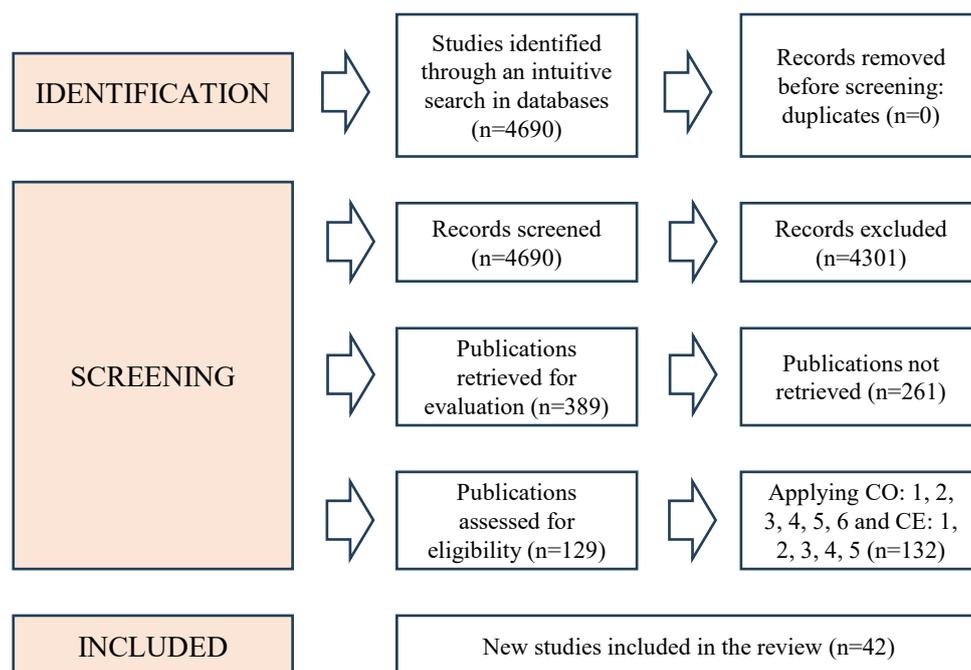


Figure 2. PRISMA Flow Diagram

## RESULTS AND DISCUSSION

### 1. Results by Year of Publication

In 2021, twelve studies on the topic were published, representing 28.6% of the total publications, a higher proportion compared to previous and subsequent years. This suggests that research on edible films as sustainable food packaging alternatives is relatively recent, with increasing interest and development in subsequent years.

### 2. Number of Publications by Country

According to the findings, India accounted for the largest number of publications, with five studies (7.14%), followed by Brazil with four (5.71%). Next were Saudi Arabia, Malaysia, Iran, Indonesia, China, and the United Kingdom, each contributing three publications (12.87%). Countries such as Turkey, Spain, Portugal, Oman, Mexico, and Argentina had two studies each (21.06%), while other nations contributed one publication each (26.25%).

### 3. Results from the PICOC Research Questions

1: What is the impact of edible films made from natural sources as a sustainable alternative to replace plastic food packaging?

Based on the results, 27 studies (64.29%) reported that edible films have a positive impact as an alternative to plastic packaging. These studies emphasize the biodegradability, protective properties, and environmental benefits of edible films. Meanwhile, 15 studies (25.71%) did not explicitly define the impact as positive or negative, but none reported adverse effects.

Edible films and sustainable packaging systems aim to reduce single-use plastics and promote biodegradable alternatives that enhance the preservation of both perishable and dry foods. These approaches integrate biopolymeric and synthetic materials for functional design, collectively

contributing to plastic pollution reduction and the promotion of sustainable practices in the packaging industry.

According to de Souza *et al.* (2024), edible films formulated with anthocyanins and Deep Eutectic Solvents (DES) provide not only ecological benefits but also stable and functional physical properties, making them viable for industrial use. Similarly, Aziza *et al.* (2023) highlights that edible films from natural sources improve food preservation while mitigating the environmental impact of single-use plastics. Furthermore, Pavlatkova *et al.* (2023) reports that edible films based on zein and chitosan, enhanced with natural antimicrobial agents such as essential oils, serve as a sustainable and effective alternative to plastic packaging by improving barrier properties and reducing the need for synthetic additives. These solutions not only offer barrier and preservation properties but also contribute to reducing the use of chemical additives, promoting a more eco-friendly and safer option for food packaging. These authors emphasize that edible films enhance food preservation by providing improved barrier properties and stability.

Terzioglu *et al.* (2024) adds that edible films and other innovative solutions complement each other in addressing plastic pollution and achieving a more sustainable packaging industry that is less dependent on conventional plastics. In line with this, Gamboni *et al.* (2023) asserts that edible films made from natural polymers share the same goal as other sustainable packaging systems: to reduce plastic waste and enhance environmental performance in food industries such as instant coffee packaging. Gamboni *et al.* (2023), Aziza *et al.* (2023), and Pavlatkova *et al.* (2023) agree on the use of natural sources for the deve-

lopment of edible films, emphasizing their focus on eco-friendly solutions. Terzioglu *et al.* (2024) highlight that edible films and other approaches are complementary in addressing plastic pollution, while other authors, such as De Souza *et al.* (2024) and Pavlatkova *et al.* (2023), focus more on the feasibility of edible films as a unique and effective solution.

## Results for the Question SQ1

### SQ1: What are edible films?

The analysis showed that most studies define edible films as coatings, with 11 articles (42.31%) using this term. Meanwhile, 8 studies (30.77%) refer to them as edible materials, and 7 (26.92%) as packaging materials. Although no single definition exceeds 50%, the prevailing concept describes edible films primarily as coating systems

According to Phengnoi *et al.* (2023), edible films are an innovative technology designed to extend food shelf life by improving water vapor permeability and reducing weight loss in products such as guava. Similarly, Atta *et al.* (2021) report that cellulose-based and yeast-derived edible films exhibit high water solubility and antimicrobial activity, extending the shelf life and quality of fruits like oranges and tomatoes. Phengnoi *et al.* (2023) and Atta *et al.* (2021) agree that edible films are used to extend the shelf life of foods. Phengnoi *et al.* (2023) focus on guava, improving water vapor permeability and reducing weight loss, while Atta *et al.* (2021) highlight their application in fruits such as oranges and tomatoes, emphasizing high water solubility and antimicrobial activity.

Otálora *et al.* (2022) describes edible films made from cassava starch and vegetable microparticles, which improve

tensile strength and can even detect food spoilage.

Pavlatkova *et al.* (2023), on the other hand, focuses on zein and chitosan-based films incorporating essential oils for added antimicrobial activity. Both studies highlight the importance of natural materials and their enhanced functionality. Gamboni *et al.* (2023) adds that edible films are used as primary packaging for dry foods like instant coffee, valued for their tensile resistance and heat-sealing properties.

Gamboni *et al.* (2023) and Otálora *et al.* (2022) address the specific applications and mechanical properties of edible films. Gamboni *et al.* (2023) mention their use as primary packaging for dry foods, such as instant coffee, highlighting their tensile strength and heat-sealing resistance. Otálora *et al.* (2022) also discuss mechanical aspects such as breaking tension and contact angle.

Suresh *et al.* (2021) further emphasizes the multifunctional nature of edible films, noting their biodegradability, antimicrobial potential, and biocompatibility, positioning them as a realistic alternative to

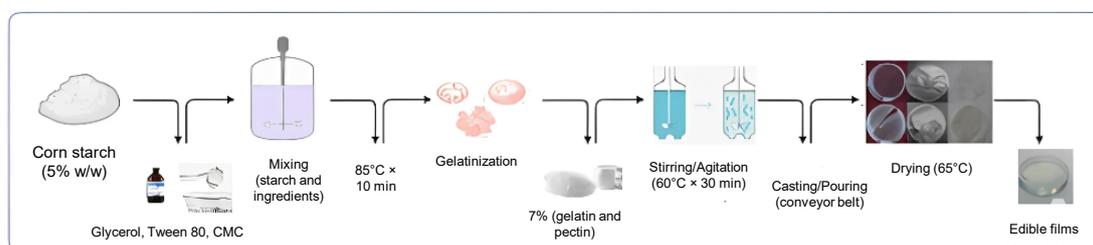
plastics. Similarly, Al-Harrasi *et al.* (2022) highlights edible films made from chitosan, porphyran, and ginger essential oil, which enhance barrier, thermal, optical, and mechanical properties while providing antioxidant effects.

Suresh *et al.* (2021) and Al-Harrasi *et al.* (2022) highlight the multifunctional properties of edible films, such as biodegradability and antimicrobial activity. Suresh *et al.* (2021) focus on the ability of these films to replace plastic materials, while Al-Harrasi *et al.* (2022) emphasize improvements in barrier, thermal, optical, and mechanical properties, as well as their antioxidant effects.

## Results for the Question SQ2

### SQ2: What are the natural sources used in the production of edible films?

According to the results obtained from various natural sources used in the production of edible films, as shown in Figure 3, the most common sources are plant-based materials, representing 52.63%, followed by gelatin and chitosan at 31.58%, and finally animal-based sources at 15.79%.



**Figure 3.** Production process for edible films

Chen *et al.* (2024) investigated the use of mango peels and tea polyphenols to create antibacterial films. These films exhibited greater density and significant improvements in their barrier properties against water vapor, oxygen, and carbon dioxide.

The combination of mango peels and tea polyphenols helped maintain the color and texture of chicken breast meat, inhibiting microbial growth and extending the product's shelf life. Meanwhile, Han *et al.* (2023) developed a composite edible

film using zein, shellac, and curcumin. The addition of curcumin notably enhanced the film's water vapor barrier, water solubility, and antioxidant properties. Moreover, these films demonstrated pH responsiveness and inhibitory effects against *E. coli*, providing a new strategy for developing functional food packaging.

Mondal *et al.* (2022) explored the use of defatted green algae biomass and chitosan to produce edible films. They utilized an ethanolic extract of raw algae, achieving improvements in tensile strength, antioxidant activity, and water vapor permeability. This eco-friendly approach offered a sustainable solution for extending the shelf life of fresh products such as green chili peppers. Similarly, Kaur *et al.* (2024) investigated the combination of aloe vera gel and chitosan to form edible films. Their formulations improved rheological and antioxidant properties, as well as water solubility and water vapor permeability. When applied to fresh figs, these films significantly reduced microbial growth during cold storage, demonstrating a sustainable solution for fresh fruit preservation.

In another study, Bahar *et al.* (2023) employed gelatin, zinc oxide nanoparticles, and chitosan nanofibers to enhance the mechanical and barrier properties of edible films. The combination of these materials provided antioxidant and antibacterial capabilities, showing great potential as a functional material for food packaging. Likewise, Tien *et al.* (2021) discussed the use of chitosan and nanoparticles to form nanofibers with excellent antioxidant and antimicrobial properties. Chitosan, often blended with other materials to improve processability, stood out for its intrinsic beneficial properties and its ability to form effective edible films for a variety of food products.

Azizah *et al.* (2023) evaluated a combination of fish gelatin, pectin, and lemongrass essential oil to develop edible films. The resulting films showed improvements in physicochemical properties and antibacterial activity, proving effective in preserving the quality of chicken breast meat during storage. Similarly, Lima *et al.* (2021) used galactomannan from *Caesalpinia pulcherrima* and *Cymbopogon citratus* essential oil to coat cheeses. This coating enhanced the microbiological and physicochemical stability of the cheeses during storage, demonstrating a viable alternative for the food industry. Finally, Nigrum *et al.* (2021) combined fish skin gelatin with roselle powder, cinnamon powder, and cinnamon essential oil to develop edible films. These films showed improved physicochemical properties and proved effective as active packaging for bread, standing out for their antioxidant and antibacterial capacities.

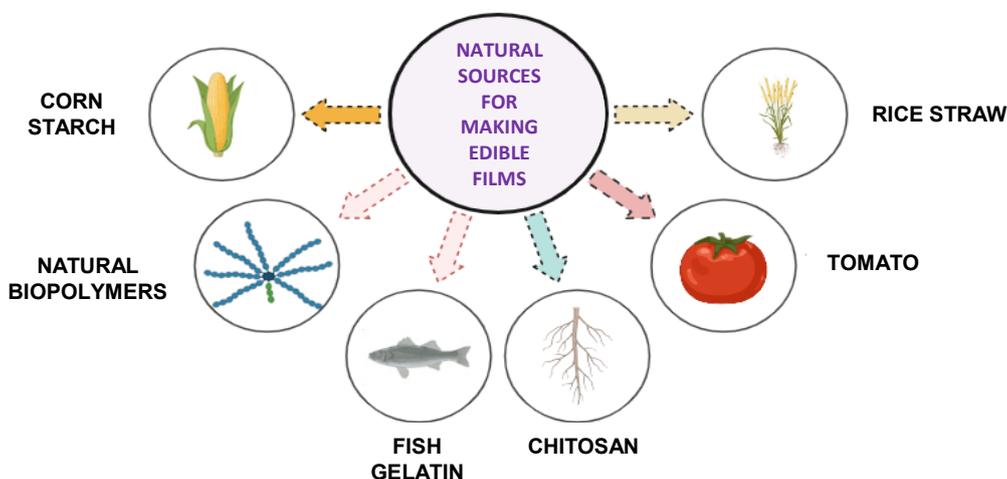
All the studies agree on the use of natural and biodegradable materials. Chen *et al.* (2024) and Azizah *et al.* (2023) highlight the use of plant-based residues (such as mango peels and pectin), while Mondal *et al.* (2022), Tien *et al.* (2021), and Bahar *et al.* (2023) focus on biopolymers like chitosan. Nigrum *et al.* (2021) and Lima *et al.* (2021) mention biopolymers derived from both animal and plant sources.

Regarding the antioxidant properties of the films, Chen *et al.* (2024) and Han *et al.* (2023) report significant improvements in density and water vapor barrier performance. Mondal *et al.* (2022) and Kaur *et al.* (2024) observe enhancements in mechanical properties and solubility with the addition of bioactive compounds.

The practical applications of these films vary widely — from the preservation

of chicken breast (Chen *et al.*, 2024; Azizah *et al.*, 2023) and green chili peppers (Mondal *et al.*, 2022), to fresh figs (Kaur *et al.*, 2024) and cheese (Lima *et al.*, 2021).

Each author emphasizes how their specific edible film formulations can effectively extend shelf life and maintain the quality of food products.



**Figure 4.** Natural sources for the production of edible films

### Results for the Question SQ3

#### SQ3: Why should plastic packaging be replaced?

Plastic packaging, as is well known, is designed for single use, and in recent years, its use has been increasingly challenged due to the urgent need to reduce or even eliminate it because of its negative impact on the environment. Furthermore, it can also affect human health, as it takes an extremely long time to decompose (Terzioğlu *et al.*, 2024).

According to the results obtained in this research, there are two main reasons why plastics should be replaced. Fifteen studies (83.3%) indicate that plastics are non-biodegradable and highly polluting, while three studies (16.7%) mention that plastic use contributes to food waste.

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Bahar *et al.* (2023) report that environmental pollution has significantly increased in recent years as a result of plastic bag use, which underscores the need to replace this packaging material. Adeyeye *et al.* (2023) agree, stating that the excessive use of plastic packaging materials over the past decades has become a major environmental concern, prompting the call for their substitution and elimination.

Suresh *et al.* (2021) also point out that the majority of conventional plastic packaging materials have caused serious environmental and sustainability issues, creating a need for biodegradable alternatives. Kuprina *et al.* (2020) note that while plastic is accessible and convenient, it is highly detrimental to the environment, as it does not naturally decompose in the short term, accumulating in massive quantities and causing long-term damage to both the planet and human health. Egolf *et al.* (2019) concur that the continued use of plastic packaging is unsustainable, emphasizing the search for eco-friendly alternatives that could transform the food system and make the packaging industry more efficient. Based on the reviewed studies, it can be concluded that conventional plastic packaging must be replaced by biodegradable and sustainable alternatives, since plastic is harmful to both the environment and food quality, and current technologies aim to eliminate its use for a healthier and more sustainable food industry.

#### Results for Question SQ4

##### **SQ4: Why are edible films sustainable alternatives for food packaging?**

According to the results, 35 articles (43.75%) state that plastic packaging should be replaced with edible films because they are biodegradable and sustainable alternatives; 34 articles (42.5%) emphasize their multifunctional properties, and 11 articles (13.75%) highlight their ability to reduce food waste.

Kampeerappun *et al.* (2024) note that the production of edible film packaging uses biodegradable agricultural residues, integrating eco-friendly raw materials. Bahar *et al.* (2024) identify gelatin as one of the most common biodegradable

materials used for edible film production, ensuring sustainability. Likewise, Adeyeye *et al.* (2023) emphasize starch as another environmentally friendly biodegradable alternative that naturally decomposes without causing harm.

Suresh *et al.* (2021) highlight that edible film packaging is biodegradable and sustainable because it is made from natural polymers designed to minimize environmental impact. Atta *et al.* (2021) mention that edible films are potentially sustainable due to their bioactive components, which give them multifunctional roles such as protection and antimicrobial activity. Tien *et al.* (2021) identify chitosan as another sustainable and multifunctional material suitable for biodegradable packaging. Egolf *et al.* (2019) add that food technology increasingly seeks to develop biodegradable and sustainable packaging materials from natural sources, with edible films being among the most promising.

Across all the studies analyzed, edible films developed for packaging purposes are consistently described as biodegradable and sustainable, designed explicitly to replace plastic and address the environmental challenges of recent decades.

The results further show that eight articles (29.63%) mention that edible films have antimicrobial properties, six (11.11%) highlight their antioxidant capacity, five (18.52%) note their protective function, and another eight (29.63%) report that they extend the shelf life of food.

Kaur *et al.* (2024) state that edible films made from natural bioactive materials protect food from microbial effects and extend shelf life. Azizah *et al.* (2023) also report that edible films composed of fish gelatin, pectin, and essential oils yield

ded promising results in preserving the shelf life of meat. Han *et al.* (2023) found that edible films containing curcumin significantly extended product shelf life by reducing water activity and enhancing antioxidant capacity. Atta *et al.* (2021) highlight that edible films made with antibacterial cellulose inhibited microbial growth, thereby improving the shelf life and quality of food products.

Naseri *et al.* (2020) observed that biopolymer-based edible films enriched with essential oils effectively controlled microbial growth, maintaining the quality, freshness, and shelf life of turkey meat. Similarly, Gola *et al.* (2019) demonstrated that polyphenolic edible films formulated with carob extracts possess high antioxidant and antimicrobial capacities suitable for food packaging.

Overall, the reviewed studies reveal a wide range of biodegradable and sustainable natural sources — both plant- and animal-based — being innovatively used to extend shelf life, inhibit microbial growth, enhance product protection, and improve antioxidant capacity, thereby adding nutritional value to food products.

Additionally, eight studies (80%) report that edible films extend shelf life, thereby reducing food waste, while one study (20%) attributes this effect to their bioactive components.

Kaur *et al.* (2023) note that bioactive edible packaging effectively prolongs shelf life and reduces food waste. Adeyeye *et al.* (2023) explain that starch nanoparticles used in edible film production are biodegradable and innovative, functioning as packaging that extends shelf life and contributes to reducing food waste. Similarly, Azizah *et al.* (2023) found that edible films

made with gelatin and essential oils inhibit microbial activity, extend shelf life, and prevent food spoilage and contamination. Gola *et al.* (2019) emphasize that the food industry has recently focused on developing antioxidant and antimicrobial packaging, with edible films standing out as one of the most effective solutions to extend shelf life, reduce water activity, and minimize global food waste.

## CONCLUSIONS

The systematic review on the impact of edible films as an alternative food packaging solution revealed numerous benefits and challenges in their adoption. Edible films, defined as an innovative technology to extend food shelf life and enhance functional properties, are developed from various natural sources, such as cassava starch, zein, and chitosan.

The analyzed studies highlight that these films have improved tensile strength, contact angle, thermal-sealing resistance, and incorporate antimicrobial and antioxidant properties, performing comparably to conventional packaging materials. However, they face significant challenges regarding standardization, consumer acceptance, production costs, and scalability.

Future prospects are promising, with innovations in materials and production technologies expected to enhance functionality and reduce costs. Growing environmental awareness and supportive policies are also driving the development and adoption of these emerging technologies.

In conclusion, edible films represent a viable and sustainable alternative to traditional plastic packaging, with significant potential to reduce food waste and plastic pollution. Continued multidisci-

plinary collaboration and research will be maximizing the benefits of this emerging key to overcoming current challenges and sustainable technology.

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- Chamorro Nelssi: Conceptualization; methodology; data analysis; writing.
- Yalupalin Soledad: Conceptualization; methodology; writing.
- Larrea Christian: Conceptualization; writing; statistical analysis; review and editing.
- Alvarado Daniel: Data analysis; writing.
- Callirgos David: Conceptualization; review and editing.

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# Analysis of the Properties of Siglalón (*Vasconcellea stipulata*) and its Application in Bakery Products

## *Análisis de las propiedades del siglalón (*Vasconcellea stipulata*) y su aplicación en productos de panificación*

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### ABSTRACT

Siglalón (*Vasconcellea stipulata*) is considered a fruit of Colombian–Ecuadorian origin. In Ecuador, its geographical distribution is found in the provinces of Azuay, Loja, Cañar, and El Oro. According to taxonomic classification, the *Vasconcellea* genus includes twenty-one species. The application of *Vasconcellea stipulata* fruit in the field of baking arises from the limited knowledge about siglalón and its culinary use, as its consumption remains low in mountainous regions and surrounding areas. This culinary proposal focuses on incorporating siglalón into bakery products to take advantage of its nutritional properties. The organoleptic characteristics of this fruit provide significant benefits to baked goods. The methodology included three experimental trials involving four preparations, among which the custard cream was the most highly rated product, achieving an 85% acceptance rate. The organoleptic properties, such as aroma, color, taste, and texture, of the preparations were also characterized in Guayaquil. However, the lower scores obtained for samples (a) and (b) by the panelists were associated with the high tannin content in siglalón, resulting from the cooking technique used. This research demonstrates innovation in baking, showing that siglalón can be successfully incorporated into bakery products due to its culinary and nutritional value.

**Keywords:** Bakery, innovation, nutritional properties, siglalón.

### RESUMEN

El siglalón es considerado una fruta de origen colombo ecuatoriano. Su distribución geográfica en el Ecuador se encuentra en las provincias de Azuay, Loja, Cañar y El Oro. De acuerdo con la clasificación taxonómica el género *Vasconcellea* contempla veintiuno



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especies. La aplicación de la fruta de *Vasconcellea stipulata* dentro del ámbito de la panificación, se debe al escaso conocimiento sobre el siglalón y su uso en la gastronomía, debido a que su consumo es bajo en sitios montañosos y alrededores. La presente propuesta culinaria es la aplicación del siglalón en la panadería, para el aprovechamiento de las propiedades nutricionales. Las características organolépticas de esta fruta son de gran aporte para los productos panificados. En la metodología se establecieron 3 experimentaciones en cuatro preparaciones, de las cuales la crema pastelera fue el producto mejor valorado, con un 85 % de aceptación. Así también se caracterizaron las propiedades organolépticas de las preparaciones, como olor, color, sabor y textura en Guayaquil. Sin embargo, el puntaje bajo en las muestras (a) y (b) por parte de los panelistas están relacionadas con la alta presencia de taninos en el siglalón, debido a la técnica de cocción empleada. La presente investigación muestra la innovación en la panificación, demostrando que el siglalón puede ser incorporado exitosamente en productos de panadería por su valor culinario y nutricional.

**Palabras clave:** Panadería, innovación, propiedades nutricionales, siglalón.

## INTRODUCTION

Despite being one of the smallest countries in South America, Ecuador possesses an extraordinary diversity of climate, flora, and fauna, making it an attractive region where most of the country's food products originate from its various ecosystems (Rodríguez *et al.*, 2013). Ecuadorian cuisine is known for its exotic flavors; however, many highly nutritious foods remain relatively unknown, and several that were once valued have now lost prominence. The fruits studied in this research have been affected by social and environmental changes—information gathered through interactions with residents of Sevilla de Oro, in the province of Azuay—where fruit consumption has decreased, and only a small number of crops remain (Vidal *et al.*, 2009).

Currently, there are no commercial products based on siglalón in Ecuador, although in the provinces of Loja, Azuay, and El Oro, fruit-based products such as jams, flavored waters, juices, and preserved fruits are produced. This limited development explains why siglalón remains unfamiliar to

most Ecuadorians, as confirmed by studies conducted in Guayaquil. Since the fruit is cultivated only on a small scale and lacks strong market demand, it has not yet been widely adopted in food production. The use of this fruit as a raw material in bakery products is therefore recommended.

The limited consumption of local foods among Ecuadorians is largely due to a lack of information in the media and to distribution challenges associated with regional variations in climate and soil conditions. The restricted availability of siglalón in uncultivated regions of the country represents a key factor in its low recognition and utilization (Espinosa & Abedini, 2016).

Based on observations from markets and supermarkets, siglalón is rarely consumed in coastal areas, in contrast to the highlands, where it is more commonly sold due to its Andean origin (Scheldeman *et al.*, 2007). Nevertheless, there is a shortage of processed products derived from this fruit. In northern South American countries such as Venezuela and Colombia, siglalón

is used to make preserves and jams through various techniques that yield nutritionally rich products (Auquiñivin & Paucar, 2020).

