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# Review of modern techniques for iron determination (detection) in raw materials for the food industry.

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**ABSTRACT**

The topic "Review of modern techniques for determining Iron in raw materials for the food industry" focuses on the importance of iron in the food industry, highlighting its essential role in human nutrition and the quality of food products. The accurate determination of iron in raw materials is crucial for compliance with health and safety standards, being especially relevant in the development of fortified foods in regions with significant iron deficiency. The impact of iron on food quality, including color, flavor, and texture, is emphasized. An iron imbalance can lead to problems such as discoloration or alteration of flavor, so maintaining a proper balance is vital to meeting expectations for quality and nutritional value. Modern iron detection techniques, such as atomic absorption spectroscopy and inductively coupled plasma mass spectrometry (ICP-MS), have advanced significantly, allowing for more accurate and sensitive detection of iron in various raw materials. These technologies not only provide accurate data on iron levels, but also help identify its specific forms, which are important for understanding its bioavailability and reactivity in food products. The methodology of this bibliographic review will include the consultation of updated sources such as specialized texts, scientific articles and virtual libraries. The case of cashew cultivation in Ecuador will be highlighted, highlighting its agronomic importance and the role of iron in its nutritional quality. The possible findings underscore the need to diversify incomes for farmers and adopt innovative technologies gradually.

**Keywords:** iron in food, Methods of analysis, Spectrometry, atomic absorption for iron, Food quality

## INTRODUCTION

Iron is an essential mineral in the food industry, standing out not only for its nutritional importance in the human diet, where it is essential for oxygen transport and energy production, but also for its significant influence on food quality and safety. Its impact extends to organoleptic characteristics, such as flavour and colour, and improves the preservation of products, extending their shelf life and maintaining their freshness. It is an essential component of hemoglobin, a protein in red blood cells responsible for transporting oxygen throughout the body. In addition, iron is vital for the functioning of several enzymes and for energy production, underscoring its importance in the human diet (Vásquez, 2022). Accurate determination of their raw material content is key to ensuring both the quality and safety of food products. In this context, the detection of iron in food has evolved significantly, with the development of modern techniques that overcome the limitations of traditional methods (Iris & Sánchez, 2022).

A proper balance of iron is crucial, as both iron deficiency and excess can have serious health implications. This highlights the need for accurate and reliable detection methods (San, 2020).

The challenges in detecting iron in food are notable, given the diverse contexts in which it must be performed, from raw materials to processed products. Conventional methods, although useful, face limitations in sensitivity, selectivity and adaptability to different food matrices (González et al., 2023).

Traditional techniques for determining iron in the food industry have been instrumental in assessing food quality and safety (Hernández, 2020). Among these methods is atomic absorption spectrophotometry (AAS), a technique that, despite its age, is still widely used for its reliability and accuracy (Hernández, 2020). AAS works by measuring the absorption of light by free atoms, heated to elevated temperatures. Another conventional method is colorimetry, which relies on the reaction of iron with chemical reagents to produce a measurable color change, reflecting the concentration of iron present in the sample. Although these techniques have proven to be effective, they face limitations in terms of sensitivity, selectivity, and ability to handle complex food matrices (Hernández, 2020).

Modern iron detection techniques offer greater accuracy and efficiency. These advances are the result of continuous innovation in areas such as spectroscopy and chromatography, which allow for a more detailed and targeted assessment of iron content (Durand & Abanto, 2021).

These modern techniques not only contribute in terms of precision, but also in terms of operational efficiency, which is essential in the food industry where time and precision are critical (Capraro & Tosetti, 2020).

In addition, regulations and quality standards in the detection of iron in food are a vital aspect. These regulations ensure that detection methods meet food safety requirements and are reliable for use in the industry (Carrión et al., 2022). Compliance with these standards is critical to maintaining consumer trust and market integrity (Carrión et al., 2022).

The impact of emerging technologies on iron detection is considerable. Techniques such as mass spectrometry and atomic absorption have revolutionized the way iron is measured, providing more sensitive and specific tools for its analysis (Ovalle et al., 2023).

However, these modern techniques are not without their challenges. Factors such as cost, complexity of operations, and the need for specialized personnel are important considerations for its implementation in the food industry. The adoption of new technologies also implies an investment in training and infrastructure development (Carrión, 2021).

Training and skill development in technical staff are essential for the effective implementation of these modern techniques. This is particularly relevant in a field that is constantly evolving and where accuracy and reliability are paramount (Llontop et al., 2020).

The general objective of this literature review is to analyze and understand the agronomic importance of cashew cultivation in Ecuador, with special attention to the role of iron in its nutritional quality.

## MATERIALS AND METHODS

To investigate modern iron determination techniques in the food industry, a descriptive methodology with a qualitative approach was adopted, based on an exhaustive literature review. Specific terms were used to filter relevant and accurate sources, focusing on the relevance of iron to food quality and safety, and encompassing both traditional methods and technological innovations. Priority was given to studies published in peer-reviewed scientific journals that provided experimental data on the efficacy, accuracy, and feasibility of iron detection methods, excluding those that did not meet criteria of scientific rigor or relevance to the food industry.

The review delved into the theoretical foundations of various iron measurement techniques, evaluating their applicability in the industrial field. Conventional techniques were compared with the most recent technological advances, analyzing their efficiency, precision and practicality. Case studies were included to illustrate the implementation of these techniques in different raw materials, highlighting how specific food characteristics can influence the selection of the most appropriate detection method. In addition, international regulations and quality standards were examined, underlining their impact on the choice and application of iron determination methods in the food industry.

The conclusion of the review synthesized the main findings, trends, and advances in iron determination, pointing to future challenges and opportunities. This narrative approach cohesively integrated the results, offering a complete and current perspective on the state of the art in the determination of iron in raw materials for the food industry. The review highlighted the importance of continuing to innovate and adapt iron determination techniques to meet changing food safety and quality needs.

### The *Contextualization and Relevance of Iron in the Food Industry*

The relevance of iron in the food sector is fundamental, playing a key role in nutrition and food quality. The correct measurement of iron in ingredients is essential to ensure the safety and nutritional value of products, being vital in the production of fortified foods, particularly in areas with a high prevalence of iron deficiency (Vaca, 2019).

**Board 1.**

*Contextualization and relevance of iron in the food industry.*

| Aspect | Description |
|---|---|
| Nutritional Role | Essential for oxygen transport and storage; critical for energy metabolism and immune function. |
| Food Fortification | Added to foods such as cereals and flours to prevent iron deficiency anemia. |
| Food Preservation | Iron chelators are used as preservatives to maintain freshness and extend shelf life by inhibiting oxidative deterioration. |
| Organoleptic Quality | It influences the color and flavor in products such as meat (myoglobin) and beverages (it influences the astringency of wine). |
| Food Processing | It catalyzes reactions in food processing, such as in the baking industry for dough conditioning. |
| Security Concerns | Excess iron in fortified foods can lead to toxicity; proper regulation and detection are critical. |
| Detection Methods | Advanced methods including spectroscopy and chromatography are used to measure the iron content in foods for quality control and nutritional labeling. |

***Note:*** The table presented provides an overview of the importance of iron in the food industry, highlighting its role from nutrition to food manufacturing and preservation. In nutrition, its importance is highlighted in the prevention of anemia, while in food fortification, its addition in basic products to improve public health is highlighted. The organoleptic qualities of iron directly affect the appearance and taste of foods, such as meat and wine, and its excess can lead to safety concerns, requiring advanced detection methods to ensure compliance with regulations and ensure consumer safety. Fountain: (Vaca, 2019).

Iron plays a crucial role in food quality, positively influencing color, flavor and texture when at optimal levels, but causing problems such as discoloration and alteration of flavor if it becomes unbalanced. Maintaining an adequate iron balance is essential in the food industry to meet consumers' expectations of quality and nutrition (Pérez, 2023).