This study aims to identify the gastronomic applications of siglalón as part of innovative approaches in baking, as well as to encourage the consumption of a largely unknown fruit among Ecuadorians. The analysis will also benefit future culinary professionals by providing a foundation for developing new applications of this fruit in diverse areas of gastronomy (Scheldeman *et al.*, 2004).

According to León-Yáñez *et al.* (2011), the *Carica* genus includes a single species, whereas the *Vasconcellea* genus in Ecuador comprises eleven recognized species, five of which are endemic. Various publications have discussed this genus in Ecuador, noting that, due to the country's favorable climatic conditions, most species are classified as of "least concern" and are found primarily in the central and southern regions. Maintaining the cultivation and commercialization of the fruit and its derivatives is important, as it contains enzymatic compounds valuable for industrial product development (Luján *et al.*, 2021).

Currently considered an underutilized or neglected papaya variety, siglalón is typically grown in small-scale artisanal plantations, where producers value it for its unique properties. It is regarded as an "isolated" crop, not only due to its low yield but also because of its inefficient utilization—not just of the fruit itself but also of its secondary metabolites. As an Andean fruit tree, siglalón is produced in limited quantities; the lack of demand and inconsistent production hinder its inclusion in culinary applications (Cárdenas, 2021).

## MATERIALS AND METHODS

Experimental trials were conducted to analyze the organoleptic properties of siglalón, resulting in three experimental tests. The ingredients used included siglalón, flour, eggs, sugar, yeast, butter, baking powder, and others. Equipment such as an electric oven, hand mixer, and balance scale were also employed.

For the first experiment, as shown in Table 1, a quatre-quarts (French pound cake) dough was prepared using 2% siglalón pulp. The second experiment involved the formulation of butter cookies with 1% butter, 1.5% sugar, 5% flour, and 1% siglalón pulp. Finally, the third experiment consisted of preparing a pastry cream as a bread filling, using 5% siglalón pulp, 1.5% egg yolks, and 0.5% cornstarch.

Each experimental process began with ingredient preparation. For the pound cake, the creaming method was applied (beating butter and sugar), followed by the gradual addition of eggs and siglalón pulp. Once combined, the dry ingredients were folded in gently, and the mixture was baked in an electric oven at 180 °C for 35 minutes.

For the butter cookies, siglalón pulp, butter, flour, and baking powder were mixed, and the dough was rolled out to a thickness of 0.4 cm. After resting for 15 minutes under refrigeration, the dough was cut into desired shapes and baked in an electric oven at 160 °C for 20 minutes.

In the final experiment, the pastry cream was prepared by infusing siglalón pulp with a vanilla bean. A portion of the pulp was reserved and used to dissolve the cornstarch. The egg yolks, sugar, and cor-

nstarch mixture were then combined with the infused milk to obtain a homogeneous cream.

A sensory evaluation was conducted using a hedonic scale to assess organoleptic attributes (color, aroma, taste, and texture) of the three experimental products. The scale ranged from 1 (“dislike”), 3 (“neither like nor dislike”), to 5 (“like

very much”). The evaluation was conducted with adult participants aged 28 to 60, who were informed about the study and provided their consent to participate. Each panelist received the hedonic scale form, a glass of water, and samples of the three products. Proper evaluation procedures and rating instructions were explained prior to testing. After completion, the data were collected and analyzed for interpretation.

**Table 1.**  
*Formulation of the experiments developed with Siglalón pulp*

<b>Experiment 1 Pound cake</b>		<b>Experiment 2 Butter cookies</b>		<b>Experiment 3 Pastry cream</b>	
<b>Ingredients</b>	<b>Quantity</b>	<b>Ingredients</b>	<b>Quantity</b>	<b>Ingredients</b>	<b>Quantity</b>
Siglalón pulp	20 g	Siglalón pulp	30 g	Siglalón pulp	500 g
Flour	250 g	Flour	300 g	Sugar	125 g
Butter	250 g	Butter	30 g	Eggs	100 g
Eggs	250 g	Sugar	45 g	Vanilla pod	1 unit
Sugar	250 g	Vanilla essence	1 g	Cornstarch	
Vanilla essence	1 g	Baking powder	3 g		
Baking powder	5 g				

## RESULTS AND DISCUSSION

In the analysis of species diversity, it is possible to determine the level of unfamiliarity and use of a fruit based on its history, stems, leaves, flowers, fruits, and nutritional value. To identify its characteristics, such as color, odor, flavor, and texture, an investigation was conducted, developing an important part of the aforementioned properties, which were incorporated into the development of this study.

Through sensory analysis, three samples corresponding to the experimental products were evaluated: the pound cake (sample a), the butter cookies (sample b),

and the pastry cream (sample c). Each product’s sensory attributes were assessed, and the pastry cream (sample c) received the highest preference, with an 85% acceptance rate, as shown in Table 2.

The high acceptance of sample (c) aligns with the findings of Salas (2021), who noted that tropical fruits often stand out for their pleasant flavor and potential for gastronomic innovation. However, the lower scores of samples (a) and (b) may be related to the high tannin content in siglalón, which can be influenced by the cooking technique used, as suggested by Ote-

ro-Lamas (2012), thereby affecting flavor acceptance.

The organoleptic evaluation revealed that siglalón has a high acceptance potential among consumers. The study developed several preparations incorporating

the fruit, all of which demonstrated favorable acceptance by the selected panelists. Furthermore, siglalón contributes to the absorption of papain, a digestive enzyme unique to fruits of the Caricaceae family (Lujan *et al.*, 2021).

**Table 2.**  
*Values Corresponding to the Analysis of Sensory Attributes in the Evaluated Experiments*

Category	Sample (a)	Sample (b)	Sample (c)
Dislike	5%	20%	4%
Neither like nor dislike	15%	7%	11%
Like very much	80%	73%	85%
Total	100%	100%	100%

## CONCLUSIONS

This research demonstrates innovation in bakery applications through the three developed formulations, pound cake, butter cookies, and pastry cream, showing that siglalón can be successfully incorporated into bakery products, highlighting its culinary and nutritional value.

The sensory evaluation results were positive, with the pastry cream being the most preferred product (85% acceptance). This demonstrates the potential of siglalón to attract consumers with its pleasant flavor and texture.

Although the preparations were well-received, improvements are recommended to reduce the tannin content in siglalón, as this could enhance attributes such as

color and flavor, thereby increasing overall acceptance.

From a gastronomic and cultural perspective, this study reinforces the importance of preserving and promoting siglalón cultivation—not only for its nutritional value but also as a resource for culinary innovation that can revitalize its consumption in Ecuador and beyond.

The incorporation of siglalón supports sustainability and biodiversity by promoting the recovery of underutilized fruits, contributing to agricultural diversity and sustainability. This opens opportunities for the development of new products and markets focused on traditional yet innovative foods.

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- Cedeño-Zambrano, A.: Conceptualization, methodology, writing, project administration.
- López-López, K.: Methodology; statistical analysis; writing; project administration.
- Salazar-Rodríguez, B.: Writing and project administration.
- Zea-Álvarez, O.: Review and editing..
- Poveda-Anchundia, T.: Review and editing.

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# Updated History of Pisco

## *Historia actualizada del pisco*

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### ABSTRACT

This document explores the origin and evolution of pisco, highlighting its history from the cultivation of the vine in Peru and Chile during the 16th century. Thanks to its favorable climate, Peru recorded the first South American wine in 1539, while Chile documented the distillation of brandy in 1586. However, the authenticity of some Chilean records is questioned due to a lack of documentary evidence. The name “pisco” originates from the Peruvian region of Pisco, known for its birds and port, where brandy was stored in clay jars called “piscos.” Peruvian documents from 1613 and 1712 confirm the early use of the term, while Chile adopted the name centuries later, even renaming a town “Pisco Elqui” in 1936 to legitimize its production. The dispute over the designation of origin has intensified, with research emphasizing the historical export of Peruvian pisco to markets such as Guatemala and Chile. Although Chile developed its own industry, 19th-century Chilean lexicographers acknowledged the Peruvian origin of pisco. The document concludes that, beyond the controversy, this research enriches the understanding of the history and quality of this iconic spirit.

**Keywords:** Brandy, Chile. distillation, Peru, Pisco, wine.

### RESUMEN

El documento explora el origen y evolución del pisco, destacando su historia desde el cultivo de la vid en el Perú y Chile durante el siglo XVI. Perú, gracias a condiciones climáticas favorables, registra el primer vino sudamericano en 1539, mientras que Chile documenta destilación de aguardiente desde 1586. Sin embargo, se cuestiona la autenticidad de algunos registros chilenos por falta de evidencia documental. El nombre “pisco” proviene de la región peruana de Pisco, conocida por sus aves y su puerto, donde se envasaba el aguardiente en botijas llamadas “piscos”. Documentos peruanos de 1613 y 1712 confirman el uso temprano del término, mientras que Chile adoptó el nombre siglos después, incluso renombrando un pueblo como “Pisco Elqui” en 1936 para legitimar su producción. La disputa por la denominación de origen se intensifica con investigaciones



que destacan la exportación histórica del pisco peruano a mercados como Guatemala y Chile. Aunque Chile desarrolló su propia industria, lexicógrafos chilenos del siglo XIX reconocen el origen peruano del pisco. El documento concluye que, más allá de la controversia, la investigación enriquece la historia y calidad de este destilado.

**Palabras clave:** Aguardiente, Chile, destilación, Perú, vino.

## INTRODUCTION

When the word history is mentioned, one might think of ancient books, monuments, or wise men recounting chronicles of the past. However, in its strictest sense, human history begins with the invention of writing, leaving everything that occurred before this event as prehistory. Though this may seem a simple starting point, it forms the foundation of this discipline: written language.

The Regulatory Council of Pisco (CRDO-PISCO) maintains that what is not written has not happened. Newspapers, magazines, legal documents, travelers' accounts, or love letters, all written records, serve as valuable historical sources, while oral traditions, poems, or tales only gain historical weight once transcribed. Based on this principle, this study compiles all available information on pisco up to the year 2024, including research from Chile, which continues to claim the origin of this renowned spirit.

### Vine Cultivation

To make brandy, one must first make wine, and to make wine, one must grow vines. Although logic suggests that the “blood of Christ” (wine) should have first been produced in New Spain and other earlier Spanish territories, the tropical climate and local pests prevented successful viticulture there. Thus, wine was mostly imported from the Old World until the conquest of Peru, as narrated by Father Joseph de Acosta in his *Natural and Moral History of the Indies* (1572–1587):

*“In the islands and on the mainland, neither wine nor grapes grow; in New Spain there are vines that bear grapes, but no wine is made from them. The reason must be that the grapes do not fully ripen due to the rains that come in July and August. Wine is brought from Spain or the Canary Islands; and so it is throughout the Indies, except in Peru and Chile, where there are vineyards, and very good wine is made.” (De Acosta, 1590)*

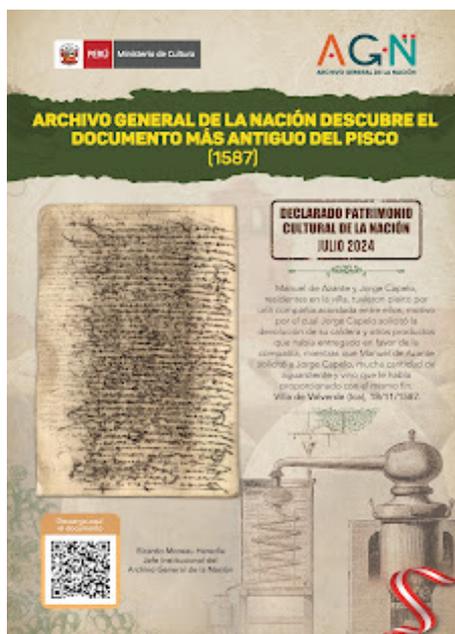
According to Acosta, both Peru and Chile were making wine by the late 16th century. But—in which country was it made first? Peru's proximity to the Equator would suggest a tropical climate similar to that of its northern neighbors. However, the cold waters of what would later be called the Humboldt Current created ideal conditions for vine cultivation and proper grape maturation in the central and southern regions of the Viceroyalty of Peru.

Guillermo Toro-Lira, in *Las Viñas de Lima* (2018), identifies Peru's, and therefore South America's, first wine as having been produced in 1539 by Hernando de Montenegro, who served as mayor of Lima (then Ciudad de los Reyes) on three occasions and is considered the father of South American viticulture. Consul Carlos Buller (2021) further notes that wine production likely emerged simultaneously in other Peruvian cities during that same period.

## Earliest Evidence of Distillation

The oldest known document referring to the distillation of brandy in Peru dates to November 18, 1587, in the town of Valverde (Ica). It records a dispute between Manuel de Azante and Jorge Capelo: Cape-

lo demanded the return of a copper still he had lent to their partnership, while Azante claimed repayment for large quantities of wine and brandy he had contributed for the same purpose.



**Figure 1.** Oldest evidence of distillation in Peru

Source: National Archives

Following this event, the document that for many years was considered the “birth certificate” of the Peruvian distilled spirit was the will of Pedro Manuel “El Griego,” dated April 30, 1613. In it, he lists the assets he bequeathed to his heirs:

*“...thirty burney jars full of brandy containing one hundred and seventy small jugs of brandy, plus one barrel full of the said brandy containing thirty jugs... also one large copper still for distilling brandy with its lid and spout, two pultayas—one through which the spout passes and another smaller one that is sound... plus seven empty burney and sangley jars...” (Huertas, 2008).*

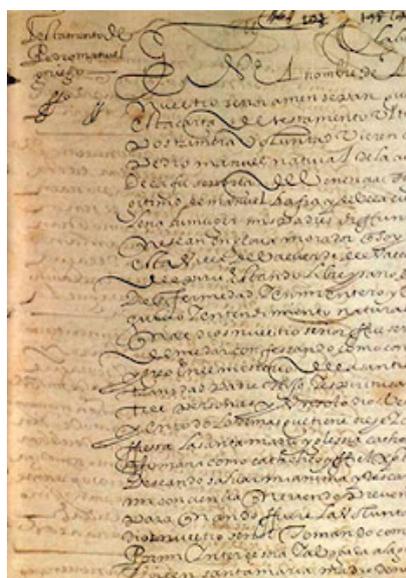
Although it may seem surprising, Chile possesses documentation of distillation that predates Peru’s, dating back to 1586 (Muñoz, 2014), with the will of María de Niza, a woman who, upon remarrying, drafted this document that mentions the presence of a “still for making brandy.” This device was likely used extensively by her first husband, who was a pharmacist, since at the time, brandy was primarily employed for medicinal purposes rather than recreational consumption.

This document is considered highly significant because, for many Chilean historians, it demonstrates the early presence of stills in the region, especially when compared to Peru, where references continue to

mention “brandy cauldrons” well into the 17th century. Based on this and other documents, the renowned table compiled by Pablo Lacoste was created, listing stills registered in Chile and Argentina since the 16th century, confirming that distillation was already a widespread practice.

However, one might still ask: Why doubt that the origins of distillation in the Americas began in Chile? While Peruvian discoveries are consistently supported by

photographs of original documents, freely available to the public, no trace of María de Niza’s supposed will has ever been found, despite repeated requests made to historians who have cited it. Although this absence does not prove falsification, it does raise questions about the alleged early presence of stills in South America, particularly since the word “alambique” (still) does not appear to have been in common use at the time.



**Figure 2.** Will of Pedro Manuel “El Griego”

Source: Chronology of Wine and Pisco Production

For instance, Diego de Santiago’s 1598 book on medicinal distillation, written after the supposed date of María de Niza’s will, does not use the term “alambique” even once in nearly 80 pages. Similarly, other works, such as “Notes on the History of Distillation” (Otero de la Gánara, 2006), in Chapter 7, titled “Evolution of the Still,” provide an important clarification on this subject.

Following this data, attention is given to the various types of stills, which, despite differences in form, maintain the same basic concept. These reflect advances in metal-shaping techniques, though it is

not possible to arrange them chronologically due to insufficient documentation. It can be said, however, that most of these innovations appeared between the late 18th and early 20th centuries (p. 107).

The appearance of stills in Chile thus seems earlier than in most parts of the world. Although Orujo from Galicia was already being consumed by 1521, the alquitara (a traditional distillation device) appears to have left no trace in any of the Spanish American viceroyalties. Interestingly, although Peru has been criticized for using “brandy cauldrons”, historically, that terminology seems the most accurate.

**Table 1.**  
*Stills Registered in Chile and Cuyo, 16th–19th Centuries*

<b>Jurisdiction</b>	<b>16th c</b>	<b>17th c</b>	<b>18th c</b>	<b>19th c</b>	<b>Total</b>
Coquimbo y Copiapó	-	5	39	3	47
Valle del Aconcagua y Valparaíso	-		10	28	38
Santiago	1	4	17	23	45
Colchagua	-	-	3	12	15
Maule y Concepción	-	1	14	3	18
Mendoza	-	4	14	29	47
San Juan		1	90	25	106
<b>Total</b>	<b>1</b>	<b>15</b>	<b>187</b>	<b>123</b>	<b>326</b>

Source: Lacoste *et al.*, 2016

### **Pisco: The Place**

Nicolás de Ribera “El Viejo”, one of Los Trece del Gallo and the first mayor of Lima, is credited with founding Sangallán in Pisco (Real Academia de la Historia, 2024). He even proposed the town as the capital of the future viceroyalty, a proposal dismissed by Pizarro in favor of Lima.

The Viceroy Francisco de Toledo later ordered the establishment of a town in Pisco under the title “Santiago de Caballeros”. A three-folio manuscript, dated July 13, 1571, and February 10, 1575, signed in Lima, serves as the earliest document referring to this settlement:

[Folio 1] “All of us who sign our names here will populate the town of Pisco that His Excellency commands to be established, making it in accordance with the articles so that it may have the intended effect for the growth and foundation of the town.” (Archivo General de las Indias)

For the native peoples, however, the area had long been known as Pisco, a name that predated even the Inca Empire, due to the abundance of birds inhabiting the region. This term also came to describe the local inhabitants, “the piscos.” One of the earliest proofs of this is Diego de Méndez’s 1584 map.

The Port of Pisco gave its name to the liquor not only because it was one of the main export ports of the viceroyalty, but also because of the clay jars, originally called *peruleras*, used to store it. Local potters influenced their renaming as *piscos*. To this day, one can hear in Ica the phrase:

“Dame pisco de Pisco en pisco” “Give me pisco from Pisco in a pisco jar,” referring simultaneously to the drink, its origin, and its container (Caballero, 2008).

It is well known that the city of Pisco Elqui in Chile is less than a century old (established in 1936). It was born from an

effort to give a topographical link to a product already marketed under the name pisco, associating it with a place, similar to the Peruvian spirit. But who initiated this? The answer lies in the Memoirs of former Chilean President Gabriel González Videla:

“When I was a congressman, I had to defend the importation of pisco into the United States, which was being contested by the Peruvian government, since it was a product exclusi-

vely from the Pisco region (Peru).

The claim was upheld but later suspended, because I, as a representative of that area, presented a bill, which was quickly approved, giving the name Pisco Elqui to a small town in that region called La Unión. And thus, Chilean pisco from Pisco Elqui gained free entry into the United States.” (Videla, 1975).

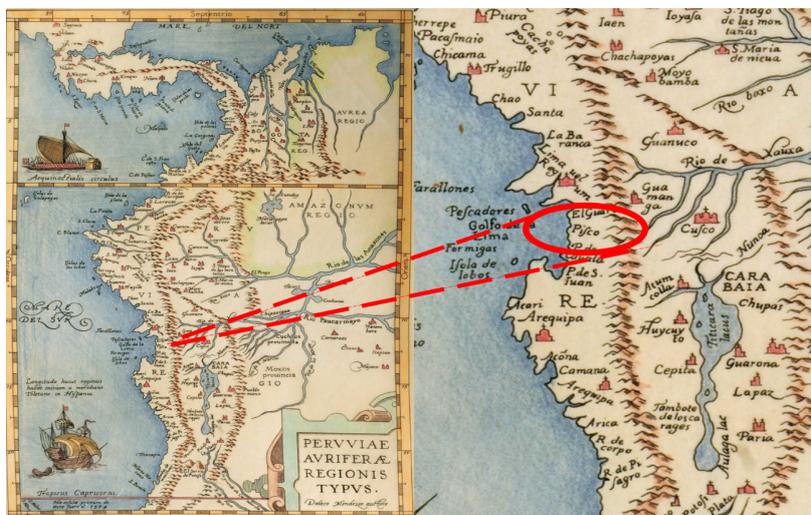


Figure 3. Peruviae Auriferæ Regionis Typus, Diego Méndez (1574)

Source: Wikipedia

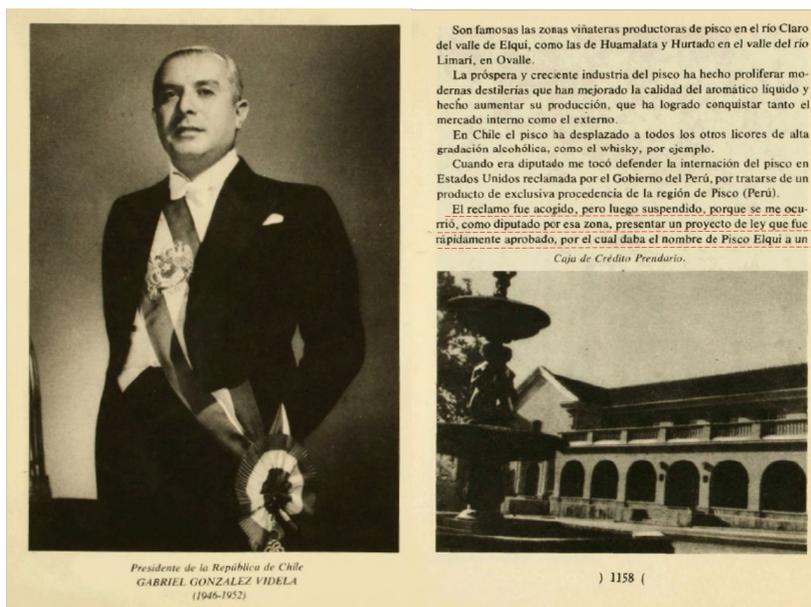


Figure 4. Photographs from the book Memorias de González Videla

Source: Memorias by González Videla

Although González Videla claimed this initiative was well received by the locals, there are also testimonies from residents who never accepted the name change, recognizing it as a commercial maneuver, downplaying the historical origin of the name La Unión

Naturally, I will never call La Unión by the name Pisco-Elqui, a sad idea by some Coquimbo resident who wanted to mock the lovely town. Someday we shall return its name, which refers to the meeting of the two rivers. I know that in some homes they danced and celebrated that foreign decree, and I was glad to hear it, but with a hint of bitterness. (Mistral, 2004)

On this specific point, there is no real debate about which location gave birth to the spirit. At one time, Neruda's countrymen argued that pisco took its name not from the place of production, but from the port of shipment, just as Porto wine takes its name from the city of Porto in Portugal, even though it is produced upriver in the Douro Valley. However, that analogy fails since the entire process, from harvest to export, occurs within the same country, unlike the case of pisco. This idea has thus been largely dismissed over time.

### **The Name “Pisco”**

The etymological, lexicographical, topographical, and cultural origins of the word pisco have been extensively studied by César Ángeles Caballero in his book *La Peruanidad del Pisco* (2008), written long before the modern controversy emerged. The debate, however, is not about the word's origin but when it was first used to refer specifically to the national spirit.

Historian Lorenzo Huertas suggests that during colonial times, “pisco” was a colloquial term used to describe what was legally defined as “aguardiente de vino de la región de Pisco.” This would explain the scarcity of formal legal documents referring to the beverage by that name.

For many years, the earliest known reference to the drink was attributed to William B. Stevenson, who, in 1814, wrote after visiting the port of Pisco: “The brandy generally called pisco, as it takes its name from the place where it is made, is of good flavor and colorless.” (Stevenson, 1972).

The historical silence of more than 200 years between the first signs of distillation and the first written record referring to the distilled beverage as pisco was broken by the discovery of the inventory of the La Torre estate in Chile, where one can clearly read, without needing a paleographer, the phrase: “por tres botijas de Pisco” (“for three jars of Pisco”). This discovery was initially celebrated in Chile, leading to an investigation that resulted in both a documentary and a book. Curiously, however, the document itself was not given much prominence, appearing only in the appendices (Lacoste, 2016).

It did not take long for the Peruvian ambassador to Brussels, Gonzalo Gutiérrez, to completely discredit Chile's “great discovery.” Upon examining the document, he noticed something that might easily escape most readers: a simple capital letter. The word Pisco was written with a capital “P,” which means it referred not to the beverage, but to its place of origin, Pisco, Peru. This interpretation is supported by another line in the same inventory that mentions “...por cinco cañones para sacar aguardiente...” (“...for five stills to produce

brandy...”). If they were supposedly producing pisco there, why would the equipment still be described as used for making aguardiente (brandy)?

Gutiérrez also pointed out that there were family and commercial ties between that estate and the Condor estate in the Pisco Valley (Peru), both belonging to relatives Francisco Cortés de Monroy and Pedro Cortés Monroy y Mendoza. This strongly suggests that the botijas de Pisco mentioned were jars from Pisco, Peru (Gutiérrez, as cited in Sánchez, 2018).

Years later, Gutiérrez presented further evidence showing that in Peru, “aguardiente de Pisco” was already being sold as early as 1726, effectively debunking the Chilean claim that the La Torre document was the oldest reference to the name. However, a new discovery in Chile shook the debate again: the 1717 inventory mentioning not three but twenty-five jars of pisco, this time written in lowercase. This seemed to dismiss the argument of a geographic reference.

This is where the expert eye of Consul Carlos Buller comes in to see beyond the obvious in the complete document and, of course, the first thing that stands out is that the inventory is from Alhué, an area near Santiago where this spirit does not appear to have been produced. This is confirmed by the fact that there is no other reference to production or distillation equipment.

Instead, the document repeatedly mentions “cordovanes peruleros” (Peruvian leather goods), that appear line after line on the only page that has been accessed, so it is very easy to deduce that this

inventory did not belong to a producer but to an importer of Peruvian products, among which pisco is obviously included (Buller, as cited in Gutiérrez 2021).

But the research did not stop there. In *Pisco: Its Name, Its History*, Gonzalo Gutiérrez presents an even older reference, this time linked to commercial exchanges between the Viceroyalty of Peru and the Captaincy General of Guatemala. Trade between these regions was relatively open until the early 17th century, when, on May 18, 1615, the importation of wines from Peru was explicitly prohibited in an attempt to maintain Spain's commercial monopoly with its colonies. This led to many complaints due to the inability to properly supply the Central American market, so a Royal Decree of May 21, 1685, allowed the entry of wines and other Peruvian products for a period of three years (with the possibility of extending the term), although with some restrictions.

These limitations meant that some Peruvian ships departing from Callao first arrived in Acapulco, and then were reloaded onto the same vessel to the Captaincy General of Guatemala. It was in this context that Juan de Recalde acquired the cargo of the ship called “Nuestra Señora de la Soledad” that arrived from Callao in 1712, and requested permission from the port authorities to depart from Acapulco to Guatemala. This request was approved on November 19, 1712, where he declared among all the products:

*“...A diez pesos por cada botija de aguardiente de pisco” (“...Ten pesos for each jar of pisco brandy”)* (Gutiérrez, 2021).



**Figure 5.** Register of the Frigate “Nuestra Señora de la Soledad”

Source: Pisco: Its Name, Its History, page 46

Obviously, this is not the only document in that publication; many more records throughout the 18th century would confirm that the place to look, if one wants to study the history of pisco, is in customs records, but the silence of exports between Guatemala and Peru for almost a century would make it very likely that the best option for finding that information would be in Chilean customs records, since the southern neighbor has always been a major consumer of the Peruvian spirit, even to this day, having competed in some years with the United States (Agrodata, 2024) for the top spot as its main importer. It should be noted that, given the protection of its designation of origin, the Peruvian spirit cannot enter under the name that has been usurped. However, what happened during the colonial period? Pablo Lacoste, author of *Pisco Was Born in Chile. Genesis of the First Designation of Origin in America* (2016), provides relevant information taken from customs guides, published in the article *Vines and Wine in South America: The Displacement of Wine-Producing Centers (16th to 20th centuries)*, in which he dedicates beautiful words to Peru, wine production, and brandy: However, it is on page 78 of the book that relevant information taken from customs guides is provided.

That is why they wrote down the entry of ‘so many bottles of brandy from the Pisco region’ over and over again, line after line, filling entire books with this data. With the repetition of the same words, abbreviations began to be used: little by little, ‘from the region of’ was eliminated and they began to write ‘so many bottles of Pisco brandy’; then the word ‘brandy’ was eliminated, and they began to write directly ‘so many bottles of Pisco’ (p. 78).

Lacoste explains how, little by little, it went from being called Pisco brandy to simply pisco, and this, although it was easy to deduce, needed to be put on paper in order to begin to be taken as true; unfortunately, this quote does not come with a year or a period of time, which raises the question that invites further investigation: Could it be that it was the Chileans who gave the Peruvian distillate the name pisco? And of course, what was slang for Lorenzo Huertas would not be so in Chile once the product passed through customs, and its use in legal documents would not be frowned upon as it would have been in Peru. It is worth noting that this does not make Chileans the owners of the name, nor does it take away the right of Peruvians to

use it. An example of this situation is the name sherry, which the English continue to use to refer to the famous wine from Jerez.”

That name comes from the ancient city of Sherish during the Arab occupation of the Iberian Peninsula, and after their expulsion, it changed to Jerez, but the English kept that name, and the Spaniards did nothing more than include it in their denomination of origin as the name of their product.

### Since when has Chilean pisco existed?

Lacoste (2004), in his article *The Vine and Wine in South America: The Shift of Viticultural Centers (16th to 20th Century)*, refers to the distillation of wine in the Elqui Valley, but never refers to these spirits as “pisco”; many Chilean lexicographic dictionaries reference the word pisco as a beverage originating in Peru:

- Rudolf Lenz Dazinger, better known as Rodolfo Lenz, was a German linguist, philologist, and folklorist naturalized as Chilean. In his “*Etymological Dictionary of Chilean Terms Derived from Indigenous American Languages*,” published in 1905, he writes: “...the current pisco was called *aguardiente de Pisco* because it came from there and from Ica. The province of Ica is fertile and rich in vineyards. The name of the city has become generic no less than Cognac, *coñac*.”

- Don Manuel Antonio Román was a priest, lexicographer, and Chilean language scholar who, in his work *Dictionary of Chileanisms and of Other Improper Words and Expressions*, written between 1901 and 1908, would say the following about the Peruvian spirit: “Pisco: a highly

esteemed brandy that is produced in Peru and known throughout the world. It undoubtedly originated in the port of Pisco, and that is why it took that name.”

- José Toribio Medina Zavala was a lawyer, bibliographer, researcher, historian, and Chilean collector, considered by many to be the greatest gatherer of sources for the study of his country’s history. In his work “*Chilenismos: Lexicographic Notes*” (1928), he wrote about Pisco: “from the town of Pisco in Peru. Brandy made from Muscat grapes from that place.”

In dates so close to the proclaimed first denomination of origin in the Americas (1931), most Chilean historians continued to affirm that pisco was a beverage originating in Peru, which is why many Peruvian authors mark the beginning of the era of southern pisco with the War of the Pacific. During that war, large-scale looting of wineries in southern Peru, and with it large volumes of the distillate crossing the border, may have inspired some producers to take advantage of the great fame that pisco had already achieved in international markets and begin to imitate it. One of the proofs of this is the *Bulletin of the War of the Pacific*, which publishes the reports of the military encounters between both countries and which, during Pinochet’s dictatorship, was republished to commemorate its centenary. In that bulletin, a small fragment stands out narrating the passage of the Chilean army through Ica:

“The brigade under the command of Colonel José Domingo Amunátegui departed on November 21 toward Ica with the objective of taking possession of that place (...) The city of Ica is a town of seven to

eight thousand inhabitants; it is surrounded by small farms dedicated especially to the cultivation of the vineyards that produce the famous Pisco.” (Chilean Academy of History, 1979).

In the report one reads “the famous Pisco”, without making any reference to it being produced in Chile or being similar to a Chilean version, which would confirm that by that time the historical Chilean distillate did not exist, and if it did, it is clear that it was still unknown to the general population.

The lifting of Prohibition in the United States was a major incentive to

“legalize” everything that was being done in the Elqui Valley, and Chile’s excellent wine industry became a powerful lever that allowed that distillate to enter international markets with great ease—using a name that had already gained fame centuries earlier: that of Peruvian Pisco.

Research on pisco must have multiplied fivefold over the last 30 years, which constitutes a major encouragement to continue exploring the history of Peru and, in particular, the distillate whose origin goes back to Pisco.

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# Aging, Free Radicals, and Antioxidants

## *Envejecimiento, radicales libres y antioxidantes*

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### ABSTRACT

The article presents aging as a multifactorial, progressive biological process shaped by intersecting theories, with special focus on oxidative stress and free radical involvement. The Free Radical Theory of Aging posits that reactive oxygen species (ROS), produced both endogenously and via environmental exposures, induce cumulative molecular damage to lipids, proteins, and DNA impacting cellular and tissue integrity. This oxidative stress contributes to age-related degenerative diseases such as cancer and Alzheimer's. Although antioxidants (both endogenous enzymes and exogenous dietary compounds) offer protective mechanisms against ROS, empirical evidence on their efficacy in extending lifespan remains inconclusive, largely due to bioavailability challenges and systemic complexity. The article also addresses mitochondrial dysfunction and genomic instability especially mitochondrial DNA mutations as key contributors to aging, proposing a dynamic interaction between genetic regulation, oxidative insults, and physiological decline. Experimental findings from animal models suggest associations between oxidative damage and aging phenotypes, though not always consistent across species. The authors advocate for a comprehensive approach that integrates molecular, genetic, and environmental perspectives, urging evidence based public health strategies to manage the rising aging population. In sum, aging is characterized as a heterogeneous, irreversible process not reducible to a single cause but rather to a complex network of biological mechanisms.

**Keywords:** Cellular damage, oxidative stress, homeostasis, longevity, lipid peroxidation.

### RESUMEN

En el artículo se examina el envejecimiento como un proceso biológico multifactorial, intrínseco y progresivo, vinculado a múltiples teorías complementarias. Se destaca el rol central de las especies reactivas de oxígeno (ROS), particularmente los radicales libres, como agentes prooxidantes que generan daño molecular acumulativo en lípidos,



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proteínas y ADN, promoviendo disfunción celular y organular. La teoría del estrés oxidativo, propuesta por Denham Harman, sugiere que el desequilibrio entre prooxidantes y antioxidantes conduce a la peroxidación lipídica, mutaciones somáticas y senescencia celular. Aunque se han investigado estrategias terapéuticas basadas en antioxidantes endógenos y exógenos (enzimáticos y no enzimáticos), los resultados *in vivo* sobre longevidad y prevención de enfermedades asociadas han sido inconsistentes, posiblemente debido a la baja biodisponibilidad y efectos pleiotrópicos. Se revisan teorías genéticas como la del “reloj biológico”, junto con la contribución mitocondrial al envejecimiento a través de la disfunción en la cadena de transporte de electrones y acumulación de daño en el ADNmt. El trabajo resalta la necesidad de un enfoque integrador que vincule modelos genéticos, moleculares y ambientales, así como la urgencia de establecer políticas de salud pública basadas en evidencia para abordar el aumento en la población adulta mayor.

**Palabras clave:** Daño celular, estrés oxidativo, homeostasis, longevidad, peroxidación lipídica.

## INTRODUCTION

When referring to old age, one addresses a controversial subject today, not only because of what it entails, given that there is no single explanation of the process, but also because the number of older adults increases every year, posing a challenge due to the social and economic implications of their treatment. Faced with these realities and influenced by them, a debate has emerged regarding whether old age should be considered an illness or not. This debate has intensified due to the World Health Organization's (WHO) proposal to update the International Statistical Classification of Diseases and Related Health Problems (ICD-11), in which, without convening expert gerontologists, it is proposed that beginning in 2022, in the chapter corresponding to “Symptoms, signs, and clinical findings,” the term senility and related terms that previously appeared and referred to pathologies be replaced with the term old age. This suggests a particular interest in emphasizing the pathological dimension

of aging and the management of treatments and medications.

It is important and useful for many health professionals to remain up to date on the different schools of thought and theories that address the aging process from various perspectives, each with its own logic (Free Radical Theory, Mutation Accumulation Theory, Wear-and-Tear Theory, Disposable Soma Theory, Oxidation–Inflammation Theory, Telomere Theory, Immunological Theory, Mitochondrial Theory, among others). This is essential in order to understand this multifactorial process and to influence the quality of life of older adults, often starting from numerous questions related to physical and social well-being (Bloom & Zucker, 2023). As populations age at an accelerated pace, it becomes increasingly necessary to consider health policies focused on preventing chronic diseases such as diabetes, obesity, and depression, among others. Furthermore, any such proposals must fall within the norma-

tive framework of each nation, supporting sound public policies grounded in scientific evidence.

The free radical theory gains importance every day in understanding aging, as it refers to and proposes the cumulative damage generated by reactive oxygen species (ROS), which gradually deteriorate the body's cells and tissues over time, causing the so-called oxidative stress, a condition associated with diseases such as cancer and Alzheimer's. Alongside other theories, the sum of harmful reactions caused by free radicals that continuously occur in cells and tissues is considered responsible for, or contributes significantly to, the aging process (Wickens, 2001).

## DEVELOPMENT

Old age will not be considered an illness by the authors, even though disabilities do appear in older adults associated with the loss of organic reserve and characteristic changes that emerge at different times and with varying intensities depending on individual variation. Such variation is related to one's prior lifestyle, predispositions to certain conditions, and the chronic diseases that often arise beginning in adulthood and accumulate with age (diabetes, rheumatism, arthritis, cardiac conditions, among others). In such cases, the older adult becomes a clinical patient according to the ailment they present, independent of the anatomical and physiological changes that manifest. Once susceptibility to illness increases, even under low-intensity stressors, it becomes important to recognize that anatomy and physiology must be understood as paired disciplines, each conditioning the other (Ribera-Casado & García, 2021; Miralles *et al.*, 2022).

A series of gradual changes beginning around age 55 exist that, at younger ages, could be considered diseases, but at this stage are associated with the aging process itself. These include:

- Changes in skin elasticity and appearance
- Changes in posture and gait
- Weakening of pulmonary function
- Weakening of immunological mechanisms
- Decrease in height
- Decrease in heart rate
- Decrease in muscle strength
- Decrease in memory
- Decrease in sensory functions (hearing, touch, taste, smell, and sight)
- Hardening of arterial walls
- Osteoporosis
- Loss of heat and cold adaptation
- Reduction in intestinal motility
- Reduction in total body water

Among others (Esmeraldas *et al.*, 2019; Bonnet-Zamponi, 2016)

There are several perspectives from the biological standpoint of old age. Davies (1992) proposed that biological aging manifests as a progressive decline in the organism's capacity to maintain homeostasis under physiological stress. This functional decline is associated with decreased cellular viability and increased individual susceptibility. From a biomedical perspective, Johnson (1999) defined the aging process as a condition in which the probability of dying, which increases over time, and the age of the organism coincide with the oc-

currence of phenotypic changes in all individuals.

These ideas have proven useful in distinguishing between the aging process itself and diseases associated with aging (Hoyl, 2016). Both perspectives agree that aging is universal, continuous, irreversible, intrinsic, heterogeneous, and lethal, affecting all living beings without exception, occurring continuously without pauses, and manifesting differently in each individual, thus granting each person a certain “uniqueness.” Aging occurs at the molecular, cellular, tissue, and organ levels.

The aging process has been and continues to be studied by many research groups and from different “angles,” all attempting to explain a process that is multifactorial in nature, an approach that is more rational and accurate (Alvarado & Salazar, 2014; Piña *et al.*, 2022; Rodríguez *et al.*, 2012). There are theories, models, and proposals that contribute valuable knowledge to the study of aging; however, none alone can fully explain the process, suggesting the need to consider them collectively and relate them to one another as complementary.

One interesting approach is the genetic one, which includes several branches:

- Gene regulation, referring to the imbalance of factors involved in the organism’s development and reproduction (Gladyshev, 2015).
- Modifications in gene expression, possibly caused by metabolism (Cutler, 1991).
- Genomic instability resulting from DNA alterations (Slagboom, 1989).

In summary, age is determined by genetic factors, and there is an “internal clock” that determines longevity (Goldstein & Cassidy, 2010). Another theory refers to

the accumulation of cellular damage over long periods that cannot be repaired due to the weakening of the DNA repair system, resulting in mutations accumulating in the mitochondria and nucleus, which later lead to abnormal proteins (Avendaño-Monsalve *et al.*, 2024).

### Free Radicals

Aging itself is a multifactorial process which, due to its complexity, has given rise to various theories related to stochastic processes, the accumulation of waste products, somatic mutations, homeostatic catastrophe, immunology, the finite replicative capacity of cells, development, genetics, and even free radicals (Quintero *et al.*, 2024). Some theories are more debated than others today, indicating that aging cannot be explained by a single theory, especially since each pertains to a different aspect or moment of the process. However, it is possible to discern that the genetic theory carries significant weight, as numerous genes and mutations are involved at every level. Matters related to free radicals in old age and degenerative diseases continue to be increasingly studied (Yang *et al.*, 2024).

The relationship among theories that identify the accumulation of damage, arising from mutations and metabolic waste, explains how irreparable damage accumulates over time, becoming present in nuclear and mitochondrial DNA and potentially leading to the synthesis of abnormal proteins (Zorrilla, 2002). A valid explanation for these errors in repair mechanisms and accumulated mutations is related to free radicals generated when oxygen is excessively converted into energy, disrupting the balance between oxidant and antioxidant production, known as oxidative stress. These radicals can even lead to cell death by reacting with other compounds present

in cells (Quintanar & Calderón, 2009; González, 1995).

Studies on free radicals, like those in other theories, evaluate the presence of mutations and unrepaired molecular-level damage that originates in the process of obtaining energy from oxygen, which produces free radicals. These radicals, within normal ranges, help eliminate toxins; however, if overproduced or accumulated, they become harmful, even causing cell death (oxidative stress) (Korovesis *et al.*, 2023; Hong *et al.*, 2024). Free radicals have the capacity to combine with DNA molecules and even with proteins, which they deactivate, forming part of their involvement in the aging process (González, 1995).

At the cellular level, aging is also considered a result of genetic programming in the development and maturation of cells, controlled at the DNA and RNA levels, which at the same time are targets of free radicals. These radicals can intervene within the cell and therefore interfere with the proper functioning of some organ (Hayflick, 1983). In many organs, it is not possible to replace the cells that die, resulting in a decrease in their number and consequently altering proper organ function. The appearance of aldehydes as a result of oxidation, anchored to collagen, leads to a loss of tissue flexibility and alterations in the exchange of substances between cells, in which collagen plays a fundamental role.

### What are free radicals?

Free radicals are atoms or groups of atoms that contain an unpaired electron, which makes them highly reactive as they attempt to capture an electron from other atoms in order to achieve stability. When this occurs, it is known as reduction, and the stable molecule that loses the electron (oxidation) becomes a new free radical that

will repeat the electron-capturing process. In this way, a chain reaction begins and, due to the lack of specific receptors, it occurs randomly, damaging any cell or tissue (Čolak, 2008; Venereo & Justo, 2002). These electron transfers occur through metal ions without the participation of enzymes. Various studies suggest that free radicals can also be generated by smoking habits, environmental pollution, radiation exposure, and indiscriminate use of medications, among others (Finkel & Holbrook, 2000).

### Since when do free radicals exist?

In 1900, free radicals were described by Gomberg, who observed the decomposition of hexaphenylethane into two triphenylmethyl radicals. Years later, Paneth and Hofeditz published the decomposition of lead tetramethyl into free radicals. In 1954, Gerschman proposed that superoxide anion radicals ( $O_2^-$ ) and hydroxyl radicals ( $OH\bullet$ ) were responsible for the molecular mechanism of oxygen and radiation toxicity. In 1956, Denham Harman, after gathering evidence, proposed the theory involving free radicals in aging, together with genetic and environmental predispositions (Hernández & McCord, 2007; Maldonado *et al.*, 2010).

The second era of free radicals began with the discovery of the enzyme superoxide dismutase (SOD) in 1969 by McCord and Fridovich, which opened the door to various hypotheses related to the antioxidant effects of free radicals on cells, their structures, and their products.

The third era of free radicals emerged ten years later, when evidence was presented on important biological effects involving the activation of guanylate cyclase (GC) by the OH derivative of the superoxide anion  $O_2^-$  (Bergendi *et al.*, 1999).

In 1985, the concept of oxidative stress was proposed, and from that point on, a field of study emerged regarding its involvement in different pathologies as well as its participation in beneficial health processes (Malonado, 2010; Mittal & Murad, 1977).

At the molecular level, free radicals are considered oxidizing agents because they contain one or more unpaired or free electrons, making them highly reactive as they try to achieve electrochemical stability by pairing with an electron from a stable molecule. When this occurs, the electron-donating molecule becomes a free radical with an unpaired electron, which will in turn seek to pair, thus initiating a damaging chain reaction of free radicals within fractions of seconds. They are considered related to aging and cellular damage, as they react with cellular structures and with the unsaturated fatty acids of phospholipid membranes, proteins, and DNA, modifying them and consequently altering their functions, which may explain the onset of certain pathologies such as cancer (Gutteridge & Halliwell, 1999; Okamoto *et al.*, 1996). In some cases, free radicals are considered part of the defense mechanisms against bacterial and viral infections (Finkel & Holbrook, 2000). Their origin may lie in human metabolism, but also in environmental pollutants—whether atmospheric, aquatic, or soil—and in radiation, alcohol consumption, tobacco, drugs, among others (Llancari & Matos, 2011).

The sum of harmful reactions of free radicals that continuously occur in cells and tissues constitutes, in itself, the aging process or contributes significantly to it. This was Denham Harman's interpretation of how aging develops, accompanied by degenerative processes such as cancer and immunosuppression (Johnson *et*

*al.*, 1886), which complements his “aging clock theory,” justified by mitochondrial disorganization that produces free radicals (Miquel, 2005).

The mitochondrial respiratory chain (or electron transport chain, ETC) is the main cellular source of reactive oxygen species (ROS), such as superoxide, which can be converted into H<sub>2</sub>O<sub>2</sub> by superoxide dismutases (SOD). The latter forms highly damaging hydroxyl radicals (OH•) through the Fenton reaction in the presence of transition metals such as iron or copper (Collin, 2019). The harmful effects of these radicals are mainly due to their lack of charge and their small size, which allows them to move among cellular structures, damaging proteins and membrane lipids, causing lipid peroxidation and DNA breaks.

A key experimental element for accumulated mtDNA damage as a cause of aging emerged from homozygous knock-in mice expressing an error-prone version of PolgA, the catalytic subunit of mitochondrial DNA polymerase. These mice exhibited an increase in somatic mtDNA mutations, reduced lifespan, and the premature onset of aging-related phenotypes (Pinto & Moraes, 2015). Consistent with these findings, an inverse correlation was observed between the degree of oxidative mtDNA damage in various mammalian species and their maximum lifespan. Although this theory is logical and highly popular—likely due to the apparent ease of intervention with antioxidants—more recent studies have questioned simplistic perspectives on a direct relationship between ROS, oxidative damage, and aging (Cui *et al.*, 2011).

There are also contradictory results that raise concerns about the topic across various species. First, the overexpression or knockout of antioxidant genes has not

always produced the expected results. For example: transgenic overexpression of Cu/Zn SOD in mice (76) and *C. elegans* did not increase lifespan (Pérez *et al.*, 2009). Conversely, worms completely lacking SOD activity have a normal lifespan (Labunskyy & Gladyshev, 2013). Homozygous mice deficient in cytoplasmic Cu/Zn SOD accumulate massive oxidative damage and have reduced lifespan, which may be due to increased sarcopenia and cancer incidence in advanced life stages (Ligibel *et al.*, 2020).

### **Antioxidants: Their Role**

Homeostasis generally allows the body to maintain functional balance in the short-, medium-, and long-term through various mechanisms. In the case of oxidation, there are different mechanisms depending on the type of free radicals and the sites where they act (Avello & Suwalsky, 2006).

Antioxidants refer to substances present in low concentrations, considering the amount of potential oxidizable substrates, which constitute a protective, defensive system. They inhibit or significantly delay oxidative reactions by interacting with oxygen-derived free radicals, sacrificing their own structure to prevent harmful alterations to molecules (lipids, proteins, DNA, among others) that would otherwise alter previously established cellular processes and functions. They contribute to maintaining the necessary balance between oxidants and antioxidants, in favor of the latter.

Antioxidants are classified according to different parameters depending on the interests of researchers. Based on their origin, they are classified as endogenous antioxidants, those produced by the human body as a defense mechanism to control the excessive formation of free radicals, and

exogenous antioxidants, those obtained from the diet, which may be natural (from fruits, vegetables, and meats) or synthetic (Mironczuk-Chodakowska *et al.*, 2018). Exogenous antioxidants are “consumed” when they oxidize upon neutralizing free radicals, and therefore must be constantly replenished through the diet.

Currently, antioxidant activity and free-radical-scavenging capacity are being intensely studied in plants with recognized medicinal activity. These studies are based on the preference for natural over synthetic products (Warjeet, 2012). In plants, phenolic compounds, flavonoids, vitamins C and E, and carotenoids have been described and used, all of which have recognized medicinal and now antioxidant activity (Aluyor & Oboh, 2014). Plant-derived compounds possess well-known and established antioxidant activity. Microorganisms must also be mentioned as efficient producers of metabolites with specific antioxidant potential (Singh *et al.*, 2019), recognized for their efficacy against fungal and bacterial infections (tetracyclines, amphotericin, penicillins, erythromycins, streptomycin, and vancomycin); against cancer (daunorubicin, bleomycin, mitomycin, and doxorubicin); in transplant rejection (rapamycin and cyclosporin); and in cholesterol control (mevastatin and lovastatin) (Demain, 2014).

To date, the consumption of antioxidants has not resulted in significant benefits related to *in vivo* longevity, possibly due to low bioavailability, considering that the most optimistic results came from *in vitro* experiments (Bjelakovic *et al.*, 2007; Biesalski *et al.*, 2010; Baguer & Menéndez-Álvarez, 2024) with doses considerably higher than those realistically consumable, meaning they do not reflect actual

effectiveness in living organisms. In studies applying high doses of antioxidants, some results have been discouraging, suggesting that not only bioavailability must be considered, but also other factors often overlooked. An example is Dr. Pauling's widely cited vitamin C supplementation (Pauling, 1971), which, even at low concentrations, can have a pro-oxidant effect in the presence of transition metals such as iron (Bast *et al.*, 1991).