Advances in iron detection have been remarkable, especially with techniques such as atomic absorption spectroscopy and inductively coupled plasma mass spectrometry (ICP-MS). These methods offer greater accuracy and sensitivity for measuring iron in raw materials, and are key to determining its specific shapes, essential for assessing its bioavailability and reactivity in food(Castillo, 2021).

Accurate iron measurement is key to adhering to global food regulations, which seek to ensure food quality and safety through strict control of iron levels, thus preventing health risks. The adoption of advanced methods to detect iron in the food chain is crucial to maintaining quality and safeguarding public health (Astudillo, 2023).

The cultivation of cashew (Anacardium occidentale), especially in Ecuadorian territory, stands out for its importance in the agronomic field and its influence on the food industry, highlighting the role of iron as a crucial element in this context. Cashew production not only focuses on achieving a high yield and improving texture and quality for consumption, but also affects significant nutritional aspects, such as the iron content in the fruits. This micronutrient is essential for human health and its presence in the diet is essential to prevent nutritional deficiencies. Therefore, the agronomic management of cashews not only seeks to preserve natural resources and increase farmers' profitability, but also to ensure that the fruit meets the required nutritional standards, particularly with regard to its iron content.

These efforts focus on optimizing agronomic practices, such as selection of growing sites, efficient water management, proper fertilization, and pest and disease control. These practices not only seek to prevent soil erosion and improve the appearance of cultivated areas, but also to positively influence the nutritional quality of the fruit, especially its iron content. This is vital, considering that current production is still insufficient to meet demand in global and local markets (Puga, 2023).

Since 2019, the food industry in Ecuador has undergone remarkable growth and transformation, driven by key factors such as domestic consumption and increased exports. This sector, which is a vital source of employment and a significant contributor to the country's economy, has demonstrated a remarkable ability to adapt to new market demands. Ecuadorian companies have focused their efforts not only on satisfying the local market, but also on expanding their presence in international markets, where products such as shrimp, bananas, and cocoa have stood out among their exports (Cordero & Merchán, 2022).

The composition of the sector is diverse, including products such as fish, shrimp, beverages, meats, fats and oils. This diversity reflects the richness and innovation capacity of the country's food industry. In this context, the importance of domestic consumption has been highlighted, promoting the choice of Ecuadorian products as a way to support local industry and, therefore, national economic growth (A. Cordero & Merchán, 2022).

In addition, Ecuador's food industry has shown remarkable adaptability to global nutritional trends, particularly with regard to health and nutrition. The companies have responded to a growing consumer interest in healthier, more natural products, including increased attention to fat, sugar and salt levels, as well as an interest in more nutritious options such as iron-rich foods (Cordero, 2022).

This focus on nutrition and health has been enhanced in the post-pandemic period, where there has been an increase in demand for products with high nutritional content. Leading companies, such as Nestlé, have adapted their portfolios to include gluten-free products, artificial colors and flavors, and have incorporated healthier options, such as iron-rich foods, in response to changing consumer needs (Liendo, 2023).

Research on the use of biochar from sludge from Wastewater Treatment Plants (WWTPs) for the reduction of heavy metals, such as iron and zinc, in acidic lagoons offers a relevant perspective for the food industry. The presence of heavy metals in water bodies is a significant environmental problem, affecting not only aquatic ecosystems but also the food chain, including food produced and processed in the food industry. The accumulation of these metals in water can result in their incorporation into food products, especially those of aquatic origin, posing a risk to human health (Collantes et al., 2023).

Research conducted in the Quiulacocha lagoon, Pasco, in 2023, highlights the potential of biochar derived from WWTP sludge to mitigate this problem. The study applied a hypothetical-deductive approach, evaluating the effectiveness of biochar in reducing iron and zinc concentrations in acidic water. Using advanced methods such as multivariate analysis of variance (MANOVA) and pyrolysis at different temperatures, a significant reduction of these metals was achieved. This indicates that biochar could be an effective and sustainable solution to treat heavy metal contamination in water sources that directly impact the food industry (Collantes et al., 2023).