### Lipid Peroxidation

It has been proposed that a major target of free radicals, due to their implications, is the cellular membrane, which contains lipids and proteins responsible for selective permeability into the cell and interactions with other cells. This structure is rich in polyunsaturated fatty acids, and when free radicals are present, a hydrogen (H) atom is extracted, producing a lipid radical that reacts with oxygen to form a lipid peroxy radical. This radical propagates, initiating a chain reaction among the fatty acids present, causing lipid peroxidation through this oxidative chain reaction (Kim *et al.*, 2012). An indicator of lipid peroxidation is the amount of malondialdehyde produced, which is stable and, at high levels, is associated with diseases such as cardiovascular disorders, cancer, and neurodegenerative conditions. It is also used as a marker in antioxidant therapies, where

its reduction indicates effective treatment (Goodsell, 2004). Evidence also exists regarding the involvement of oxidative stress mechanisms in Parkinson's disease (Avello & Suwalsky, 2006). This membrane-level damage can be avoided by means of stable complexes formed by antioxidants (Halliwell, 1990).

Just as with fatty acids, free radicals can interact with proteins, oxidizing them. When this occurs, peptide chains fragment, resulting in loss of enzymatic activity and degradation of structural proteins, ultimately leading to dysfunction and cell death (Chrzyszcz *et al.*, 2021; Rani *et al.*, 2021).

### CONCLUSIONS

Aging results from several factors involved in multiple theories, which together reveal that there is no single explanation—thus adding greater complexity to the process.

The constant production of free radicals constitutes a physiological process with important implications in cellular senescence and oncogenesis. Nevertheless, other theories and molecular processes must be considered, particularly those associated with mitochondrial signaling.

Antioxidants are gaining increasing prominence in research related to various pathologies and aging.

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- Menéndez-Álvarez, Eduardo: Conceptualization, methodology, writing.
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# Nutritional Status and Gastrointestinal Issues in School-Aged Children with Autism Spectrum Disorder

## *Perfil nutricional y alteraciones gastrointestinales en escolares con trastorno del espectro autista*

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### ABSTRACT

The relationship between gastrointestinal alterations and the characteristics of children with autism spectrum disorders highlights the importance of a nutritional approach in their multidisciplinary care. The objective of this research was to determine the relationship between nutritional profiles and gastrointestinal alterations. This descriptive, correlational, and cross-sectional study evaluated 55 school-aged children with autism. The nutritional profile was determined using the anthropometric indicator body mass index for age (BMI/age). The dietary assessment included a record of macronutrient, gluten, and casein intake. The clinical evaluation included signs of gastrointestinal alterations and malnutrition. Anthropometric results showed that 63.6% of the children were within the normal range, 1.8 % were underweight, and 34.5 % were overweight. The most frequent gastrointestinal alterations were foul-smelling flatulence, constipation, abdominal pain, and distension. No relationship was found between gastrointestinal alterations and anthropometric diagnosis or macronutrient intake. However, a statistically significant positive relationship ( $p < 0.01$ ) was found between gastrointestinal alterations and clinical signs of nutritional deficiencies, gluten consumption, and the degree of autism. Additionally, a positive trend was observed between gastrointestinal alterations and casein consumption. In conclusion, the consumption of gluten- and casein-containing foods directly affects gastrointestinal alterations and, in turn, the severity of autism in children. These findings underscore the need for early nutritional intervention as an effective strategy to improve symptoms associated with autism.

**Keywords:** Gluten, casein, gastrointestinal issues, autism, ASD.



## RESUMEN

La relación entre las alteraciones gastrointestinales y las características de los niños con trastornos del espectro autista resalta la importancia del abordaje nutricional en su atención multidisciplinaria. El objetivo de esta investigación fue determinar la relación entre el perfil nutricional y las alteraciones gastrointestinales. Este estudio descriptivo, correlacional y transversal evaluó a 55 niños escolares con autismo. El perfil nutricional se determinó a través del indicador antropométrico índice de masa corporal para la edad (IMC/edad), la evaluación dietética incluyó un registro de consumo de macronutrientes, gluten y caseína. La evaluación clínica incluyó los signos de alteraciones gastrointestinales y desnutrición, El 63,6 % de los niños se encontraron antropométricamente normales, 1,8 % en déficit y 34,5 % en exceso, las alteraciones gastrointestinales más frecuente fueron flatulencias fétidas, estreñimiento, dolor y distensión abdominal. No hubo relación entre las alteraciones gastrointestinales y el diagnóstico antropométrico ni el consumo de macronutrientes, sin embargo, se halló una relación positiva estadísticamente significativa ( $p < 0,01$ ) entre las alteraciones gastrointestinales y los signos clínicos de deficiencia nutricional, consumo de gluten y grado de autismo, además se encontró una tendencia positiva entre las alteraciones gastrointestinales y el consumo de caseína. En conclusión, el consumo de alimentos con gluten y caseína tienen un efecto directo en las alteraciones gastrointestinales y a su vez en el grado de severidad de los niños con autismo. Estos hallazgos subrayan la necesidad de una intervención nutricional temprana como estrategia eficaz para mejorar los síntomas asociados al autismo.

**Palabras Clave:** Gluten, caseína, manifestaciones gastrointestinales, autismo.

## INTRODUCTION

Autism spectrum disorder (ASD), also referred to as pervasive developmental disorders, comprises a group of conditions associated with neurodevelopment and feeding, with predominantly cognitive and behavioral manifestations that cause significant limitations in the autonomy of affected children (Ojeda *et al.*, 2013). These disorders typically appear in early childhood and tend to persist into adulthood, although in most cases they manifest within the first five years of life. They are also commonly characterized by comorbid conditions such as epilepsy, depression, anxiety, and attention deficit hyperactivity disorder (ADHD) (WHO, 2023).

According to the World Health Organization (WHO), one in every 100 chil-

dren is diagnosed with ASD. These figures represent an increase in the prevalence of this condition (WHO, 2023). Research has shown that the prevalence of ASD is alarming in many low-income countries. In this regard, in Latin America there are no studies that allow for an accurate understanding of the current situation of children with ASD; it is estimated that one in every 100 people presents some type of autism spectrum disorder. Likewise, in 2008 in Venezuela, the prevalence of individuals with ASD was 17 per 10,000 children aged 3 to 9 years (Montiel *et al.*, 2023).

The role of nutrition in children with ASD is a determining factor in their recovery, as an inadequate diet can cause chronic inflammation of the gastrointesti-

nal tract, from the esophagus to the colon, compromising the integrity of the intestinal wall, which plays an important role in adequate nutrient absorption. In most cases, these children suffer from indigestion and present significant gastrointestinal alterations as a result of consuming foods containing certain proteins whose structure, or parts thereof, are not fully digested and exhibit opioid properties, thereby affecting the nutritional status of these children (Higuera *et al.*, 2010).

This situation arises because children on the autism spectrum have a greater tendency to present metabolic errors due to enzymatic deficiencies that prevent proper protein breakdown and/or increased permeability of natural barriers. As a result, these external morphines (exorphins) cross the blood–brain barrier, affecting brain regions related to language development, communication, social relationships, and sensory alterations. These changes disrupt all processes involved in cognition and communication, in addition to causing an inadequate immune response, multiple food allergies, and micronutrient deficiencies (Higuera *et al.*, 2010; Audisio *et al.*, 2013; Carmenate *et al.*, 2023).

There is clear evidence of a relationship between nutritional profile and good health status in children with ASD. Research has shown that this situation worsens during the preschool, school-age, and adolescent stages, as these periods involve higher nutrient demands that support adequate physical, mental, and social health (Rodríguez, 2010).

For this reason, timely nutritional intervention is an effective approach to improving the characteristic symptoms of this disorder, yielding positive results such as reduced hyperactivity and gastrointesti-

nal problems, as well as improvements in language, attention, development, learning, eye contact, cognitive functioning, communication skills, and, consequently, social interaction (Audisio *et al.*, 2013).

Scientific evidence has demonstrated that nutritional factors play an important role in autism. Several studies specifically addressing treatment approaches (Audisio *et al.*, 2013; Carmenate *et al.*, 2023) indicate that nutritional intervention can be an alternative to medical treatments due to its demonstrated benefits on cognitive and behavioral development. Thus, it may be considered a potential solution in the future, without disregarding psychoeducational and language therapies to improve various aspects of social and academic development (Higuera *et al.*, 2010).

In this context, malnutrition (resulting from inadequate diet and lifestyle, whether due to excess or deficiency) further aggravates the condition. This is due to multiple factors, including food selectivity, lower physical activity, and medication use, which may lead to abnormal anthropometric measurements (Egan *et al.*, 2013).

Therefore, nutritional management is critically important within the multidisciplinary care of children with autism. Consequently, the objective of this study was to determine the relationship between nutritional profile and gastrointestinal alterations in children within the autism spectrum, with the aim of improving signs and symptoms and enhancing quality of life in this age group.

## MATERIALS AND METHODS

A descriptive, field-based, correlational, cross-sectional study was conducted (Hernández *et al.*, 2014) in a group of children with autism attending the Comprehen-

sive Care Centers for People with Autism (CAIPA and Albatros), located in the city of Maracaibo, Zulia State, Venezuela. Inclusion criteria were boys and girls diagnosed with ASD, attending one of the aforementioned centers, residing in Zulia State, aged 6 to 12 years, and enrolled in school. Children who did not meet these criteria were excluded.

### Population and Sample

The sample consisted of all children who attended their appointment with their legal guardians for nutritional evaluation: 55 children aged 6–12 years of both sexes. Given the characteristics of the study population, non-probabilistic (intentional) sampling was used (Hernández *et al.*, 2014). Epidemiological data collected included age, sex, anthropometric assessment, and dietary evaluation, provided by the legal guardians. Written informed consent was obtained from all parents or guardians. All procedures complied with the ethical standards of the Declaration of Helsinki and CIOMS.

### Measurement Instruments and Techniques

The diagnosis of ASD must be made by a specialized psychologist; therefore, all children evaluated in this study had been previously diagnosed. The nutritional profile of school-aged children with ASD was determined using the following indicators:

#### Anthropometric Assessment

Weight and height were measured, and the body mass index-for-age (BMI-for-age) indicator was calculated and compared with WHO reference standards. Excess weight was defined as  $> +1$  SD (standard deviation), normal as between  $+1$  SD and

$-2$  SD, and deficit as  $< -2$  SD (de Onis *et al.*, 2007).

#### Clinical–Gastrointestinal Assessment

Clinical-nutritional and gastroenterological evaluations were conducted by a nutritionist and a pediatric gastroenterologist. A physical-clinical examination was performed to identify gastrointestinal alterations, including diarrhea, constipation, vomiting, stools with undigested food, mucus and/or blood, foul-smelling flatulence, and abdominal pain, to determine the presence of gastrointestinal disorders in school-aged children with ASD.

Additionally, signs of nutritional deficiencies were assessed, such as glossitis, papillary atrophy, lingual hypersensitivity, gingival edema and bleeding, xerosis, cheilosis, dermatitis, hyperkeratosis, depigmentation, and hair loss, along with personal and family medical history.

#### Dietary Assessment

A 24-hour dietary recall was used to assess macronutrient intake. Parents were interviewed about the foods they typically consume during a day. The 24-hour dietary recall instrument consisted of the times at which meals were consumed, the foods eaten, and the quantities of each item. Data were recorded and analyzed using the Venezuelan Food Composition Table (National Institute of Nutrition, 2001). Macronutrient adequacy was calculated based on national dietary reference values (National Institute of Nutrition, 2000) using the formula:

$$\% \text{ Adequacy} = (\text{Daily intake} \times 100) / \text{Daily recommendation}$$

Adequacy was classified as deficient ( $<90\%$ ), normal ( $90\text{--}110\%$ ), or excessive ( $>110\%$ ) (Borno, 2005). After administering the 24-hour dietary recall, a food

frequency questionnaire was also administered to determine dietary patterns.

### Data Analysis

Results were analyzed using descriptive statistics, reporting means  $\pm$  standard error and ranges. Data distribution was assessed using the Shapiro–Wilk test, and the Mann–Whitney U test was applied for nonparametric distributions. Pearson’s correlation was used to assess associations between nutritional profile and gastrointestinal alterations. Statistical significance was set at  $p < 0.05$ , with analyses performed using SPSS version 20.0.

## RESULTS AND DISCUSSION

Increasing evidence highlights the impact of gastrointestinal alterations on the characteristics commonly observed in children with ASD. These alterations are associated with a high frequency of intestinal symptoms due to lesions in both the small and large intestine, as demonstrated by

endoscopic findings and alterations in the human microbiome. Scientific evidence supports nutritional intervention as an alternative to medical treatments due to its beneficial effects on cognitive and behavioral development. Accordingly, dietary, clinical, and anthropometric indicators were evaluated to relate gastrointestinal alterations to the nutritional profile of school-aged children with ASD (Higuera, 2010; Audisio *et al.*, 2013; Carmenate *et al.*, 2023; Rodríguez, 2010; González *et al.*, 2006; Luna *et al.*, 2016; Lovene *et al.*, 2017).

Table 1 shows the demographic characteristics of the children, with a mean age of  $8.20 \pm 2.48$  years, weight of  $27.96 \pm 14.34$  kg, height of  $127.28 \pm 20.92$  cm, arm circumference of  $17.48 \pm 3.62$  cm, hip circumference of  $66.96 \pm 11.39$  cm, waist circumference of  $59.36 \pm 8.76$  cm, and BMI of  $16.98 \pm 2.94$  kg/m<sup>2</sup>. No significant differences were observed between sexes ( $p > 0.05$ ).

**Table 1.**  
*Demographic and Anthropometric Characteristics of School-Aged Children with ASD*

	<b>Total n= 55</b>	<b>Female n= 13</b>	<b>Male n= 42</b>	<b>p</b>
Age (years)	8.20 $\pm$ 2.48	7.76 $\pm$ 2.04	8.54 $\pm$ 2.52	0.336
Weight (Kg)	27.96 $\pm$ 14.34	26.16 $\pm$ 9.68	30.06 $\pm$ 12.58	0.321
Height (cm)	127.28 $\pm$ 20.92	122.69 $\pm$ 15.51	127.43 $\pm$ 27.48	0.250
MUAC (cm)	17.48 $\pm$ 3.62	17.50 $\pm$ 3.46	17.92 $\pm$ 3.85	0.647
Hip circumference (cm)	66.96 $\pm$ 11.39	64.15 $\pm$ 7.52	67.54 $\pm$ 10.91	0.361
Waist circumference (cm)	59.36 $\pm$ 8.76	57.00 $\pm$ 6.89	59.66 $\pm$ 7.95	0.284
BMI (kg/mt <sup>2</sup> )	16.98 $\pm$ 2.94	16.80 $\pm$ 2.51	17.04 $\pm$ 3.08	0.921

SD = Standard deviation. MUAC = Mid-upper arm circumference. BMI = Body mass index. Mann–Whitney U test; \*significant difference at  $p \leq 0.05$ .

Table 2 presents anthropometric nutritional diagnoses: 1.8% undernutrition, 63.6% normal, and 34.5% overweight. When classified by gender, a higher incidence of malnutrition, both due to excess and deficiency, was found in males compared with females. The classification of ASD according to severity among school-aged children is presented, showing that 54.5% (n = 30) were classified as having mild autism, 32.7% (n = 18) as moderate autism, and 12.7% (n = 7) as severe autism, according to the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) (American Psychiatric Association, 2014).

These results are consistent with those reported in a study conducted in Nuevo León, Mexico, involving children aged 3 to 12 years with ASD, where 54% of the children had a normal anthropometric diagnosis, 27% were obese, 15% were overweight, and 4% were undernourished (Hernández et al., 2017). Similar findings

were observed in a study carried out in Paraguay, in which 10% of the children were classified as undernourished or at risk of undernutrition, 60% had a normal nutritional status, and 30% were overweight or obese (Ojeda et al., 2013).

The frequency of clinical signs of nutritional deficiencies, as well as gastrointestinal alterations, is shown in Table 3. It can be observed that 45.5% (n = 25) of school-aged children with ASD presented irritability, 40% (n = 22) presented pallor, with statistically significant differences between sexes, 34.5% (n = 19) presented apathy, and 36.4% (n = 20) presented dry hair. In addition, 23.6% (n = 13) presented xerosis, 23.6% (n = 13) ascites, 14.5% (n = 8) hair depigmentation, 12.7% (n = 7) spongy gums, 10.9% (n = 6) bleeding gums, 10.9% (n = 6) stomatitis, 10.9% (n = 6) hair loss, 3.6% (n = 2) dermatitis, and 3.6% (n = 2) cheilosis, with no statistically significant differences between sexes (p > 0.05).

**Table 2.**  
*Anthropometric Nutritional Diagnoses and Classification of ASD According to Severity Among School-Aged Children*

Anthropometric diagnosis (BMI/Age)	Total		Female		Male	
	n	%	n	%	n	%
Undernutrition	1	1.8	0	0.0	1	2.4
Normal Nutritional Status	35	63.6	10	76.9	25	59.5
Overweight	19	34.5	3	23.1	16	38.1
<b>ASD Classification</b>						
Mild	30	54.5	7	53.8	23	54.5
Moderate	18	32.7	5	38.5	13	32.7
Severe	7	12.7	1	7.7	6	12.7

Values are expressed as frequency (n) and percentage (%).

**Table 3.**  
*Clinical Assessment and Gastrointestinal Alterations*

Clinical assessment	Total		Female		Male		P
	n	%	n	%	n	%	
Apathy	19	34.5	4	30.8	15	35.7	0.743
Irritability	25	45.5	6	46.2	19	45.2	0.954
Stomatitis	6	10.9	2	15.4	4	9.5	0.554
Cheilosis	2	3.6	0	0.0	2	4.8	0.423
Dermatitis	2	3.6	0	0.0	2	4.8	0.423
Pallor	22	40.0	9	69.2	13	31.0	0.014*
Xerosis	13	23.6	1	7.7	12	28.6	0.122
Spongy gums	7	12.7	3	23.1	4	9.5	0.200
Bleeding gums	6	10.9	2	15.4	4	9.5	0.554
Hair depigmentation	8	14.5	2	15.4	6	14.3	0.922
Hair dryness	20	36.4	6	46.2	14	33.3	0.401
Hair loss	6	10.9	1	7.7	5	11.9	0.670
Ascitis	13	23.6	2	15.4	11	26.2	0.423
<b>Gastrointestinal alterations</b>							
Diarrhea	22	40.0	7	53.8	15	35.7	0.244
Stools with undigested food	21	38.2	5	38.5	16	38.1	0.981
Mucus in stools	12	21.8	5	38.5	7	16.7	0.096
Gas	26	47.3	4	30.8	22	52.4	0.173
Foul-smelling flatulence	39	70.9	9	69.2	30	71.4	0.879
Gas (belching)	20	36.4	7	53.8	13	31.0	0.134
Gastric ulcer	7	12.7	2	15.4	5	11.9	0.742
Intestinal dysbiosis	11	20.0	3	23.1	8	19.0	0.751
Gastroesophageal reflux (GERD)	9	16.4	0	0.0	9	21.4	0.068
Fungal infection	8	14.4	2	15.4	6	14.3	0.922
Constipation	32	58.2	9	69.2	23	54.8	0.355
Vomiting	10	10.2	2	15.4	8	19.0	0.765
Abdominal pain	30	54.5	8	61.5	22	52.4	0.562
Abdominal distension	31	56.4	6	16.2	25	59.5	0.396
Infection	18	32.7	5	38.5	13	31.0	0.614

\*Values are expressed as frequency (n) and percentage (%). Pearson's chi-square test; statistically significant difference at  $p \leq 0.05$ .

Nutrient deficiencies have been proposed as a causal factor in the manifestation of autism spectrum disorder (Adams *et al.*, 2011). In this regard, a study conducted by Adams *et al.* evaluated metabolic and nutritional deficiency indicators in children aged 5 to 16 years and concluded that there are statistically significant differences in nutritional and metabolic characteristics between neurotypical children and those with ASD, serving as biomarkers indicative of vitamin insufficiency and increased oxidative stress. This leads to reduced capacity for absorption, energy transport, sulfation, and detoxification. Likewise, several biomarker groups were significantly associated with autism severity, which may be related to the presence of gastrointestinal alterations.

Regarding gastrointestinal alterations, it was observed that 40% (n = 22) of the children presented some degree of diarrhea, 38.2% (n = 21) stools with poorly digested food, 21.8% (n = 12) stools with mucus, 47.3% (n = 26) gas, 70.9% (n = 39) foul-smelling flatulence, 36.4% (n = 20) gas (belching), 12.7% (n = 7) gastric ulcer, and 20% (n = 11) intestinal dysbiosis.

Additionally, gastroesophageal reflux disease (GERD) was reported in 16.4% (n = 9), fungal infection in 14.4% (n = 8), constipation in 58.2% (n = 32), vomiting in 10.2% (n = 10), abdominal pain in 54.5% (n = 30), abdominal distension in 56.4% (n = 31), and parasitic infection in 32.7% (n = 18), with no statistically significant differences between sexes ( $p > 0.05$ ). These results are consistent with those reported in a study conducted in 51 children with autism aged 3 to 15 years, which found that 63% of children with autism had moderate to severe chronic diarrhea and/or constipation, demonstrating that gastrointestinal symp-

toms are common in autism (Adams *et al.*, 2011).

These findings play a fundamental role, as these gastrointestinal alterations allow the absorption of potentially harmful toxins, bacteria, allergens, and food-derived peptides, due to alterations in the intestinal microbiota known as dysbiosis (Luna *et al.*, 2016; Lovene *et al.*, 2017). This condition is characterized by abnormal growth of Gram-negative aerobic bacteria, *Helicobacter pylori*, flagellates such as *Giardia lamblia*, overgrowth of fungi and yeasts of the genus *Candida* (Audisio *et al.*, 2013; Rodríguez, 2010; Lovene *et al.*, 2017; CANIA, 2009), anaerobic bacteria such as *Clostridium difficile*, and pro-inflammatory bacteria such as *Sutterella* sp., leading to increased levels of intestinal inflammation markers such as calprotectin, lactoferrin, eosinophil-derived enterotoxin, and Anti-ASCA antibodies (Montiel *et al.*, 2017).

These alterations are also associated with a deficiency in one or more disaccharidase enzymes (Williams *et al.*, 2011; Kushak *et al.*, 2017), especially lactase and maltase, which prevents the adequate breakdown of carbohydrates and/or leads to increased permeability of natural barriers due to altered zonulin levels (Esnafoglu, 2017). When this occurs, the passage of substances into the systemic circulation can produce the behavioral abnormalities described in autism, such as impairments in language development, communication, social relationships, and sensory processing, which affect the functioning of all processes involved in cognition and communication, in addition to an inadequate immune response and multiple food allergies (Higuera, 2010; Carmenate *et al.*, 2023; Knivsberg *et al.*, 2001; Johnson *et al.*, 2007; Adams *et al.*, 2018).

When considering the energy and nutrient recommendations for the Venezuelan population, the average usual energy intake of children with ASD was found to be normal, at 118.85% ( $2,152 \pm 567.80$  kcal/day), with no statistically significant differences between sexes ( $p < 0.051$ ). Likewise, the remaining macronutrients showed a similar pattern, with adequate intake of proteins, fats, and carbohydrates being the most prevalent dietary diagnosis among children with ASD, with no differences between sexes. Similar results were reported in a study conducted in Argentina, which found an average caloric intake of 2,051 kcal with a mean adequacy percentage of 104%. In addition, an average protein intake of 85.27 g was reported, highlighting that the entire sample consumed protein levels above the recommended requirement (Audisio *et al.*, 2013). Similarly, no relationship was found between macronutrient intake and gastrointestinal alterations.

Based on the aforementioned results and given that several authors have associated the consumption of gluten and casein with the occurrence of gastrointestinal alterations, the intake of these components was evaluated in this group. It was reported that the children included these foods in their diet. Foods such as whole milk, soft white cheese, bread, pasta, cookies, and cakes exceeded 80% inclusion in the diet, which is similar to findings reported in Paraguay, where 94% of the children evaluated consumed cow's milk or its derivatives and 74% consumed foods containing gluten (Ojeda *et al.*, 2013). Furthermore, when assessing gluten and casein intake, it was observed that the average consumption of these proteins was higher in boys than in girls, with statistically significant differences in the case of gluten consumption (Table 4).

**Table 4.**  
*Energy and Nutrient Intake and Percentage of Adequacy in Children with ASD*

	<b>Total</b>	<b>Female</b>	<b>Male</b>	<b>p</b>
Calorie intake (kcal)	2152 ± 567.80	1880 ± 515.10	2236 ± 562.35	0.051
Calorie adequacy (%)	118.85 ± 31.80	113.28 ± 28.74	120.57 ± 32.82	0.782
Protein intake (g)	78.26 ± 22.01	72.01 ± 19.11	80.21 ± 22.70	0.255
Protein adequacy (%)	116.19 ± 36.31	118.73 ± 43.54	115.40 ± 34.33	0.968
Fat intake (g)	64.07 ± 34.88	55.36 ± 39.36	66.76 ± 33.42	0.201
Fat adequacy (%)	103.95 ± 51.66	96.90 ± 62.52	106.13 ± 48.48	0.342
CHO intake (g)	330.07 ± 100.06	284.80 ± 80.02	344.09 ± 102.29	0.067
CHO adequacy (%)	133.30 ± 44.40	125.38 ± 38.36	135.75 ± 46.26	0.513
Gluten intake (g)	16.12 ± 15.42	8.61 ± 11.24	18.44 ± 15.91	0.044*
Casein intake (g)	18.78 ± 12.43	13.98 ± 13.03	20.27 ± 12.00	0.111

CHO = carbohydrates. Mann-Whitney U test; \*statistically significant difference at  $p \leq 0.05$ .