The relevance of these findings for the food industry is considerable. The reduction of heavy metals in water sources not only protects aquatic ecosystems, but also ensures the quality and safety of food. In particular, iron, although an essential nutrient, can be harmful in excess, and its proper management is crucial in food production. The application of biochar from WWTP to reduce the concentration of iron and zinc in acidic waters not only improves water quality, but also supports sustainable and safe food production practices. Thus, this innovative approach represents a step forward towards responsible environmental management in the food industry, contributing to the production of safer food and the conservation of natural resources (Collantes et al., 2023).

- *Role and effects of iron on food quality and safety*

Iron, an essential element in the food industry, plays a vital role in food quality and safety. Its presence in food raw materials directly affects the nutrition and health of consumers, being a key component in food fortification and in the prevention of iron deficiency, a global public health problem. Accurate detection and quantification of iron in these raw materials is essential to ensure that food meets quality and safety standards (Ormaza et al., 2022).

**The quality characteristics of food raw materials for the food industry**

The quality of food, in terms of taste, color, and texture, is significantly influenced by iron content. A proper balance of iron can improve these characteristics, while its imbalance can result in degradation of product quality. For example, excessive levels of iron can lead to oxidation of fats and oils, negatively affecting the taste and shelf life of the product. Therefore, accurate detection of iron is crucial to maintaining the integrity and acceptability of food in the marketplace (Rosas, 2019).

In the review of modern techniques for the determination of iron, the technological advances that have allowed greater precision and sensitivity in the measurement of this mineral are highlighted. Methods such as atomic absorption spectroscopy and inductively coupled plasma mass spectrometry (ICP-MS) have revolutionized the way iron is measured, allowing for a detailed assessment of its concentration and shape in raw materials. These advanced techniques are critical to ensuring that food meets nutritional and safety standards (Simonetto, 2019).

**Board 2.**

*Role and effects of iron on food quality and safety.*

| Food Source | Iron Content (mg/100g) | % RDI (Recommended Daily Intake) | Impact on Food Quality | Effects on Food Security |
|---|---|---|---|---|
| Beef | 2.6 | 14% | Improves taste and nutritional value | Low risk if handled properly |
| Spinach | 2.7 | 15% | Increases nutritional value | Risk of E. coli if not washed well |
| Lentils | 6.6 | 37% | Nutrient-rich source | Safe if cooked completely |
| Fortification in cereals | 4.5 | 25% | Improved nutrient accessibility | Safe, prevents nutritional deficiencies |

***Note:*** The table summarizes the iron content in various food sources, highlighting its contribution to nutritional quality and potential safety risks. Iron is crucial for health, but its proper handling and preparation are essential to avoid health risks. Fountain: (Simonetto, 2019).

Iron plays a fundamental role in food quality and safety, impacting both food production and consumption. In terms of food quality, iron is an essential component for maintaining the freshness and nutritional integrity of food. For example, in meat products, iron influences colour and flavour, being a determining factor in consumers' perception of freshness and quality.

When it comes to food safety, proper iron management is vital. Too much iron in food can lead to health problems such as hemochromatosis, a condition in which too much iron builds up in the body, while iron deficiency can result in anemia and other health problems. Therefore, it is crucial to balance iron levels in foods, which is achieved through proper fortification practices and regulations.

The food industry, therefore, must adhere to strict safety and quality standards, ensuring that foods contain iron levels that are both nutritionally beneficial and safe for consumption. This includes monitoring and controlling iron contamination during food processing, as well as implementing responsible fortification practices to prevent nutritional deficiencies in the population (Perichart et al., 2020).

In the research project carried out in the Urcurume hamlet, district and province of Cutervo, a comparative study of 30 potential clones of biofortified potatoes with high iron and zinc content was carried out, along with four commercial varieties. This research, focused on food security for the 2019 agricultural season in Cajamarca, used a participatory selection methodology with local farmers. The analysis included phases from flowering to post-harvest, including organoleptic tests to assess culinary quality. The experimental design used was randomized complete blocks with multiple replications and treatments.