The relationship between nutritional profile and gastrointestinal alterations (GIA) in children with ASD is shown in Table 5. To evaluate the nutritional profile, each indicator was analyzed separately. From the anthropometric perspective, no relationship was found between anthropometric diagnosis and gastrointestinal alterations in children with ASD ( $r = -0.103$ ,  $p = 0.455$ ).

Following this line of reasoning, a statistically significant positive correlation was found between clinical nutritional signs and gastrointestinal alterations ( $r = 0.636$ ,  $p = 0.000$ ), indicating that greater gastrointestinal alterations are associated with a higher number of clinical signs of nutritional deficiency. However, when correlating dietary assessment with gastrointestinal alterations, no relationship was observed between average macronutrient intake and gastrointestinal alterations (calories  $p = 0.354$ , proteins  $p = 0.186$ , fats  $p = 0.151$ , CHO  $p = 0.176$ ). Likewise, no relationship was observed between macronutrient adequacy and GIA (calories  $p = 0.863$ , proteins  $p = 0.761$ , fats  $p = 0.176$ , CHO  $p = 0.456$ ).

Based on the above results and on scientific evidence regarding the influence of foods containing proteins such as gluten and casein on the occurrence of gastrointestinal alterations in children with ASD (Carmenate *et al.*, 2023; Knivsberg *et al.*, 2001; Johnson *et al.*, 2007; Adams *et al.*, 2018), gluten and casein intake were analyzed in relation to gastrointestinal alterations. Although the amounts of gluten and casein were not high, a statistically significant positive correlation was found between gluten intake and GIA ( $r = 0.369$ ,  $p = 0.006$ ), while casein intake showed a positive trend ( $r = 0.225$ ,  $p = 0.099$ ). This indicates that

higher consumption of these proteins is associated with greater gastrointestinal alterations in this group, and that high intake is not necessary to observe gastrointestinal symptoms in individuals with ASD.

These findings are consistent with those reported by Adams *et al.* (2011), who found that gastrointestinal alterations are related to gluten and casein consumption and are strongly correlated with autism severity ( $r = 0.59$ ,  $p < 0.001$ ). This agrees with the results of the present study, which showed a statistically significant positive relationship between autism severity and gastrointestinal alterations ( $r = 0.648$ ,  $p = 0.000$ ). Multiple studies (Audisio *et al.*, 2013; Adams *et al.*, 2011; Adams *et al.*, 2018) support the role of a gluten- and casein-free diet as a treatment to improve gastrointestinal alterations and ASD-related behaviors. For example, Hernández *et al.* (2017) concluded that nutritional intervention with a gluten- and casein-free diet (mainly excluding bread, yogurt, and milk) was associated with a reduction in gastrointestinal signs and symptoms related to intestinal permeability, improving nutrient absorption.

Similarly, a randomized controlled study evaluated the effect of a gluten- and casein-free diet on behavior in 20 children with ASD aged 4 to 11 years, of whom 10 followed the diet and 10 served as controls. The results showed a reduction in autism-related behaviors in the diet group (Adams *et al.*, 2011). Likewise, a study conducted in Arizona in 2018 evaluated the effect of a gluten-, casein-, and soy-free diet and found a significant improvement in nonverbal intellectual ability in the treatment group compared with the untreated group. This suggests that comprehensive nutritional and dietary intervention is effective.

tive in improving nutritional status, IQ, autism symptoms, and other symptoms in most individuals with ASD. Additionally, the reappearance of ASD-related traits after discontinuation of the diet has been reported (Knivsberg *et al.*, 2001; Adams *et al.*, 2018).

**Table 5.**  
*Pearson Correlation Analysis Between Nutritional Profile and Gastrointestinal Alterations in Children with ASD*

	Gastrointestinal Alterations	
	r	p
Anthropometric diagnosis	-0.103	0.455
Clinical signs	0.636	0.000*
Calories consumed	0.127	0.354
Proteins consumed	0.181	0.186
Fats consumed	0.196	0.151
CHO consumed	-0.014	0.176
Calorie adequacy	0.024	0.863
Protein adequacy	0.042	0.761
Fat adequacy	0.185	0.176
CHO adequacy	-0.103	0.456
Gluten intake	0.369	0.006*
Casein intake	0.225	0.099
ASD severity	0.648	0.000*

\*Correlation is significant at  $p \leq 0.01$ . r = Pearson correlation coefficient.

## CONCLUSIONS

This study shows that specific evaluation of the intake of certain foods, particularly those rich in gluten and casein, has a direct effect on gastrointestinal alterations in children with ASD. Due to underlying metabolic abnormalities, these alterations are associated with increased hyperactivity, behavioral changes, and impaired absorption of essential nutrients, leading to the

appearance of clinical signs of nutritional deficiency. Therefore, early nutritional intervention represents an effective approach to improve the characteristic symptoms of this clinical condition, serving as a central component of biomedical treatments and evidence-based nutrition aimed at problem-solving-oriented nutritional care.

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- María G. García-Valecillo: Writing; review and editing.
- Diego J. Romero-Hernández: Conceptualization; Writing; Methodology; Statistical analysis; review and editing.
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# Food Security and Child Food Poverty in Peru: Analysis for Public Policy Design Toward 2030

## *Seguridad alimentaria y pobreza alimentaria infantil en Perú: Análisis para el diseño de políticas públicas hacia el 2030*

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### ABSTRACT

Food security is one of the most pressing challenges of the 21st century, particularly with regard to the child population. This article analyzes the situation of food security and child food poverty at the global, regional, and national levels, with an emphasis on the Peruvian case. Through a review of current data, it examines the prevalence of food insecurity, which affected 51% of Peruvian households in 2021, and its evolution through 2023. The data reveal that globally, 181 million children under five years of age live in conditions of severe food poverty, while in Peru, 56.5% of households with children under five experience food insecurity. The analysis identifies three key structural factors: poor food environments, inadequate feeding practices in early childhood, and low income levels. The findings show that more than 54% of children living in severe food poverty belong to middle- or high-income households, indicating that the problem goes beyond traditional economic barriers. Specific recommendations are proposed for consideration in the implementation of Peruvian public policies aligned with the 2030 Agenda, including the transformation of food systems, strengthening of health systems, activation of social protection mechanisms, and improvement of data systems to achieve continuous monitoring.

**Keywords:** Food insecurity, child food poverty, early childhood.

### RESUMEN

La seguridad alimentaria constituye uno de los desafíos más apremiantes del siglo XXI, especialmente en lo que respecta a la población infantil. Este artículo analiza la situación de la seguridad alimentaria y la pobreza alimentaria infantil a nivel global, regional y nacional, con énfasis en el caso peruano. A través de una revisión de datos actuales, se examina la prevalencia de la inseguridad alimentaria que afectó al 51 % de los hogares peruanos en el 2021 y su evolución hasta el 2023. Los datos revelan que globalmente 181



millones de niños menores de cinco años viven en situación de pobreza alimentaria grave, mientras que en Perú el 56,5 % de hogares con presencia de niños menores de 5 años presenta inseguridad alimentaria. El análisis identifica tres factores estructurales clave: entornos alimentarios precarios, malas prácticas alimentarias en la primera infancia y bajos niveles de ingresos. Los hallazgos demuestran que más del 54 % de los niños en pobreza alimentaria grave pertenecen a hogares de clase media o alta, indicando que el problema trasciende las barreras económicas tradicionales. Se proponen recomendaciones específicas para tomar en cuenta en la implementación de las políticas públicas peruanas orientadas a la Agenda 2030, incluyendo la transformación de sistemas alimentarios, el fortalecimiento de los sistemas de salud, la activación de mecanismos de protección social y la mejora de los sistemas de datos para lograr un monitoreo continuo.

**Palabras clave:** Inseguridad alimentaria, pobreza infantil, primera infancia.

## INTRODUCTION

Food security and child food poverty are complex and multifactorial problems that affect millions of people worldwide, with direct implications for human development, health, and social well-being. In the Peruvian context, these challenges have intensified in recent years due to a combination of structural, economic, social, and environmental factors that affect the country's regions in different ways.

This article provides a comprehensive analysis of the situation of food security and child food poverty in Peru, identifying underlying causes, contextual factors that intensify the problem, and selected international experiences that offer valuable lessons. Based on this analysis, specific recommendations are proposed for the design and implementation of sustainable public policies aimed at guaranteeing the right to adequate food by 2030.

Food insecurity is not limited to a lack of food, but also involves restricted access to diverse and nutritious diets that meet the specific requirements of early childhood. This phenomenon has profound consequences for children's physical and cognitive development and perpetuates intergenerational cycles of poverty and ex-

clusion. Therefore, understanding its multiple dimensions is essential for formulating effective interventions tailored to Peru's cultural, geographic, and socioeconomic characteristics.

Likewise, the situation of child food poverty is exacerbated by deep inequalities between urban and rural areas, as well as by gaps in access to basic health, education, and social protection services. The analysis of these factors shows that there is no single cause of the problem, but rather a complex web of determinants that require intersectoral and coordinated solutions. The complexity of the issue demands moving beyond fragmented or isolated approaches toward comprehensive and sustainable policies.

Finally, it is important to emphasize that fulfilling the 2030 Agenda and achieving Sustainable Development Goal 2: Zero Hunger (SDG 2) require concrete and sustained commitments from the State, civil society, and the private sector. International experiences have shown that it is possible to significantly reduce child food poverty through the implementation of strategies adapted to the Peruvian reality, ensuring the right to adequate food for all children in Peru.

## DEVELOPMENT

### Food Security

Food security, according to the definition established by the Food and Agriculture Organization of the United Nations (FAO), exists “when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their daily energy needs and food preferences for an active and healthy life” (FAO, 2024). This multidimensional concept is based on four fundamental pillars that interact in complex ways to determine the nutritional status of populations.

Food availability constitutes the first pillar and refers to the quantity of food available at the national, regional, and local levels. This dimension is related to having an adequate food supply to meet population requirements and depends on local, regional, and national production or food imports (FAO, 2024). As noted by Peru’s Ministry of Development and Social Inclusion (MIDIS), determining factors include the productive structure (fishing, agriculture, industry), marketing and distribution systems, productive resources (land, credit, water, technology, human resources), ecosystem conditions (climate, biodiversity), production and trade policies, and sociopolitical conflict (MIDIS, 2024).

Access to food represents the second pillar and refers to households’ ability to obtain food in sufficient quantity and quality to meet nutritional needs. Access can be achieved through direct purchase, social assistance, donations, or self-production (MIDIS, 2024). The main determinants of access include income level and distribution, food prices, primary production, and the coverage of food-related assistance programs (FAO, 2024).

Food utilization constitutes the third pillar and refers to the ability to effectively use the nutritional potential of consumed foods. This dimension depends on factors such as culture, the level of food and nutrition education, and access to basic goods and services for food preparation. Effective utilization requires appropriate food storage, processing, and preparation practices, as well as access to clean water and adequate fuel (MIDIS, 2024).

Finally, stability represents the fourth pillar and refers to consistent and reliable access to sufficient, safe, and nutritious food over time. This dimension includes factors such as stable food production, efficient distribution systems, sustained access to markets, and the capacity to withstand and recover from crises that may threaten food availability and access.

### Child Food Poverty

Child food poverty, according to the United Nations Children’s Fund (UNICEF), is defined as “the inability of children to access and consume a nutritious and diverse diet in early childhood, that is, during the first five years of life” (UNICEF, 2023). This condition is characterized by the lack of access to a diverse diet that includes at least five of the eight essential food groups necessary for healthy development.

The eight food groups required to achieve minimum dietary diversity include: breast milk, dairy products, meat and fish, eggs, legumes and nuts, vitamin A-rich fruits and vegetables, other fruits and vegetables, and cereals, roots, and tubers. Children who consume only zero to two food groups per day are considered to be in

severe food poverty, while those who consume three or four food groups per day are considered to be in moderate food poverty (UNICEF, 2024).

The measurement of child food poverty uses the minimum dietary diversity indicator developed by UNICEF and the World Health Organization (WHO). This indicator assesses dietary diversity among children aged 6 to 23 months and extrapolates these data to the population under 5 years of age. The basis of this measurement is that dietary diversity is associated with micronutrient adequacy and is a reliable indicator of diet quality in early childhood.

The consequences of child food poverty are profound and multidimensional. In the short term, it increases the risk of infectious diseases, micronutrient deficiencies, and even child mortality. In the long term, it compromises physical development, reduces school performance, and severely limits economic opportunities in adulthood, perpetuating an intergenerational cycle of poverty (UNICEF, 2023).

## Global Overview

The global situation of food security presents an alarming picture that has deteriorated significantly in recent decades. According to the report *The State of Food Security and Nutrition in the World (SOFI 2023)*, moderate or severe food insecurity affected between 1.5 and 2.0 billion people worldwide prior to the pandemic. In 2020, the first year of the COVID-19 pandemic, an estimated 29.4% of the global population (2.307 billion people) experienced food insecurity, a figure that remained around 29.6% in 2021 and 2022.

In terms of undernourishment or hunger, the situation worsened considerably after the pandemic, increasing from

621.8 million people suffering from hunger in 2019 to more than 700 million in subsequent years, with an estimated 733 million people affected in 2023, nearly 10% of the world's population (WHO, 2023), a level similar to that observed in 2008 and 2009. This trend indicates that the goal of eradicating hunger by 2030 (SDG 2) appears increasingly unattainable, with projections estimating that around 600 million people will still suffer from hunger by that date.

In the specific context of child food poverty, UNICEF data reveal that globally 181 million children under the age of five (27% of the world's early childhood population) live in severe food poverty, with no significant change since 2020. This crisis disproportionately affects South Asia and Sub-Saharan Africa, which together account for more than two-thirds (68%) of affected children. In Somalia, 63% of children suffer from severe food poverty as a result of droughts and floods, while in the Gaza Strip, 90% of children survive on only two food groups per day (UNICEF, 2023).

A particularly revealing finding is that more than half (54%) of children suffering from severe food poverty belong to middle- or high-income households. This evidence shows that the problem does not stem exclusively from income shortages, but also from factors such as nutritional misinformation, inadequate cultural practices, and easy access to unhealthy foods.

## Panorama in Latin America

Latin America presents significant particularities in terms of food security. By 2022, it was estimated that 36.4% of the population of South America was exposed to moderate or severe food insecurity, while 12.7% faced severe food insecurity. It is important to note that most countries

**Table 1.**  
*Relevant Factors That Impacted Progress or Setbacks in Food Security*

<b>Factor</b>	<b>Impact: Progress / Setback</b>	<b>Scenario</b>
Integrated interventions	Progress: 50% reduction in child food poverty in Burkina Faso.	Programs combining agriculture, health, and social protection.
Climate crises	Setback: Crop losses.	Droughts in Somalia (63% of the population affected).
Armed conflicts	Setback: Collapse of food systems.	Gaza: 90% of children with insufficient diets.
Poor-quality diets	Setback: Obesity and undernutrition	East Asia: 45% of children experiencing food poverty due to excessive sugar and salt intake.

Source: UNICEF. (2024).

in the region do not have systematic measurements of food insecurity and therefore rely on estimates produced by international organizations.

Regional comparisons reveal substantial disparities among South American countries. Uruguay shows the lowest estimated prevalence at 15.2%, followed by Chile at 18.1%, Paraguay at 25.9%, Colombia at 30%, Brazil at 32.8%, Argentina at 36.9%, and Ecuador at 37.3%. In absolute terms, Brazil exceeds all other countries in the region, with an estimated 70.3 million people experiencing food insecurity, followed by Peru with approximately 16.9 million affected individuals (FAO, 2023).

The region has faced additional challenges arising from the COVID-19 pandemic, geopolitical conflicts, and economic crises. According to the World Bank, the pandemic led to a significant increase in informal employment and a reduction in working hours, with direct effects on declining labor income. The percentage of households experiencing food insecurity

in Latin America and the Caribbean nearly doubled, rising from 12.8% in 2020 to 23.9% in 2021 (World Bank, 2021).

## **Analysis of the Situation in Peru**

### **a) Evolution of Food Insecurity**

Peru presents the most critical case of food insecurity in South America, according to the results of the study Emergency Food Security Assessment (ESAE) 2021 (MIDIS, 2023). The findings revealed that moderate or severe food insecurity affected 51% of Peruvian households, representing the highest estimated prevalence in the region.

This first measurement coincided with the second year of the COVID-19 pandemic, a period characterized by significant increases in the prices of basic food items, low labor demand due to the economic effects of the pandemic, and restrictive mobility measures that caused massive job losses, particularly in the informal sector.

The results of the ESAE 2023 show some evolution in the situation, although

specific prevalence figures are not fully detailed in the available documentation. However, it was identified that 56.5% of households with children under five years of age experience food insecurity, a particularly alarming figure for the most vulnerable population group.

### **b) Contextual Factors That Worsened the Situation**

The post-pandemic period in Peru was characterized by improved economic performance, with growth of 2.7% in 2022 compared to the previous year. However, monetary poverty remained high, affecting 27.5% of Peruvians in 2022, while inflation reached its highest level in the past 26 years at 8.6%.

Additionally, the country faced multiple simultaneous crises that exacerbated food insecurity. Social protests (with more than one thousand collective protests recorded in early 2023), political instability evidenced by eight changes in leadership at the Ministry of Agrarian Development and Irrigation during 2022, and adverse climatic events such as the worst drought recorded in 50 years, frost, high input costs, and fertilizer shortages significantly affected agricultural production.

The international context also negatively impacted Peru's situation. The conflict between Ukraine and Russia led to increases in the prices of oil, grains, wheat, and cereals, influencing higher transportation and food prices. Particularly relevant was the fact that 80% of fertilizers were imported from Russia, with urea being the most widely used; its imports declined by 84% during the first quarter of 2022 (MIDIS, 2023).

### **c) Demographic and Geographic Characteristics**

The analysis of food insecurity in Peru reveals significant disparities based on demographic and geographic characteristics. At the geographic level, differences among natural regions (coast, highlands, and jungle) and between urban and rural areas show distinct patterns that require differentiated interventions.

The methodology used in ESAE 2023 applied the Consolidated Approach for Reporting Indicators of Food Security (CARI) of the World Food Programme (WFP), which evaluates three main indicators: food consumption, economic vulnerability, and livelihood coping strategies. This methodology allows for a comprehensive understanding of the multiple dimensions of food insecurity.

The study covered 4,700 households distributed across the country's 25 strata (23 departments, Metropolitan Lima, and Lima Provinces), with national, urban, rural, and geographic domain representativeness. Data collection was conducted between March and July 2023 through structured telephone surveys.

### **d) Structural Factors That Perpetuate Food Insecurity**

#### **• Deficient Food Environments**

Food environments in Peru exhibit characteristics that significantly contribute to the persistence of food insecurity, especially among children. In rural, remote, and conflict-affected areas, the supply of fresh and diverse foods is frequently disrupted by extreme climatic events, violence, poor infrastructure, or the absence of local markets. This situation creates what are known

as “food deserts,” where even when families have financial means, there is simply no physical availability of nutritious foods.

In contrast, urban areas face the opposite, but equally serious problem: an overabundance of ultra-processed foods with low nutritional value. These products, which are often cheaper and heavily marketed, crowd out healthier options. This situation not only reduces dietary diversity but also promotes unhealthy eating habits that persist into adulthood.

The transformation of food systems requires specific interventions to ensure that healthy foods are more accessible, affordable, and attractive. This involves addressing both physical availability and economic accessibility, while considering the geographic and socioeconomic particularities of the Peruvian territory.

### **Inadequate Feeding Practices**

Feeding practices in early childhood in Peru are deeply influenced by cultural, social, and educational factors that often limit the diversity and quality of children’s diets. The intergenerational transmission of beliefs and traditional practices, such as avoiding certain foods for fear of allergies or considering them inappropriate for young children, significantly restricts dietary options.

The lack of reliable information, or the presence of misinformation, constitutes another critical factor. Health systems do not always have sufficient resources or adequately trained personnel to provide appropriate and personalized nutritional guidance. Mothers and caregivers frequently do not receive adequate support or training to implement proper complementary feeding

practices, which are particularly critical between 6 and 24 months of age.

Additionally, social structures persist that limit women’s access to education and decision-making, directly affecting child nutrition. This situation is exacerbated in rural contexts and among Indigenous populations, where cultural and linguistic barriers may hinder access to appropriate nutritional information.

- **Economic Vulnerability**

Economic vulnerability is one of the most significant determinants of food insecurity in Peru. Families living below the poverty line face severe limitations in accessing fresh and nutritious foods. These households tend to prioritize quantity over quality, purchasing calorie-dense but nutrient-poor foods, such as cereals, roots, or processed products, that are more economically accessible.

Foods of animal origin, fresh vegetables, and dairy products are significantly more expensive per calorie, especially in middle-income countries such as Peru. This situation is aggravated by food inflation and upward fluctuations in food prices, along with the absence of adequate social protection networks.

The situation is further complicated by the prevalence of informal employment in Peru, which characterizes a significant proportion of the workforce. Informal workers face income instability, lack of social benefits, and the absence of protection mechanisms against economic shocks. During the pandemic, this sector was particularly affected by restrictive measures, revealing the structural vulnerability of the Peruvian economic system.

## **Response Systems to Food Insecurity in Peru**

### **a) Food System**

The Peruvian food system presents mixed characteristics that require substantial transformation to ensure food security. On the one hand, the country has exceptional biodiversity and ancient agricultural traditions that constitute fundamental strengths. On the other hand, the system faces significant challenges related to productivity, distribution, and access.

Agricultural production in Peru is characterized by marked seasonality and vulnerability to extreme climatic events. The drought, reported as the worst in 50 years, along with frost and other adverse weather phenomena, has demonstrated the fragility of the productive system. Additionally, dependence on imported fertilizers, particularly from Russia, exposes the system to geopolitical vulnerabilities.

Food markets suffer from deficiencies in infrastructure, cold chains, and distribution systems, especially in rural and remote areas. This situation leads to significant post-harvest losses and limits producers' access to markets that value the quality and diversity of their products.

### **b) Health System**

The Peruvian health system faces substantial limitations in providing essential nutrition services, particularly in the prevention and treatment of child malnutrition. The shortage of personnel trained in nutrition, especially in primary health care facilities and rural communities, limits the capacity to deliver high-quality nutritional counseling.

Growth and development programs represent a significant opportunity for early intervention, but they require strengthening in terms of coverage, quality, and follow-up. Integrating nutrition services with other maternal and child health services could optimize resource use and improve the effectiveness of interventions.

Training and supervision of health personnel in infant feeding require substantial improvements. Community health workers could play a key role in nutrition education and follow-up, but they need adequate training and support systems.

### **c) Social Protection System**

The Peruvian social protection system has limited coverage and fragmentation, which reduces its effectiveness in preventing and mitigating food insecurity. Existing programs such as the National School Feeding Program (formerly known as Qali Warma, now Wasi Mikuna) and the National Direct Support Program for the Poorest (Juntos) represent important advances, but they require evaluation and optimization to maximize their nutritional impact.

The lack of coordination among social programs limits the effectiveness of interventions and may generate duplication or coverage gaps. An integrated approach that considers the multiple dimensions of poverty and food insecurity could create significant synergies.

Conditional cash transfer programs have proven effective in other Latin American contexts in improving child food security. However, their implementation in Peru requires adaptation to local characteristics and articulation with nutrition education services.

## Successful Experiences and Lessons Learned

International experience provides valuable lessons for public policy design in Peru. Countries such as Burkina Faso, Nepal, and Rwanda have achieved significant reductions in severe child food poverty through coordinated and sustained interventions.

Burkina Faso reduced severe child food poverty from 67% (2010) to 32% (2021) by combining conditional cash transfers with community-based food education programs, in which mothers received training on the importance of dietary diversity and practical techniques for preparing nutritious foods. At the same time, subsidies were implemented to facilitate access to fresh products, and local production networks were strengthened by promoting family farming (UNICEF, 2024).

Nepal reduced severe child food poverty from 20% (2011) to 8% (2022) by developing a national child nutrition strategy that integrated local nutrition surveillance, health services with food interventions, and empowered community promoters to conduct home visits. This community-based care model generated trust and promoted sustainable changes in feeding practices (UNICEF, 2024).

Rwanda implemented a comprehensive approach combining nutrition-sensitive agriculture with community nutrition, investing in infrastructure for water access and irrigation of nutritious crops. School feeding programs not only improved child nutrition but also stimulated the local economy through the procurement of products from local farmers (UNICEF, 2024).

Analysis of these successful experiences reveals common elements that

could be adapted to the Peruvian context, including intersectoral approaches, family training and support, direct financial assistance, and promotion of physical and economic access to nutritious foods.

Sustained political will is a fundamental element, reflected in adequate resource allocation, continuity of programs beyond governmental changes, and the institutionalization of intersectoral coordination mechanisms. Active community participation and family empowerment emerge as critical factors for the sustainability of interventions.

Moreover, continuous monitoring and evaluation allow for timely adjustments and generate evidence for informed decision-making. Robust information systems facilitate early identification of food crises and rapid responses to emergencies.

## Recommendations for Public Policy Implementation Toward 2030

### 1. Transformation of the Food System

#### Diversification and strengthening of local production

Implement programs that promote diversification of nutritious crops, especially those rich in essential micronutrients for child development. This includes the development of household and community gardens producing fruits, vegetables, and legumes, with special emphasis on native varieties adapted to local conditions.

#### Regulation of ultra-processed foods

Implement strict regulatory policies to limit advertising of ultra-processed foods aimed at children, establish mandatory front-of-package nutrition labeling, and create fiscal incentives that favor the consumption of fresh and nutritious foods over processed products.

## **Strengthening the food value chain**

Invest in storage infrastructure, cold chains, and transportation systems to reduce post-harvest losses and ensure the availability of fresh foods in all regions of the country, with particular attention to rural and remote areas.

## **2. Strengthening the Health System**

### **Expansion of community nutrition services**

Develop a network of trained nutrition health promoters to provide education, counseling, and home-based nutritional follow-up, especially in rural and peri-urban communities where access to formal health services is limited.

### **Integration of maternal and child health services**

Strengthen integration among growth and development programs, immunizations, family planning, and prenatal care to create a continuous care mechanism that ensures timely nutritional interventions from pregnancy through age five.

### **Specialized training of health personnel**

Implement continuous training programs for health professionals and technicians in infant nutrition, complementary feeding, and early detection of malnutrition, with mandatory certification and periodic updates.

### **Nutrition surveillance systems**

Establish a national nutrition surveillance system that enables continuous monitoring of child nutritional status, early identification of food crises, and evaluation of intervention impacts.

## **3. Improvement of Data and Monitoring Systems**

### **Improvement of Data and Monitoring Systems**

Develop a technological platform integrating data from health, education, agriculture, and social protection sectors to generate real-time information on child nutritional status and intervention effectiveness.

### **Regular food security surveys**

Institutionalize food security assessments every two years using standardized methodologies that allow temporal and geographic comparability, with emphasis on early childhood.

### **Nutritious food price observatory**

Create a permanent monitoring system for prices of essential nutritious foods in local markets nationwide, enabling early alerts for price increases that may affect food access.

### **Policy impact evaluation**

Establish mandatory impact evaluation mechanisms for all food security and child nutrition policies and programs, using rigorous methodologies and transparent publication of results.

## **4. Intersectoral Coordination and Governance**

### **National pact for child nutrition**

Promote a long-term political agreement that transcends governmental terms, establishing specific goals, monitoring indicators, and accountability mechanisms to ensure continuity of nutrition policies.

## **Institutionalized community participation**

Establish formal mechanisms for community participation in the design, implementation, and evaluation of nutrition programs, recognizing local knowledge and promoting community ownership of interventions.

## **Responsible public–private partnerships**

Develop strategic partnerships with the private sector to promote the production, distribution, and commercialization of nutritious foods, establishing standards of social and environmental responsibility.

Effective implementation of these recommendations may require a sustained investment estimated at 0.5% of annual GDP distributed among the involved sectors. However, the expected benefits in terms of human development, reduced health costs, and improved economic productivity more than justify this investment. Sustained political commitment, effective intersectoral coordination, and active community participation are essential elements for the success of a transformative agenda that will lead Peru toward food security by 2030.

## **CONCLUSIONS**

The analysis of food security and child food poverty in Peru reveals a complex landscape that requires urgent, coordinated, and multisectoral interventions. The prevalence of food insecurity affecting 51% of Peruvian households in 2021 (the highest in South America) together with the fact that 56.5% of households with children under five were food insecure in 2023, highlights the magnitude of the challenge facing the country.

The findings demonstrate that child food poverty transcends traditional economic barriers, affecting families living in poverty as well as those from middle- and high-income groups. This reality underscores the need to address deeper structural factors, including deficient food environments, inadequate feeding practices, and fragmented social protection systems.

The situation is further aggravated by contextual factors such as political instability, extreme climatic events, food inflation, and dependence on imported agricultural inputs. These elements reveal the systemic vulnerability of the Peruvian food system and the urgency of developing resilience mechanisms.

Successful international experiences provide evidence that it is possible to significantly reduce child food poverty when there is sustained political will, coordinated intersectoral approaches, and active community participation. Countries such as Burkina Faso, Nepal, and Rwanda demonstrate that well-designed and effectively implemented interventions can generate substantial changes within relatively short periods.

The food security conceptual framework, based on the pillars of availability, access, utilization, and stability, provides structured guidance for the design of comprehensive public policies. However, effective implementation requires adaptation to the geographic, cultural, and socioeconomic specificities of the Peruvian context.

It is also essential to prioritize transformation of the Peruvian food system through diversification of local production, reduction of post-harvest losses, and regulation of ultra-processed food supply with clear and sustained policies over time.

Strengthening health and social protection systems with a preventive and community-based approach is equally indispensable, allowing expanded coverage of nutrition services and improved food education for families, especially in rural areas and vulnerable populations.

A long-term political commitment is required to ensure intersectoral coordination, adequate resource allocation, and active participation of civil society and communities in order to advance toward the eradication of child food poverty by 2030.

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# Climate Change and Its Effects on Biodiversity Conservation and Gastronomy

## *El cambio climático y sus efectos en la conservación de la biodiversidad y la gastronomía*

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### ABSTRACT

Climate change is one of the main concerns currently faced by humankind. Its effects are numerous in economic, social, and environmental terms. This article addresses the implications of biodiversity conservation in Peru and its close relationship with gastronomy, one of the country's principal economic activities and a fundamental pillar in the recognition and preservation of its cultural identity. The objective is to analyze the effects of climate change on biodiversity and its impact on Peruvian gastronomy. The study is qualitative and descriptive, based on three thematic axes. The findings indicate that climate change is generating significant effects on biodiversity conservation, altering the distributional limits of populations and modifying population patterns, thereby placing the survival of many species at risk. Additionally, the study highlights that biodiversity is the essential source of inputs that supply Peruvian cuisine; therefore, efforts aimed at its conservation will directly contribute to the sustainability of gastronomy in the country.

**Keywords:** Gastronomy, climate change, biodiversity, flora and fauna.

### RESUMEN

El cambio climático es una de las principales preocupaciones que afronta la especie humana en las actuales circunstancias. Los efectos que de ello se derivan son muchos en términos económicos, sociales y ambientales. En el presente artículo nos referimos a las implicancias de la conservación de la biodiversidad en el Perú y su estrecha relación con la gastronomía, una de las principales actividades económicas del país y un pilar fundamental en el reconocimiento y la preservación de nuestra identidad cultural. El objetivo es analizar los efectos del cambio climático sobre la biodiversidad y su impacto en la gastronomía peruana. La investigación es cualitativa y descriptiva, tomando como base tres ejes temáticos. Se concluye que el cambio climático está generando efectos



significativos en la conservación de la biodiversidad, alterando los límites de distribución de las poblaciones y modificando los patrones poblacionales, lo que pone en riesgo la supervivencia de muchas especies. Asimismo, se destaca que la biodiversidad es el eje fundamental de insumos que abastecen la cocina peruana, por lo que los esfuerzos para su conservación contribuirán directamente a la sostenibilidad de la gastronomía en el país.

**Palabras clave:** Gastronomía, cambio climático, biodiversidad, especies de flora y fauna.

## INTRODUCTION

Climate change, population growth, the global economy, national defense, health, food security, and poverty are pressing concerns that demand our attention, even as the uncertainties surrounding their evolution and development continue to grow. In the current context of demographic expansion, global trends suggest we are shaping a different vision of the future, one in which current patterns of human development may no longer be viable. This is particularly evident when considering that politics, economics, culture, religion, and environmental change have shaped the course of events throughout history (Fuertes *et al.*, 2017).

The use of natural resources and the generation of all types of waste over thousands of years of civilization are pushing the Earth's capacity to its limits. In recent times, demographic growth, intensive access to abundant and low-cost energy sources, and the widespread use of technology to intervene in nature have dramatically disrupted ecosystems (Olivera-Carhuaz & Pulido-Capurro, 2023). In recent decades, the excessive rise in extraction, transformation, production, transportation, consumption, and waste generation has surpassed the planet's geological and physicochemical thresholds, triggering an environmental crisis with serious social and economic consequences at a global scale (Prats *et al.*, 2016).

In this scenario, climate change has caused an increase in average land and ocean surface temperatures, altered precipitation patterns, significant shifts in the intensity and frequency of climate events, and a rise in mean sea level (Intergovernmental Panel on Climate Change [IPCC], 2023). Planetary temperature records over the last 100,000 years reveal that climate fluctuations were abrupt during the first 90,000 years, whereas the last 10,000 years have shown a trend toward stability (Lovejoy, 2008). Historically, this latter period saw the beginnings of permanent human settlements, the rise of agriculture, the expansion of livestock rearing, and the onset of deforestation. Human civilization has evolved under the assumption of a stable climate; however, the current scenario reveals that rising greenhouse gas concentrations are intensifying the greenhouse effect and causing drastic climatic changes (Uriarte, 2010).

Since the mid-20th century, the concentration of greenhouse gases has driven a 0.75 °C increase in global average temperature. As a consequence, the physical environment has undergone striking changes: earlier spring ice breakup in lakes, the retreat of glaciers in Alaska and Greenland, the melting of tropical ice caps such as those on Mount Kilimanjaro and in the tropical Andes, and the rapid decline of Arctic sea ice, an expected outcome given

the heat-absorbing capacity of open water compared with ice. A pessimistic projection forecasts an ice-free Arctic by 2030. Sea levels are also rising due to the thermal expansion of seawater (Schoolmeester *et al.*, 2019; Pallmall, 2021).

According to the IPCC (2023), global warming is expected to increase by 1.5 °C between 2030 and 2035 unless swift action is taken. By the end of the 21st century, surface temperature is projected to rise between 2.6 °C and 4.8 °C, and mean sea level could increase by 45 to 82 centimeters. Additionally, precipitation intensity is projected to increase in high latitudes and near the equator, while decreasing in subtropical regions.

Another critical indicator is the significant rise in forest fires across all five continents. These fires are associated with the destruction of forest, livestock, and agricultural resources, and in some cases, loss of human life and infrastructure, although fire does play a natural ecological role in some landscapes. Longer and warmer summers, along with earlier snowmelt, have created drier environments with greater vulnerability to fire. Drought-induced dryness of vegetation is a key factor in fire propagation (Pausas, 2020). The increase in tropical cyclones follows a similar trend. In August 2017, satellite images from Greenland showed active fires even in this typically cold and sparsely vegetated region (Úbeda & Francos, 2018).

In Peru, the climate has been shifting gradually in recent years due to irregular increases in sea surface temperature. Climate projections show amplified precipitation variability linked to warmer El Niño conditions, which have triggered extreme climate events that impact agriculture, livestock, public health systems,

infrastructure, and social, economic, and governance structures. The 2017 El Niño event was the third strongest in recent history, with devastating economic losses and significant health impacts from heavy rainfall and river flooding (Yglesias-Gonzalez *et al.*, 2023).

At the same time, biodiversity is being directly transformed by the effects of climate change, despite having played a major role in species evolution. Biodiversity (the sum of genetic, species, and ecosystem diversity) is not evenly distributed across the planet. Relatively small areas, particularly in the high Andes, contain significant concentrations of endemic species with narrow distribution ranges, making them areas of exceptionally high species richness and endemism.

Furthermore, there are also biodiversity hotspots, which are areas of high biological diversity that are currently threatened by human activity. These areas, located mainly in the tropics and high mountains, have escaped some of the effects of glaciation (Myers *et al.*, 2000; Ministerio del Ambiente, 2019; Hernández-Ruedas *et al.*, 2019).

In this context, Peru has developed a gastronomy that reflects extraordinary richness and benefits millions of Peruvians through its economic and social impact. As such, it generates significant implications for the economic and social relationships within the various settings in which food industry actors participate, particularly regarding the flow of biodiversity from rural to urban areas, job creation, and the activation of services such as hotels, restaurants, and supply chains. This has contributed to Peru being recognized as one of the world's best gastronomic destinations (Guardia, 2020).

For precisely this reason, Peru, one of the most biodiverse countries on the planet, has fostered the development and evolution of a bountiful gastronomy. Coastal cuisine is well known for its desserts and raw seafood preparations; Andean cuisine for its consumption of tubers, corn, and meats such as llama, alpaca, and guinea pig; and Amazonian cuisine for its abundance of forest resources, including wild meats such as deer, peccary, and agouti, fish such as paiche, dorado, and gamitana, fruits like camu camu and aguaje, and other preparations like root macerations (Luza, 2014).

The interrelationship of these three variables leads this article to analyze the effects of climate change on biodiversity conservation and its influence on Peruvian gastronomy.

## MATERIALS AND METHODS

This study was conducted using a qualitative approach with a non-experimental and descriptive design. No variables were manipulated; instead, the aim was to understand and analyze the effects of climate change on biodiversity and its impact on Peruvian gastronomy from an interpretive perspective (Hernández *et al.*, 2014; Katayama & Pulido, 2017; Pulido-Capurro *et al.*, 2024).

The analysis was structured around three main thematic axes:

- Climate change in the Peruvian context,
- Alterations in biodiversity (flora and fauna species), and
- Implications for traditional and contemporary Peruvian gastronomy.

### Study Design

This was a non-experimental, cross-sectional, and documentary study,

relying on the collection and analysis of pre-existing information without direct intervention in the observed phenomena. The analysis was based on secondary sources and relevant scientific literature, allowing for an in-depth approach to the issue across environmental, ecological, and cultural dimensions.

### Procedure and Data Collection

A systematic documentary search of scientific and academic literature published between 2005 and 2024 was conducted to ensure the inclusion of recent and relevant studies. The databases used were Scopus, Web of Science, and SciELO.

The search was performed in both Spanish and English, using Boolean operators (AND, OR) and the following keywords:

- “Climate change” AND “Peru”
- “Biodiversity” OR “native species” OR “flora and fauna”
- “Peruvian gastronomy” OR “traditional food”
- “Climate impact on food”
- “Climate change” AND “food systems” AND “gastronomy”

International organization reports were also reviewed, as they provide updated data on the effects of climate change in the Andean and Amazonian regions of Peru.

### Inclusion and Exclusion Criteria

Inclusion: Academic journal articles, technical reports, peer-reviewed papers, official documents, and gray literature addressing at least one of the three thematic axes within the Peruvian or South American context.

Exclusion: Articles without academic support, journalistic notes lacking scientific sources, studies prior to 2005, or papers addressing the topics only theoretically with no connection to Peru.

### Information Analysis

Collected data were organized and examined using a thematic analysis matrix, which allowed the identification of patterns, relationships, and effects linking climate change, biodiversity, and gastronomy. Additionally, a critical discourse analysis was applied to key documents to identify predominant narratives on sustainability, cultural identity, and gastronomic adaptation in the context of climate change.

## RESULTS AND DISCUSSION

### Climate Change in Peru

The intensity and impacts of climate change in each country are closely related to structural factors and environmental and socioeconomic characteristics. Although such impacts have existed for centuries, they have intensified since 1970 due to global surface temperature variations, which increased by approximately 0.99 °C between 2001 and 2020 compared with 1850–1900. Moreover, the stratospheric ozone layer decreased by about 2.2% between 60°N and 60°S from 1980 to 2017 due to human-generated pollution (Gulev *et al.*, 2023). These changes compromise various productive sectors, economic activities, public health, and life zones across the planet (IPCC, 2023; Cabezas, 2023).

In Peru, as elsewhere, the progressive rise in average land and Pacific Ocean temperatures has contributed to glacier retreat, altered precipitation patterns, rising mean sea levels, and increased frequency and intensity of El Niño and La Niña events. These phenomena have trigge-

red climate variability, including extreme events, driven by increasing greenhouse gas emissions. Consequences include reduced per-capita income, decreased industrial efficiency, damage to road infrastructure, reduced electricity generation, increased natural disaster risk, heightened precipitation intensity, weakened nutrient-rich upwelling, shifts in the distribution of fisheries and marine resources, reduced freshwater availability, decreased agricultural and livestock productivity, degradation of agro-silvopastoral and fishing systems, savannization of tropical forests, flooding and salinization risks in coastal zones, habitat loss, and changes in the physical, chemical, and biological properties of lakes and rivers, all affecting biodiversity composition (Vargas, 2009; Navarro Guzmán *et al.*, 2020).

Since 1992, Peru has taken important steps by joining the United Nations Framework Convention on Climate Change (UNFCCC), which it ratified in 1993, thereby committing to stabilize greenhouse gas concentrations and prevent dangerous anthropogenic interference with the climate system. This commitment was reaffirmed in 2002 when Peru joined the Kyoto Protocol (Ministerio del Ambiente, 2016).

Additionally, the National Adaptation Plan for Climate Change (an input for updating the National Climate Change Strategy) has been in effect since 2021. It is a milestone in climate action, mandated by the Climate Change Framework Law and its Regulation. The plan focuses on climate adaptation planning and guides the update of the National Climate Change Strategy (Ministerio del Ambiente, 2021).

Peru has 28 of the 35 recognized global climates and ranks third worldwide in climate-related vulnerability. In 2021,

25.9% of the population lived in poverty, with 4.1% in extreme poverty; 34.6% were at risk of falling into monetary poverty due to potential economic shifts. A large percentage of the population depends on agriculture, fishing, and other climate-sensitive activities. Additionally, 90% of the population lives in arid, semi-arid, or sub-humid zones (Chirinos, 2021; Ministerio del Ambiente, 2021).

Climate change is impacting biodiversity across Latin America and the Caribbean, requiring populations dependent on agriculture, livestock, fishing, and hunting to adopt new strategies for conserving biological and ecosystem resources. Climate change directly affects biological processes at the individual, population, and ecosystem levels. For individuals, it alters development, physiology, growth phases, reproduction, migration, and behavior (Pulido *et al.*, 2021). Changes in rainfall patterns and temperature shifts affect species distribution, population size, structure, and abundance. Climate-induced shifts in the hydrological cycle also alter species interactions, nutrient cycles, and ecosystem structure and functioning, ultimately affecting ecosystem services (IPCC, 2023).

Since the late 20th century, a near 1 °C increase in average temperature has been recorded. Although this increase may appear modest, it has serious consequences, including reduced crop yields in developing countries (potentially leading to famine), glacial melting and disappearance (threatening water supplies), and loss of ecosystem components (Chirinos, 2021). According to Peru's Third National Communication (2014), 64% of national emergencies were climate-related events such as droughts, rains, floods, and cold spells. Over the last 15 years, emergencies due to

natural hazards have increased significantly, 72% of which were climate-related (Ministerio del Ambiente, 2016).

In response to increasingly intense climate events, the Ministry of the Environment has implemented various adaptation and mitigation measures. In 2010, the Adaptation and Mitigation Action Plan was introduced to guide regional climate change risk management. In December 2019, the Ministry published the Catalog of Mitigation Measures, which includes 62 guidelines across sectors such as energy, industrial processes, waste management, agriculture, livestock, and land use. The goal is for Peru to achieve net-zero greenhouse gas emissions by 2050 (Ministerio del Ambiente, 2016; Chirinos, 2021).

### **Biodiversity**

There are references indicating that, since Columbus's second voyage to the Americas in 1493, the introduction of cultivable plants and domesticated animals, mainly from Europe and other regions, began (Capdevila *et al.*, 2006). Since the arrival of Europeans in the Americas in the sixteenth century, they contributed to the understanding of geological structure and the identification of numerous new species, thus expanding biodiversity. From that moment, and through a long historical process marked by the voyages of explorers, it became possible to record in detail the exchange of species between Europe and the Americas (Hernández-Ruedas *et al.*, 2019). One of the first explorers, between 1799 and 1804, was the renowned German scientific explorer, geographer, and naturalist Alexander von Humboldt, who, together with the French botanist Aimé Bonpland, traveled through Venezuela, Ecuador, Colombia, and Peru. The findings of their research were published in Voyage

to the Equinoctial Regions (Escobar-Mamani & Pulido-Capurro, 2021).

These journeys and exchanges intensified beginning in the eighteenth century. Between 1857 and 1869, the Italian scholar Antonio Raimondi explored the coast and the Andes, gathering valuable information that was later published, starting in 1875, in six volumes of his monumental work *El Perú* (Escobar-Mamani & Pulido-Capurro, 2021). However, it was in the twentieth century that the development and modernization of transport systems facilitated the movement of living organisms by reducing travel duration, which in turn increased the exchange of species (Bendjoudi *et al.*, 2015). In 1945, Augusto Weberbauer, a German naturalist and professor of Botany at the Universidad Nacional Mayor de San Marcos, published an essential contribution to the knowledge of Peruvian flora in his work *The Plant World of the Peruvian Andes* (Pulido, 2023).

In 1951, Russian botanist and geneticist Nikolai Ivanovich Vavilov emphasized that the Andean region is one of the world's centers of origin and diversification of crops. For ten thousand years, plants and animals have been domesticated, resulting in new varieties created by pre-Inca and Inca cultures in highly sustainable and productive lands (Vavilov, 1951; Krapovickas, 2010).

Today, Peru is one of the world's seventeen megadiverse countries, as it contains more than 70% of the planet's biodiversity, represented by a wide range of ecosystems, flora and fauna species, and genetic diversity. These not only form part of the national heritage but also contribute to regional and global development and sustainability. More than 20,375 species of

flora have been recorded, along with 530 mammals, 1,892 birds, 446 reptiles, 1,070 marine fish, and 873 freshwater fish; additionally, Peru contains 84 of the planet's 117 life zones and more than 73 million hectares of forests. Five species of wild fauna and 182 species of native domesticated plants have been domesticated, 174 of which are of Andean origin, including well-known crops such as potato (*Solanum tuberosum*), maize (*Zea mays*), ulluco (*Ullucus tuberosus*), oca (*Oxalis tuberosa*), and quinoa (*Chenopodium quinoa*). Introduced species include the rock pigeon (*Columba livia*), rainbow trout (*Oncorhynchus mykiss*), and Nile tilapia (*Oreochromis niloticus*) (Brack, 2003; Cossíos, 2010; Ministerio del Ambiente, 2019; Olivera-Carhuaz & Pulido-Capurro, 2023).

In the Andes, approximately 182 species of domesticated native plants have been recorded, 174 of which are of Andean origin, including potato (*Solanum tuberosum*), maize (*Zea mays*), ulluco (*Ullucus tuberosus*), oca (*Oxalis tuberosa*), and quinoa (*Chenopodium quinoa*), among other valuable species. There are nearly 200 species of potato distributed throughout the Andes of Peru, Bolivia, and Argentina; the principal species, *Solanum tuberosum*, was domesticated in the Lake Titicaca region (Brack, 2003). There is also the inventory *The Grasses of Peru* by Óscar Tovar, who in 1993 described 680 species of native agrostological flora (Brack, 2003; Escobar-Mamani & Pulido-Capurro, 2021). Peru has contributed five native species of domesticated animals inhabiting the Andes: llama (*Lama glama*), alpaca (*Lama pacos*), guinea pig (*Cavia porcellus*), Muscovy duck (*Cairina moschata*), and cochineal (*Dactylopius coccus*) (Brack, 2003; Cossíos, 2018; Pulido, 2023).

Ecosystem representation is protected within the National System of Protected Natural Areas (SINANPE), which administers 76 protected natural areas (PNA) under different categories, such as National Parks, National Sanctuaries, National Reserves, Wildlife Refuges, Landscape Reserves, Communal Reserves, Protection Forests, Hunting Grounds, and Reserved Zones. These areas cover 29,768,595.74 hectares, representing 17.90% of the terrestrial area protected by PNAs and 7.89% of the marine area protected by PNAs within national territory. These areas safeguard Peru's rich biodiversity, scenic beauty, and the heritage of Andean and Amazonian Indigenous populations (Myers, 1990; Ministerio del Ambiente, 2023; Servicio Nacional de Áreas Naturales Protegidas por el Estado (SERNANP), 2024).

Peru contains a significant number of wetlands, located on the Pacific, Atlantic, and Titicaca basins, with an estimated preliminary area of nearly 8 million hectares. There are also 13 wetlands of international importance, or Ramsar sites, covering 6,784,042 hectares, registered under the Ramsar Convention. Their importance is highlighted in the National Wetlands Strategy of Peru, which establishes guidelines for the protection of these ecosystems, their biodiversity, and the environmental services they provide (Ministerio del Ambiente, 2015).

Glaciers in the Peruvian Andes cover an area of 2,042 km<sup>2</sup>, representing 77% of the world's tropical glaciers. Over the last 30 years, 22% of their surface area has been lost. These glaciers account for 71% of all tropical glaciers worldwide, and it is estimated that by the year 2030, due to global warming, all glaciers below 5,000 meters will disappear or drastically shrink.

This loss represents 7 billion cubic meters of water, equivalent to ten years of water consumption for the population of Lima. The energy sector would also be affected since nearly 80% of electricity is generated in hydroelectric plants (Schoolmeester *et al.*, 2019).

Agriculture is a first-order system of adaptation, as its mission is to feed populations so that they can fulfill their assigned functions (Córdova, 2020). Twenty-seven crops have been identified, such as potato, maize, and rice, that constitute basic household staples and are vulnerable to climate change. In the Amazon, the largest expanses of forest are the areas of greatest biodiversity and the most vulnerable. These habitats hold the greatest diversity of flora and fauna, providing food sources such as aguaje and camu-camu, as well as medicinal resources like cat's claw and oje. The Andean highlands are among the most affected zones, as they are home to the poorest populations in Peru, whose survival depends on small-scale farming for family consumption. In the Andes, a temperature increase is somewhat favorable because it allows crops to develop more quickly and extend to higher elevations than they currently reach. However, higher temperatures also cause stress in crops, reducing their productivity, especially those located in the desert coast and intended for agro-export, such as avocados, asparagus, blueberries, and grapes (Ministerio del Ambiente, 2019; Lozano-Povis *et al.*, 2021; Escobar-Mamani *et al.*, 2025).

In the oceans, natural systems connected to snow, ice, and frozen terrain are being affected by rising temperatures, indicating that global warming alters both climatic and biological systems. Evidence shows a retreat of snow cover and sea ice

in the Northern Hemisphere, shorter durations of frozen seasons in lakes and rivers, glacier melt, rock avalanches in mountain regions, changes in some Arctic and Antarctic ecosystems, and shifts of animal and plant species toward higher latitudes and elevations. If the global average temperature increases by 1.5–2.5 °C, approximately 30% of plant and animal species will likely face extinction risks (Vargas, 2009; Ministerio del Ambiente, 2016; Gulev *et al.*, 2021).

The vulnerability of the Peruvian coast is impacted by water scarcity and drought and is also one of the regions most affected by the El Niño Phenomenon, which is increasingly frequent and intense. One of the main effects of El Niño is the rise of ambient temperature above average levels, even higher than those typically experienced in summer. It also brings increased relative humidity and torrential rains in the northern part of the country, causing severe economic and infrastructural losses (Ministerio del Ambiente, 2019).

## Gastronomy

To speak of Peruvian gastronomy, one must probably trace its origins back 5,000 years, to the first civilization that inhabited the Americas, Caral, in the Supe Valley north of Lima. Since then, and over the centuries, gastronomy has broadened its horizons, enriched by extraordinary biodiversity and multiculturalism, expressed through the interaction of coastal, Andean, and Amazonian cultures. Peruvian cuisine is recognized as one of the most exquisite and diverse worldwide, with a rich heritage rooted in pre-Inca and Inca periods, as well as interactions with foreign culinary traditions from other Latin American countries and from Europe (Spanish, Italian, French), Asia (Chinese-Cantonese, Japanese), and

Africa (Arab). The delicate flavors of gastronomy arriving from four continents have produced a vast diversity of iconic dishes in the Peruvian culinary arts, dishes that are in continual evolution.

Thus, gastronomy is perceived as an important cultural expression that manifests flavors, aromas, and delicate combinations of animal components, plants, fungi, and diverse microorganisms. All of this is the result of a long historical process that began in pre-Columbian societies and has been revitalized today as an expression of profound cultural heritage. The concept of heritage is understood as the art of inheritance, tradition, past, identity, culture, and nostalgia (Luza, 2014; Mauro Martín *et al.*, 2019; Guardia, 2020; Manallay, 2022).

Gastronomy structures its foundations on a value chain that begins with the production and processing of food, continuing through distribution and transformation, and culminating in consumption. It is estimated that this value chain represents 11.2% of the national GDP. Gastronomy provides employment to more than two million people across nearly 200,000 establishments throughout the country. The development of this process is supported by values such as gastronomic landscapes, cultural and culinary identity, and tangible and intangible heritage, and it is related to other factors such as public policy, administrative regulations, available infrastructure, academic training, research, and innovation (Pizarro-Ramos *et al.*, 2024). It is part of the social and economic context of communities throughout the country and serves as a powerful tool for national, regional, and municipal development (Aguilar, 2016). Additionally, Peru's privileged megadiverse territory includes 84 of the planet's 117 life zones, giving rise to a rich

flora with 20,375 species, including the production of 4,400 native plants, as well as species from aquatic environments, especially freshwater and marine algae (Ministerio del Ambiente, 2019). This helps explain the extraordinary variety of flavors and textures in Peruvian cuisine.

Another important aspect is the sustained growth of gastronomy, the evolution of its recognition and global positioning, the increase in restaurants and in tourists attracted by Peruvian cuisine, the recovery of native products, traditional recipes, and ancestral cooking techniques, the production of specialized literature, and the growing interest of young people in professional culinary training, all of which have contributed to expanding the range of academic certification alternatives (Quea-Campos, 2024).

However, Peruvian cuisine, represented by diverse stakeholders such as entrepreneurs, chefs, professional associations, media outlets, universities, and journalists who have driven the promotion of Peruvian cuisine would be seriously affected by disruptions in the biological cycles of biodiversity and by climate change.

A series of changes will occur, altering the functionality of ecosystem services provided by biological communities such as tropical forests, wetlands, and grassland prairies. These changes will lead to the emergence of forest pests and recurring damage that affects the survival, reproduction, and dispersal of organisms. There will also be impacts on ecological relationships, such as disproportionate increases in producers, competitors, parasites, and predators, thereby altering the trophic chain. At the ecosystem level, the frequency and intensity of forest fires will increase due to warmer and drier climatic conditions,

compounded by irresponsible human activities. By 2030, as a result of global climate change, 15% of Protected Natural Areas (both state and private) will experience persistent conditions of exposure, risk, and adaptive capacity, placing them under high vulnerability to climate change. This will cause drastic reductions in biodiversity, modification and redistribution of biological communities, increased desertification, soil erosion and salinization, more frequent droughts, and atypical and unpredictable rainfall events. These changes will result in scarcity of forest resources that provide animal- and plant-based foods, as well as water, to rural and Indigenous communities (Ministerio del Ambiente, 2019; Córdova, 2020).

In the coastal and Andean regions, high temperatures will produce excessive humidity, loss of agricultural land due to soil salinization, reservoir sedimentation, destruction of productive infrastructure, lower meat and milk production, and decreases in crop yields—particularly disastrous for the Andean farmer, affecting potato crops and the 174 species of Andean-origin plants, such as ulluco, oca, and quinoa. Thus, climate change presents a risk to farmers and agricultural workers, as well as to the country's food security. This situation is exacerbated by the fact that 55% of people living in poverty work in activities supporting the primary food production systems of the country, and 14 million Peruvians are vulnerable to food insecurity (Arteaga & Burbano, 2018; Chirinos, 2021; Lozano-Povis *et al.*, 2021).

In the ocean, there will also be direct consequences for the productivity and spatial distribution of both pelagic and benthic hydrobiological resources due to rising sea temperatures, potential displacement

of marine currents, and changes in CO<sub>2</sub> concentration. The rise in sea level causes erosion of the shoreline and threatens existing infrastructure, affecting artisanal fisheries, coastal fishing towns, tourism, and recreational activities. The upwelling system, driven by the dynamics of marine currents along the coast and serving as a catalyst for high fishery productivity, will be affected, causing losses due to reduced fishery resources, whether from low productivity or from the displacement and migration of species toward areas with more favorable temperatures. In coastal zones, damages will occur in aquaculture systems due to climatic conditions associated with El Niño events, characterized by significant sea temperature increases and torrential rains on land. It is important to note that all aquaculture species are poikilothermic, meaning that temperature variations can significantly affect their overall metabolism, growth rates, and total production levels (Serrano *et al.*, 2016; Torres, 2019; Córdova, 2020; Navarro, 2020).

## CONCLUSIONS

Climate change is producing significant effects on biodiversity conservation,

modifying the distributional ranges of animal, plant, fungal, and microbial populations, severely altering population patterns and endangering the survival of many species.

Given that biodiversity is the primary source of inputs that supply Peruvian cuisine, efforts directed toward its conservation will have a direct impact on the sustainability of gastronomy in the country.

Efforts to mitigate global warming require a commitment to restructure our energy base and manage carbon within ecosystems, which implies a transition that promotes ecological development aligned with the sustainability framework necessary for biodiversity conservation.

The sustainability of Peruvian gastronomy depends largely on the efforts undertaken by the government and civil society to reduce greenhouse gas emissions that intensify climate change, as well as on actions aimed at conserving biodiversity in protected natural areas, agroforestry systems, agri-food systems, small- and medium-scale agriculture, and both extensive and enclosed livestock production.

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#### **Author Contribution Statement**

- Víctor Pulido-Capurro: Conceptualization, review, and project administration.
- Edith Olivera-Carhuaz: Writing, review, and editing.
- Augusto Dalmau-Bedoya: Review

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# Effect of Hot Air Drying on Remaining Water Content and Total Phenolic Content of Three Morphotypes of Mashua (*Tropaeolum tuberosum* Ruíz y Pav.)

*Efecto del secado con aire caliente en la humedad libre y el contenido de fenólicos totales de tres morfotipos de mashua (Tropaeolum tuberosum Ruíz y Pav.)*

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## ABSTRACT

*Tropaeolum tuberosum* Ruíz y Pav. (mashua) is a tuber cultivated in Andean zones as Huancavelica, with traditional use in food and functional potential due to its content of bioactive compounds. Due to its short fresh shelf life, its preservation is required. Hot air drying, an alternative to solar drying, can affect the stability of these compounds depending on the temperature applied. Therefore, the objective was to evaluate the effect of temperature (50, 60, 70 and 80 °C) of hot air drying on remaining water content (Y) and total phenolic content (TPC) in three morphotypes of mashua (Zapallo, Sangre de Cristo and Negra). The tubers were washed, disinfected with sodium hypochlorite (50 ppm), cut (2.5 mm), and dried (150 g) for 16 h. Free moisture was determined in the dried samples. They were then ground (particles < 850 µm) and extracts (80% methanol, 50 mg/mL) were prepared for TPC determination. Drying temperature significantly ( $p < 0.05$ ) influenced the TPC as it increased from 50 to 80 °C, and did not influence the Y. TPC ranged from  $1608 \pm 80.22$  to  $2069 \pm 82.01$ ,  $1732 \pm 59.43$  to  $2069 \pm 30.32$  and  $5286 \pm 143.74$  to  $7929 \pm 120.48$  mg gallic acid equivalent/100 g dry mashua for Zapallo, Sangre de Cristo and Negra, respectively. These results indicate that hot air drying at 60 °C can be used to obtain dried mashua of the Sangre de Cristo and Negra varieties with higher TPC, while at 80 °C the TPC for the Zapallo variety is better preserved.

**Keywords:** Phenolics, bioactive compounds, dehydration, andean tuber, Huancavelica.



## RESUMEN

*Tropaeolum tuberosum* Ruiz & Pav. (mashua) es un tubérculo cultivado en zonas altoandinas como Huancavelica, con uso tradicional en la alimentación y potencial funcional por su contenido de compuestos bioactivos. Debido a su corta vida útil en fresco, se requiere su conservación. El secado por aire caliente, alternativa al secado solar, puede afectar la estabilidad de estos compuestos según la temperatura aplicada. Por tanto, el objetivo fue evaluar el efecto de la temperatura (50, 60, 70 y 80 °C) de secado con aire caliente en la humedad libre (Y) y el contenido de fenólicos totales (CFT) en tres morfotipos de mashua (Zapallo, Sangre de Cristo y Negra). Los tubérculos fueron lavados, desinfectados con hipoclorito de sodio (50 ppm), cortados (2,5 mm), y secados (150 g) durante 16 h. La humedad libre se determinó en las muestras secas. Luego, se molieron (partículas < 850 µm) y se prepararon extractos (metanol al 80 %, 50 mg/mL) para la determinación del CFT. La temperatura de secado influyó significativamente ( $p < 0,05$ ) en el CFT, a medida que se incrementó de 50 a 80 °C, y no influyó en la Y. El CFT variaron de  $1608 \pm 80,22$  a  $2069 \pm 82,01$ ,  $1732 \pm 59,43$  a  $2069 \pm 30,32$  y  $5286 \pm 143,74$  a  $7929 \pm 120,48$  mg equivalente de ácido gálico/100 g mashua seca para la Zapallo, Sangre de Cristo y Negra, respectivamente. Estos resultados indican que el secado con aire caliente a 60 °C puede ser usado para obtener mashua seca de la variedad Sangre de Cristo y Negra con mayor CFT, mientras que a 80 °C se preserva mejor el CFT para la variedad Zapallo.

**Palabras clave:** Fenólicos, compuestos bioactivos, deshidratación, tubérculo andino, Huancavelica.

## INTRODUCTION

*Tropaeolum tuberosum* Ruiz and Pavón, commonly known as mashua, has traditionally been used for both food and medicinal purposes across a broad Andean region extending from Colombia to northwestern Argentina. However, archaeological evidence from present-day Peru indicates that mashua was consumed by pre-Inca populations more than 7,500 years ago, and its presence has been documented in the ceramics of the Nasca and Chimú cultures. Today, this tuber is cultivated in Colombia, Ecuador, Peru, and Bolivia, and exhibits remarkable phenotypic variability, expressed in external colorations such as orange, pale yellow, yellowish orange, deep yellow, grayish purple, dark purple,

and reddish gray. Likewise, the color of the flesh ranges from yellow to orange and violet. It also presents pigmented buds, which sometimes display purple or red streaks (Siqueira *et al.*, 2023; Grau *et al.*, 2025).

Mashua has been widely used in traditional medicine for its digestive, cleansing, wound-healing, and diuretic properties. It is also employed in the treatment of diseases such as diabetes, dengue, malaria-related fever, and various postpartum conditions, particularly in the management of kidney disorders. Additionally, it is attributed preventive effects against pathologies such as prostate hyperplasia, skin ulcers, gonorrhoea, and tonsillitis. Its high glucosinolate content confers antibacterial,

antimutagenic, anticancer, and antifungal properties. Furthermore, its potent antioxidant activity is associated with its high concentration of phenolic compounds (Grau *et al.*, 2025; Luziatelli *et al.*, 2023).

At present, mashua continues to be consumed by rural populations and has begun gaining wider acceptance in urban markets due to its versatility in food preparation and its potential for industrial processing. Its applications include stews, creams, soups, porridges, panna cotta with milk, mashua in walnut sauce, cookies with rocoto caviar and avocado mayonnaise, cocido boyacense, bottled mashua–pineapple juice, black mashua jam, dehydrated mashua, flour production, and second-generation snack development (Grau *et al.*, 2025; Leidi *et al.*, 2018; Luziatelli *et al.*, 2023; Zambrano *et al.*, 2025; Acurio *et al.*, 2023).

Mashua is also notable for its high content of nutrients, phytochemicals, and natural pigments with antioxidant properties (Betalleluz-Pallardel *et al.*, 2012; Campos *et al.*, 2006; Costa *et al.*, 2008; Warnier *et al.*, 2008; Chirinos *et al.*, 2006, 2015; Pacheco *et al.*, 2019; Paucar-Menacho *et al.*, 2020), making it a functional ingredient of high commercial value. However, its high water content (between 74.51 and 92 g/100 g fresh mashua) (Campos *et al.*, 2006; Castañeta *et al.*, 2024; Coloma *et al.*, 2022) limits its shelf life, prompting interest in studying preservation methods and parameters that prolong it while minimizing impacts on bioactive compounds.

Dried mashua has been obtained using hot air at 60 °C for 6 to 24 hours and air velocities of 1.8 to 2 m/s in a convective dryer as part of the production of dried mashua flour, flour for second-generation snacks (Acurio *et al.*, 2023, 2025), or as a pretreatment for mashua characterization

(Aguilar-Gálvez *et al.*, 2022; Salazar *et al.*, 2021).

Drying is one of the most consolidated and widely used methods for food preservation, enabling shelf-life extension and reduction of fresh-product waste (Berk, 2018; Onwude *et al.*, 2022). This process is based on reducing water content to levels that ensure microbiological stability. Drying also inhibits microbial growth and slows undesirable chemical reactions, while reducing storage and transportation costs by decreasing the weight and volume of the final product (Castillo-Zapata *et al.*, 2024).

Industries in developing countries still favor hot-air drying, considered a low-cost and simple operation in which solid foods are directly exposed to hot air in the drying chamber (Castillo-Zapata *et al.*, 2024; Kerr, 2019). However, the total phenolic content (TPC) of foods may be affected by the drying temperature.

Multiple studies have used the colorimetric Folin–Ciocalteu assay to evaluate TPC. Its preference over other methods is often justified by its recognized reliability, long history of use, and broad acceptance within the scientific community. Moreover, it is more economical than alternative analytical techniques, making it accessible for researchers with limited resources. Its simplicity and applicability have made it one of the most commonly used tools for analyzing phenolic compounds in the food industry (Li *et al.*, 2025).

Several studies have reported TPC values in freeze-dried mashua (Behar *et al.*, 2021; Campos *et al.*, 2006; Castañeta *et al.*, 2024; Costa *et al.*, 2008; Campos *et al.*, 2007; Warnier *et al.*, 2008; Chirinos *et al.*, 2006; Rogez *et al.*, 2007; Choquecham-

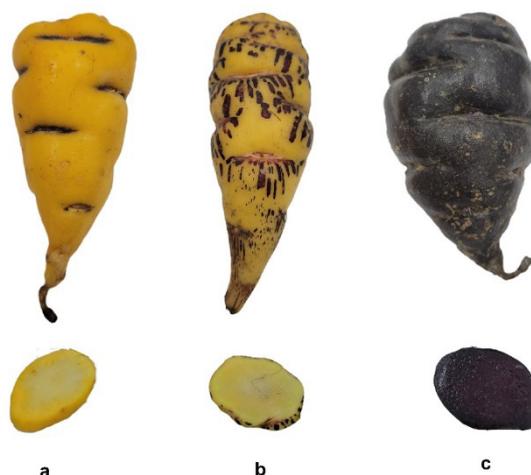
bi *et al.*, 2019; Coloma *et al.*, 2022; Jacobo-Velázquez *et al.*, 2022; Pacheco *et al.*, 2020) and in hot-air-dried mashua (Acurio *et al.*, 2025; Salazar *et al.*, 2021). However, no studies have reported the effects of drying temperature on mashua of the zapallo, Sangre de Cristo, and negra morphotypes. Therefore, the objective of this study was to evaluate the effect of drying temperature (50, 60, 70, 80, and 90 °C) using hot air on

the free moisture content and total phenolic content of mashua of the zapallo, Sangre de Cristo, and negra morphotypes.

## MATERIALS AND METHODS

### Raw material

Mashua (Figure 1) was obtained from the rural community of Carpapata, Colcabamba district, Tayacaja, Huancavelica, Peru.



**Figure 1.** Whole and sliced mashua morphotypes: a) zapallo, b) Sangre de Cristo, and c) negra.

### Preparation of the raw material

The three mashua morphotypes were washed with potable water and disinfected with a 50 ppm sodium hypochlorite solution. Residual hypochlorite was then removed by rinsing with potable water. Finally, the tubers were cut into slices 2.5 cm thick and placed on drying trays.

### Drying of mashua

Slices of the three mashua morphotypes were dried using a forced-air dehydrator (AISTAN, model ST04, China). Drying temperatures of 50, 60, 70, and 80 °C were evaluated based on previous studies conducted by our research group (Castillo-Zapata *et al.*, 2024). For each condition, approximately 150 g of fresh mashua slices

were placed in the dehydrator and dried for 16 hours at a constant air velocity of 2.5 m/s. Each treatment was performed in triplicate.

### Grinding and sieving of dried mashua

The three morphotypes of mashua, previously dehydrated at different temperatures, were ground individually for 3 minutes using a blade mill. The pulverized material was then sieved using an 850- $\mu$ m mesh. Fractions passing through the sieve were stored in airtight bags until further use.

### Preparation of mashua extracts

Extracts were obtained following the protocol described by Castillo-Zapata *et al.* (2024). Approximately 2 g of finely ground dried mashua were weighed and ex-

tracted with 40 mL of 80% (v/v) methanol. The mixture was homogenized on a magnetic stirrer at 1,000 rpm for 20 minutes at room temperature. It was then centrifuged at 4,500 rpm for 20 minutes, and the supernatant, corresponding to the extract containing solubilized compounds, was collected.

### Determination of total phenolic content

The TPC was determined following the procedure described by Castillo-Zapata *et al.* (2024). In 10-mL test tubes, 1.364 mL of distilled water, 300  $\mu$ L of previously diluted extract, and 136  $\mu$ L of Folin–Ciocalteu reagent were mixed. The mixture was gently agitated and allowed to rest for 8 minutes at room temperature, protected from light. Subsequently, 1.2 mL of a 7.5% (w/v) sodium carbonate ( $\text{Na}_2\text{CO}_3$ ) solution was added, homogenized, and incubated for 2 hours under the same conditions.

Absorbance was measured at 760 nm using a UV-Visible spectrophotometer (Genesys 150, Thermo Scientific, USA). Quantification of TPC was performed using a calibration curve prepared with gallic acid standard solutions at concentrations of 10, 20, 30, 40, 50, and 60  $\mu$ g/mL. Results were expressed as milligrams of gallic acid equivalents (mg GAE) per 100 g of dried mashua.

### Statistical analysis

TPC was evaluated through an analysis of variance (ANOVA), followed by Tukey's multiple comparison test, using a significance level of 5% ( $p < 0.05$ ). Statistical analyses were performed using RStudio (version 2021). Additionally, data related to free moisture and the standard curve were processed using Origin Pro 2025 (SR1, v10.2.0.196).

## RESULTS AND DISCUSSION

### Effect of drying temperature on the free moisture content of mashua

Figure 2 shows the effect of drying temperature on the free moisture content (kg water/kg dry solid) of the three mashua morphotypes: zapallo, Sangre de Cristo, and negra. Free moisture values ranged from 0.0228 to 0.0042, 0.0216 to 0.0066, and 0.0217 to 0.0076 kg water/kg dried mashua for zapallo, Sangre de Cristo, and negra, respectively, across the temperature range of 50 to 80 °C.

At 80 °C and 16 hours, the zapallo morphotype exhibited the lowest free moisture content (0.0042 kg water/kg dry solid), followed by Sangre de Cristo (0.0066 kg water/kg dry solid) and negra (0.0076 kg water/kg dry solid). At 60 and 70 °C, the three morphotypes showed similar behavior, whereas at 50 °C, zapallo showed a slightly higher value than the other two morphotypes (Figure 2).

It is important to note that in all cases, the final free moisture remained below the maximum limit allowed for dry products processed into flour (15%, equivalent to 0.1765 kg water/kg dry solid), as established by the Codex Alimentarius (1985).

For a 200g load of fresh mashua cut into 2.5 cm slices, a drying time of 16 hours and an air velocity of 2.5 m/s were sufficient to reduce free moisture in all three morphotypes to levels compatible with dehydrated products, according to microbiological stability and reduced degradation reaction criteria (Ibarz & Ribas, 2005). This also contributes to lowering storage and transportation costs (Bahnasawy & Shenana, 2004).

Other studies have reported similar values. Acurio *et al.* (2025) observed a free moisture content of 0.064 kg water/kg dry solid in mashua slices (2 cm thick) dried at 60 °C for 24 hours with an air velocity of 2 m/s, comparable to results from this study under similar conditions. Differences likely relate to initial moisture content and morphotype.

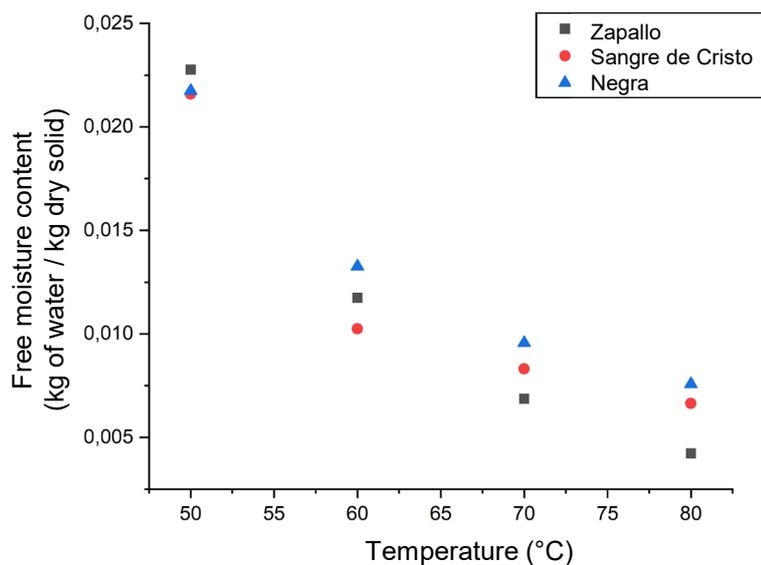
In contrast, Salazar *et al.* (2021) reported a higher value (0.2326 kg water/kg dry solid, equivalent to 18.87% moisture) for 3 cm slices dried at 60 °C for 6 hours, suggesting that slice thickness and drying time influenced moisture retention, and likely the air velocity also affected the drying process.

Fresh mashua moisture values were recorded as 88 ± 0.5% for zapallo and 90 ± 0.5% for Sangre de Cristo and negra. These values are slightly higher than those reported by Coloma *et al.* (2022) for purple mashua (74.51–89.72%), yellow mashua

(82.86–87.81%), and yellow-purple mashua (76.11–83.48%); by Castañeta *et al.* (2024) for santo jonk'ori (81.5%), Achakani (83%), and ch'iyara (80.3%); and by Campos *et al.* (2006) for yellow–yellow (87–92%), purple–yellow (85–89%), purple–purple (87%), and yellow–purple–purple (86%). This confirms that moisture content in fresh mashua is influenced by morphotype, genotype, and ecological conditions of cultivation.

### Effect of drying temperature on the total phenolic content of mashua

Table 1 shows the TPC results for zapallo, Sangre de Cristo, and negra mashua morphotypes dried at 50, 60, 70, and 80 °C. In the zapallo morphotype, TPC ranged from 1,523 ± 61.83 to 2,069 ± 82.01 mg GAE/100 g dried mashua. For Sangre de Cristo, values ranged from 1,732 ± 59.43 to 2,069 ± 30.32 mg GAE/100 g. The negra morphotype showed the highest values, ranging from 5,286 ± 143.74 to 7,929



**Figure 1.** Effect of Drying Temperature on the Free Moisture Content (kg of water/kg of dry solid) of Zapallo, Sangre de Cristo, and Negra

± 120.48 mg GAE/100 g depending on drying temperature (Table 1), mainly due to the anthocyanins found in black mashua (Coloma *et al.*, 2022).

Significant differences ( $p < 0.05$ ) were observed in TPC among the different mashua morphotypes. However, no significant differences were observed between Sangre de Cristo and zapallo morphotypes at 50 and 80 °C.

Regarding temperature influence, significant differences ( $p < 0.05$ ) were observed in TPC among drying temperatures of 50, 60, 70, and 80 °C. For the negra morphotype, no significant differences were found between 60 and 70 °C, although differences were observed between 50, 60, or

70 °C compared to 80 °C. For Sangre de Cristo, there was a significant difference between 50 and 60 °C, but no differences among 60, 70, and 80 °C, nor between 50, 70, and 80 °C. In zapallo, significant differences ( $p < 0.05$ ) were found among temperatures, except between 50 and 70 °C, and between 60 and 70 °C, where no differences were detected.

In the negra and Sangre de Cristo morphotypes, an increase in TPC was observed as drying temperature increased from 50 to 60 °C, likely due to a higher concentration of phenolic compounds resulting from water loss. Moreover, increasing temperature may break covalent bonds, facilitating the release of bound phenolics from the cellular matrix (Onwude *et al.*, 2022).

**Table 1.**  
*Relevant Factors That Impacted Progress or Setbacks in Food Security*

Mashua Morphotypes	Temperature (°C)	TPC (mgGAE/100g dried mashua)*
Zapallo	50	1792.4 ± 6.9 <sup>B;b</sup>
	60	1523.3 ± 61.8 <sup>C;c</sup>
	70	1607.6 ± 80.2 <sup>C;bc</sup>
	80	2069.5 ± 82.0 <sup>B;a</sup>
Sangre de Cristo	50	1732.1 ± 59.4 <sup>B;b</sup>
	60	2069.5 ± 30.3 <sup>B;a</sup>
	70	1932.9 ± 96.6 <sup>B;ab</sup>
	80	1932.9 ± 18.4 <sup>B;ab</sup>
Negra	50	5286.3 ± 143.7 <sup>A;c</sup>
	60	7928.9 ± 120.5 <sup>A;a</sup>
	70	7768.3 ± 283.2 <sup>A;a</sup>
	80	6543.4 ± 150.9 <sup>A;b</sup>

The data are presented as mean ± standard deviation. Identical superscript letters indicate that no significant differences exist ( $p < 0.05$ ) according to Tukey's test.

However, at higher temperatures (70 and 80 °C), a slight reduction in TPC was observed in Sangre de Cristo and a more pronounced reduction in negra. This reduction is likely associated with thermal degradation of thermolabile phenolic compounds, particularly anthocyanins in the negra morphotype.

In contrast, the zapallo morphotype showed a decrease in TPC from 50 to 60 °C, which may be related to polyphenol oxidase activity, a thermostable enzyme that remains active up to temperatures close to 60 °C. This enzyme catalyzes oxidation of phenolics, reducing their concentration (Onwude *et al.*, 2022). Once the enzyme is inactivated at temperatures above 60 °C, an increase in TPC was observed at 70 and 80 °C, likely due to the release of phenolic compounds not degraded by enzymatic action and the concentration of thermoresistant phenolics.

Compared with the results obtained in the present study at 60 °C (Table 1), lower TPC values have been reported for mashua dried at 60 °C for 24 h with an air velocity of 2 m/s (450 mg GAE/100 g) (Acurio *et al.*, 2025), and for mashua dried at the same temperature for 6 h (6.8 mg GAE/100 g) (Salazar *et al.*, 2021). These differences reflect not only the influence of drying conditions on the retention or degradation of phenolic compounds, but also the impact of the crop's origin and production characteristics. In particular, for the lowest reported value, factors such as the final moisture content of the product, air-flow velocity, and extraction method may have contributed to the reduction in TPC.

On the other hand, different TPC values have been reported for freeze-dried mashua compared with those obtained in

this study. Jacobo-Velázquez *et al.* (2022) indicated that TPC in twenty-seven morphotypes of Peruvian mashua ranged from 162.54 mg GAE/100 g (MAC 090 – white, Apurímac region) to 1,316.16 mg GAE/100 g (MAC 092 – black, Ayacucho region).

Similarly, Coloma *et al.* (2022) reported that TPC in purple mashua ranged from 385 to 1,143 mg GAE/100 g dry matter; in yellow mashua, from 182 to 405 mg/100 g dry matter; and in yellow mashua with purple eyes, from 116 to 225 mg/100 g dry matter.

Behar *et al.* (2021) reported TPC values in six fresh mashua accessions ranging from 77.48 to 220.83 mg GAE/100 g, with Tt-19 (skin/flesh: yellow/yellow) and Tt-23 (skin/flesh: purple/purple) being the extreme accessions.

Likewise, Castañeta *et al.* (2024) reported TPC values of 260, 200, and 1,170 µmol GAE/100 g fresh sample for the Santo Jonk'ori, Achakani, and Ch'iyara varieties, respectively.

Additionally, Choquechambi *et al.* (2019) reported the following TPC values, expressed as mg of chlorogenic acid equivalents (CAE)/100 g dry matter: Kellu (yellow), 790 mg; Chejchi (yellow, black eyes), 1,190 mg; Chiar (black), 2,230 mg; Kellu (yellow), 1,280 mg; Keni Kellu (yellow-purple), 1,310 mg; Jachir (yellow, red stripes), 970 mg; and Asuthi (yellow, purple stripes), 800 mg, for mashua samples from Peru and Bolivia.

Different TPC values have also been reported for freeze-dried mashua compared with those obtained in the present study. Campos *et al.* (2006) found that TPC in eleven fresh mashua genotypes ranged from 92 to 337 mg GAE/100 g, with genotypes

ARB-5241 (337 mg GAE/100 g), DP-0224 (305 mg GAE/100 g), and AGM-5109 (275 mg GAE/100 g) presenting the highest values.

Similarly, Chirinos *et al.* (2006) reported TPC values for genotypes ARB-5241 (374.4 mg GAE/100 g), DP-0224 (131.9 mg GAE/100 g), and AGM-5109 (45.5 mg GAE/100 g), all expressed on a fresh-weight basis. Rogez *et al.* (2007) reported maximum TPC values on a dry-weight basis for ARB-5241 (2,200 mg GAE/100 g) and DP-0224 (1,710 mg GAE/100 g).

Likewise, Campos *et al.* (2007) reported TPC values ranging from 1,400 to 2,400 mg GAE/100 g dry matter for cultivars ARB-5241, DP-0224, and AGM-5109. Later, Costa *et al.* (2008) reported TPC values in fresh mashua for genotypes ARB-5241 (skin/flesh, purple/yellow) with 395 mg GAE/100 g, DP-0224 (skin/flesh, purple/purple) with 262 mg GAE/100 g, and ARB-5576 (skin/flesh, yellow/yellow) with 52.2 mg GAE/100 g.

Additionally, Warnier *et al.* (2008) reported the following TPC values in fresh mashua: ARB-5241 (323 mg GAE/100 g; 83.4% moisture), DP-0224 (205 mg GAE/100 g; 84.2% moisture), AGM-5109 (166 mg GAE/100 g; 87.0% moisture), and ARB-5576 (56.3 mg GAE/100 g; 87.1% moisture).

Finally, Campos *et al.* (2018) analyzed eighty-four mashua genotypes and found TPC values on a dry-weight basis ranging from 550 to 1,670 mg GAE/100 g.

Overall, the results obtained in this study, as well as those reported by other authors, demonstrate that mashua morphotypes with black, purple, or dark pigmentation tend to show higher TPC values than

those with yellow or lighter bicolorations. Likewise, the cultivation area exerts a significant influence on TPC, as demonstrated in mashua samples from different agroecological zones in the Puno region (Coloma *et al.*, 2022). Furthermore, TPC values depend on factors such as genotype, solvent type, pH level, solvent-to-water ratio, and extraction time (Rogez *et al.*, 2007).

Compared with other plant species, the black mashua morphotype exhibits a TPC within the range of values reported for maqui (*Aristotelia chilensis*) (3,190 mg/100 g dry matter) (Quispe-Fuentes *et al.*, 2018), aronia (*Aronia melanocarpa*) (2,190 mg GAE/100 g fresh fruit and 9,400 mg GAE/100 g dried fruit) (Kaloudi *et al.*, 2022), and camu camu (12,798.80 mg GAE/100 g fresh fruit) (García-Chacón *et al.*, 2023), species widely recognized for their high antioxidant capacity and classified as superfoods.

The black mashua used in this study exhibits morphological characteristics similar in shape to the black mashua from the AGM-5118 collection (Lingán Grande, Chota, Cajamarca) and in color to the mashua yana ojo from the CM DPA 02 24 collection (Socorro, Ninacaca, Pasco). It is possible that this mashua represents a new collection, which aligns with the statement by Campos *et al.* (2018), who suggest that many more likely exist, given the considerable genotypic variability in shape and color, variability that appears to correlate with the content of bioactive compounds.

## CONCLUSIONS

Drying mashua at temperatures between 50 and 80 °C for 16 h with an air velocity of 2.5 m/s reduced the free moisture content of the zapallo, Sangre de Cristo, and black morphotypes to levels below

those established by the Codex Alimentarius (0.1765 kg water/kg dry solid). The zapallo morphotype exhibited the lowest remaining water content (0.0042 kg/kg). The differences observed between morphotypes and in comparison with previous studies can be attributed to variables such as slice thickness, drying time and air velocity, as well as the tuber's initial moisture content. Likewise, it was confirmed that moisture in fresh mashua is conditioned by morphotype, genotype, and agroecological conditions, factors that must be considered when optimizing industrial drying processes.

Furthermore, TPC showed significant variations according to morphotype and drying temperature. The black morphotype exhibited the highest TPC values, attributable to its elevated anthocyanin

content. The drying temperature of 60 °C favored the concentration of phenolic compounds in most morphotypes, whereas higher temperatures led to partial degradation of thermolabile compounds. The behavior of TPC was influenced by enzymatic activity, particularly polyphenol oxidase, and by the dehydration of the plant matrix.

Discrepancies with previous studies can be explained by variations in genotype, origin, drying conditions, and extraction methods. These results underscore the potential of the black morphotype as a rich source of phenolic compounds, with levels comparable to recognized superfoods, highlighting the importance of continued research on mashua for potential applications in nutraceuticals or functional food ingredients.

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#### Author Contribution Statement

- Veliz-Sagarvinaga R. N.: Conceptualization; methodology; data analysis; and writing.
- Chamorro-Díaz N. G.: Conceptualization; methodology; data analysis; and writing.
- Chávez-Solano Y. M.: Conceptualization; methodology; data analysis; and writing.
- Cornelio-Santiago H. P.: Conceptualization; writing; statistical analysis; review and editing.
- Gutiérrez-Valverde K. S.: Conceptualization; review and editing.

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# Knowledge, attitudes and practices of pregnant mothers about anemia at the Centro de Salud San Luis - 2022, Lima

## *Conocimientos, actitudes y prácticas de madres gestantes sobre la anemia en el Centro de Salud San Luis - 2022, Lima*

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### ABSTRACT

The objective of this study was to determine the level of knowledge, attitudes, and practices regarding anemia among pregnant women attending the San Luis Health Center. The research was quantitative, descriptive-correlational, and cross-sectional in design. A total of 77 pregnant women who attended prenatal checkups during January–February 2023 participated in the study. A validated questionnaire was administered, consisting of two sections: general information and dietary regimen. The results showed that hemoglobin levels among the pregnant women were distributed as follows: 61.1% (47) without anemia, 31.1% (24) with mild anemia, and 7.8% (6) with moderate anemia. Regarding knowledge, 58.4% (45) demonstrated good knowledge, 37.7% (29) regular knowledge, and 3.9% (3) poor knowledge. In terms of attitudes, 93.5% (72) showed positive attitudes and 6.5% (5) negative attitudes. Finally, with respect to practices, 97.4% (75) reported adequate practices and 2.6% (2) inadequate practices. Data were analyzed using Jamovi software version 2.6.22 through the chi-square test, which revealed a significant relationship between anemia level and knowledge, attitudes, and practices. Overall, the findings indicate that the pregnant women had good knowledge, positive attitudes, and adequate practices regarding anemia.

**Keywords:** Anemia, pregnant women, knowledge, attitudes, practices.

### RESUMEN

El objetivo de este estudio es determinar el nivel de conocimiento, actitudes y prácticas sobre la anemia en las gestantes del Centro de Salud San Luis. La investigación fue de tipo cuantitativa, descriptiva orrelacional y con un enfoque transversal. El total de las participantes fueron 77 gestantes que acudían a sus controles prenatales en los meses de



enero-febrero (2023). Se les entregó un cuestionario validado distribuido en 2 partes, los datos generales y régimen dietario. Se obtuvo que los porcentajes de hemoglobina en las gestantes son 61,1 % (47) sin anemia, 31,1 % (24) anemia leve y 7,8 % (6) anemia moderada. En cuanto a sus conocimientos se obtuvo que el 58,4 % (45) fue bueno, 37,7 % (29) regular y 3,9 % (3) malo. Acerca de sus actitudes el 93,5 % (72) fue positiva y el 6,5 % (5) negativas. Por último, en sus prácticas el 97,4 % (75) adecuadas y 2,6 % (2) inadecuadas. Se analizaron los datos con el programa Jamovi versión 2.6.22 mediante la prueba del chi cuadrado y se encontró una relación significativa entre el nivel de anemia y los conocimientos, actitudes y prácticas. Además, se obtuvo como resultado que las gestantes tenían conocimientos buenos, actitudes positivas y prácticas adecuadas acerca de la anemia.

**Palabra clave:** Anemia, gestantes, conocimientos, actitudes, prácticas.

## INTRODUCTION

In Peru, there is a high prevalence of anemia at different stages of life. One of the most vulnerable stages is pregnancy, since the expectant mother must maintain sufficient hemoglobin levels both for herself and for the developing fetus. For this reason, constant attention must be paid to the diet of pregnant women, in addition to reminding them of the importance of undergoing hemoglobin testing at the indicated times (Taipe, 2019). It is important to consider that there are different levels of anemia and that, during pregnancy, reference values differ from those of non-pregnant women, as the type of treatment required depends on these values. According to the World Health Organization (WHO), anemia in pregnant women is diagnosed when hemoglobin levels are  $< 11$  g/dL. When anemia is mild (10–10.9 g/dL), in most cases it can be corrected solely through an adequate iron-rich diet; however, when anemia is moderate (9–9.9 g/dL) or severe ( $< 7$  g/dL), dietary improvement must be complemented with supplementation and, in some cases, blood transfusions. There are also different types of anemia, among which iron-deficiency anemia is the most common and best known, as it is caused by iron deficiency.

When experienced during pregnancy, some of its consequences may include low birth weight, postpartum depression, increased risk of neonatal mortality, among others. According to the Demographic and Family Health Survey (ENDES, 2021), 18.8% of women aged 15 to 49 years suffered from anemia. This figure is particularly relevant, as it corresponds approximately to women of reproductive age. Likewise, according to the National Institute of Health (INS), of the 220,632 pregnant women who attended Ministry of Health (MINSA) health facilities between January and December 2021, 20.6% had anemia; of these cases, 12.1% corresponded to mild anemia, 8.2% to moderate anemia, and 0.3% to severe anemia. It is important to emphasize that all cases of anemia must be addressed promptly, regardless of whether they are mild, moderate, or severe.

For this reason, it was considered highly important to assess, through a survey conducted with prior informed consent, the knowledge, attitudes, and practices of pregnant women. This approach allows for a clearer understanding of how much they know about anemia, about iron-rich foods, and about compliance with pre-

natal nutritional care appointments at the indicated times (approximately six visits during pregnancy). In this way, anemia can be prevented or treated, thereby avoiding the aforementioned consequences for both the mother and the baby. The objective of this study was to determine the knowledge, attitudes, and practices regarding anemia among pregnant women attended at the "San Luis" Health Center during January and February 2023.

## MATERIALS AND METHODS

For the development of this research, a questionnaire validated by Diez and Guerrero in 2011 was used. The instrument consists of two sections: the first addresses general data of the pregnant women, and the second corresponds to the dietary regimen questionnaire, which includes questions related to knowledge, attitudes, and practices. To initiate data collection, authorization was requested from the head of the San Luis Health Center, and all guidelines and protocols established in the Research Ethics Code of Universidad Le Cordon Bleu were followed (Resolution No. 078-CU-ULCB-2021).

After obtaining authorization, during January and February 2023, informed consent was requested from pregnant women receiving care at the "San Luis" Health Center to participate in the study. They were informed that the survey was being conducted by students from the Nutrition and Dietetics program at Universidad Le Cordon Bleu. Inclusion criteria required participants to agree to take part in the study, be in the second or third trimester of pregnancy, and receive care at the "San Luis" Health Center. Exclusion criteria included being in the first trimester of pregnancy, having any pathology, or having a multiple pregnancy. At the end of the data

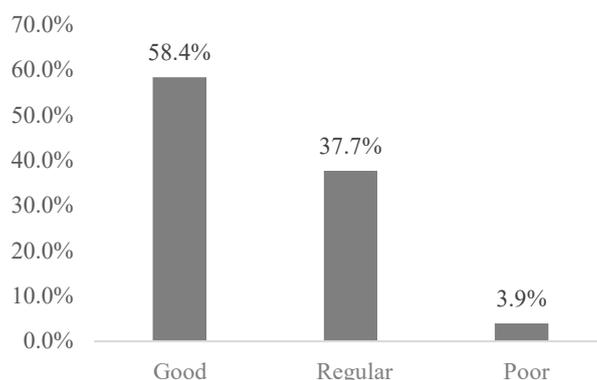
collection period, information from 100 pregnant women was obtained, of which 77 met the inclusion and exclusion criteria.

For the construction of cross-tabulations, data obtained from the surveys were processed using Jamovi software version 2.6.22, applying the chi-square test.

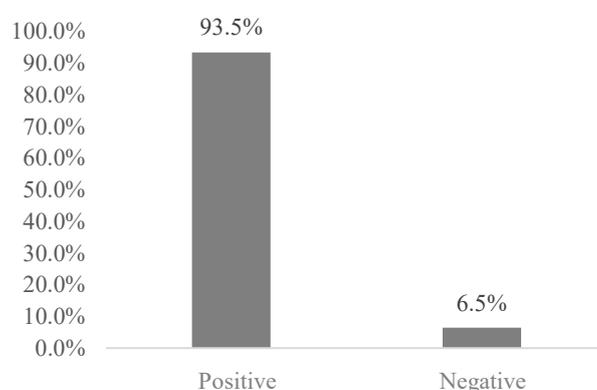
## RESULTS AND DISCUSSION

Figure 1 shows that 58.4% (45) of the surveyed pregnant women had a good level of knowledge, 37.7% (29) had a regular level, and 3.9% (3) had a poor level. In contrast, Aldana L. (2019) reported that 56.3% of pregnant women had a medium level of knowledge, 32.5% had a low level, and 11.2% had a high level. It is worth noting that the study by Aldana L. (2019) was conducted in Huancavelica, and according to the National Institute of Health (INS, 2023), this department ranked third nationwide in 2023 for the highest number of anemia cases among pregnant women, with a total prevalence of 27.16%. The lack of knowledge may be associated with insufficient guidance from health professionals.

Figure 2 shows that 93.5% (72) of the surveyed pregnant women had positive attitudes, while 6.5% (5) exhibited negative attitudes. In contrast, the study by Fernández and Huamán (2019) reported that 70% of pregnant women had an indifferent attitude, 18.3% a favorable attitude, and 11.7% an unfavorable attitude toward anemia prevention. Unlike the present study, the research conducted by Fernández and Huamán (2019) involved adolescents aged 14 to 19 years. This difference could indicate a lack of interest in that population and may also be related to insufficient knowledge about the consequences of gestational anemia, such as preterm birth, growth retardation, and cardiac problems, among others.



**Figure 1.** Classification of the Level of Knowledge of Pregnant Women Regarding Anemia



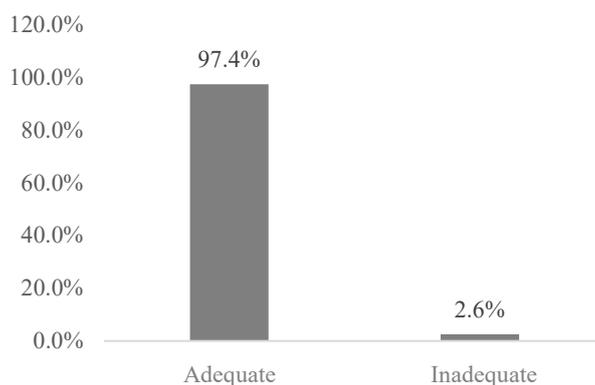
**Figure 2.** Classification Regarding the Attitudes of Pregnant Women Toward Anemia

Figure 3 shows that 97.4% (75) of the surveyed pregnant women demonstrate adequate practices for the prevention of anemia, while 2.6% (2) exhibit inadequate practices. In contrast, Huamán, T., and Contreras, E. (2022) reported that 73.4% of the pregnant women surveyed had poor practices and 26.6% had good practices. Poor practices may be associated with various factors, such as insufficient knowledge, limited access to food, low economic resources, among others.

Table 1 shows the relationship between knowledge levels and anemia status among pregnant women. Twenty-eight res-

pondents with good knowledge do not have anemia, 14 present mild anemia, and 3 have moderate anemia. It is also shown that 2 pregnant women with moderate anemia have a poor level of knowledge. According to the chi-square test performed ( $\chi^2 = 15.6$ ;  $p > 0.05$ ), there is a significant relationship between the variables.

Table 2 shows the relationship between attitudes and anemia level. Among the surveyed pregnant women, 44 with positive attitudes do not have anemia, 24 have mild anemia, and 3 have moderate anemia. In turn, 3 pregnant women with negative attitudes present moderate anemia. Ac-



**Figure 3.** Classification Regarding Women’s Practices Toward Anemia

**Table 1.**  
*Relationship Between Knowledge and Anemia Level*

KNOWLEDGE	ANEMIA LEVEL			Total	Chi-square test (X <sup>2</sup> )			
	NO ANEMIA	MILD ANEMIA	MODERATE ANEMIA		Valor	df	p-value	
GOOD	28	14	3	45	X <sup>2</sup>	15.6	4	0.004
REGULAR	18	10	1	29				
POOR	1	0	2	3				
Total	47	24	6	77				

According to the chi-square test ( $\chi^2 = 17$ ;  $p > 0.05$ ), there is a significant relationship between the variables.

Similarly, Godoy *et al.* (2019) reported a p-value of 0.000 when relating attitudes to anemia levels in pregnant women, indicating a significant association between the variables.

Table 3 presents the relationship between practices and anemia levels among the surveyed pregnant women. Of the par-

ticipants, 47 with adequate practices do not have anemia, 23 have mild anemia, and 4 have moderate anemia, while 2 pregnant women with inadequate practices present moderate anemia. According to the chi-square test ( $\chi^2 = 15.8$ ;  $p > 0.05$ ), the variables show a significant relationship. In contrast, Yurivilca (2024) reported a chi-square value of 5.689 and a p-value of 0.058 when analyzing the same variables, concluding that there was no significant relationship.

**Table 2.**  
*Relationship Between Attitudes and Level of Anemia*

ATTITUDE	ANEMIA LEVEL			Total	Chi-square test (X <sup>2</sup> )		
	NO ANEMIA	MILD ANEMIA	MODERATE ANEMIA		Valor	df	p-value
POSITIVE	44	24	3	71			
NEGATIVE	3	0	3	6	X <sup>2</sup>	17	2 <.001
Total	47	24	6	77	N	77	

**Table 3.**  
*Relationship Between Practices and Level of Anemia*

PRACTICES	ANEMIA LEVEL			Total	Chi-square test (X <sup>2</sup> )		
	NO ANEMIA	MILD ANEMIA	MODERATE ANEMIA		Valor	df	p-value
ADEQUATE	47	23	4	74			
INADEQUATE	0	1	2	3	X <sup>2</sup>	15.8	2 <.001
Total	47	24	6	77	N	77	

## CONCLUSIONS

Most pregnant women demonstrate good knowledge, positive attitudes, and adequate practices regarding anemia. This is likely because they attended their prenatal checkups, consumed iron-rich foods, and prepared them taking into account factors that enhance or inhibit nutrient absorption.

Furthermore, the chi-square test results revealed a significant relationship between anemia levels and knowledge, suggesting that pregnant women applied

the knowledge they had acquired to prevent anemia. The relationship between anemia levels and attitudes may be explained by the women’s interest and adherence to the recommendations provided by healthcare personnel during prenatal visits. Finally, the association between practices and anemia levels may be attributed to the frequent consumption of iron-rich foods, complemented with sources of vitamin C to ensure adequate iron absorption.

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#### **Author Contribution Statement**

- Alejo, R.: Conceptualization; writing; methodology; review and editing; statistical analysis; project administration.
- Castro, M.: Conceptualization; writing; methodology; review and editing; statistical analysis; project administration.

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*Relationship between sleep hours and academic performance of university students.*

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