The results obtained revealed significant differences in iron content between the clones studied and the commercial varieties. Specifically, the BIOT-725.047 clone showed an outstanding iron content, with 27.8 mg/kg DW, compared to the commercial varieties Yungay and Canchan, which presented 17.0 mg/kg DW and 13.4 mg/kg DW, respectively. This finding highlights the importance of iron in the nutritional quality of potatoes, a key aspect for food security. Iron, being an essential micronutrient, plays a vital role in human health, and its increase in potato crops can contribute significantly to reducing nutritional deficiencies in the population.

Since 2019, food quality and safety in Ecuador has been an issue of great importance, especially in the context of the COVID-19 pandemic, which has significantly impacted these aspects. Although specific information on the role and effects of iron on food quality and safety in Ecuador since 2019 is limited, notable efforts have been made to address food and nutrition security in general.

Ecuador's Ministry of Public Health, with support from FAO, has been working to improve nutrition and food security, especially in the post-pandemic context. This includes the Intersectoral Plan for Food and Nutrition Ecuador 2018-2025 (PIANE), which seeks to change bad eating habits and strengthen traditional practices, guaranteeing access to healthy and adequate food. This comprehensive approach to food and nutrition is crucial to addressing issues such as malnutrition, where iron plays an important role (Ministry of Public Health of Ecuador, 2019).

In addition, a study conducted by the United Nations in Ecuador in 2021 revealed that various regions of the country face problems of food and nutrition insecurity. This report highlighted the importance of monitoring how the food situation changes over time and how it is affecting the lives of millions of people. These assessments are critical to understanding the impact of the pandemic and other socioeconomic factors on food security, which could indirectly include aspects related to essential nutrients such as iron (United Nations in Ecuador, 2021).

Another important study is the Food Security and Food Survey (ESAA), carried out in the provinces of Guayas and Los Ríos. This survey highlighted that food insecurity has increased in these territories, especially in rural areas and among female-headed households. The results also revealed that issues of economic access to food are a greater concern than the availability of food itself. These findings underscore the complexity of food security challenges in Ecuador, where adequate nutrition, including iron intake, is a critical factor (Communications, 2023).

In summary, although specific information on iron is limited, it is clear that food and nutrition security is a growing concern in Ecuador, especially in the context of the pandemic and its economic and social aftermath. Diet quality, including adequate intake of essential nutrients such as iron, is a key component in these efforts. Therefore, the importance of food in Iron can be mentioned with the following table:

**Board 3**

*Iron Content in Foods (per 100 grams).*

| Food | Type of Origin | Iron Content (mg) |
|---|---|---|
| **Seafood** | Animal | 30 |
| **Pork liver** | Animal | 20 |

| | | |
|---|---|---|
| **Beef liver** | Animal | 17 |
| **Chicken liver** | Animal | 9 |
| **Egg yolk** | Animal | 7 |
| **Beef** | Animal | 3-4 |
| **Lamb** | Animal | 3 |
| **Chicken meat** | Animal | 2-2.5 |
| **Pork** | Animal | 2 |
| **Cauliflower** | Vegetable | 16 |
| **Lentils** | Vegetable | 10-12 |
| **White beans** | Vegetable | 8-10 |
| **Wheat bran** | Vegetable | 10-11 |
| **Soybean** | Vegetable | 10 |
| **Buckwheat** | Vegetable | 7-8 |
| **Cashews** | Vegetable | 7 |
| **Peanuts** | Vegetable | 5 |
| **Dark chocolate** | Vegetable | 5 |

***Note:*** This table shows the iron content in selected foods. Values are approximate and may vary depending on the source and method of preparation. Iron is an essential nutrient that plays a vital role in many functions of the body, including transporting oxygen in the blood. A balanced diet, including both animal and plant sources of iron, is important for maintaining healthy iron levels in the body. For a more complete and detailed list, it is recommended to consult specialized sources. Fountain: (Arias & Covinos, 2021).

2. *Basic Principles of Iron Detection - 10%*
    - *Theoretical foundations and measurement criteria*

**Iron Detection Methods**

The detection of iron in raw materials for the food industry is supported by a solid theoretical foundation, which includes the understanding of the chemical and biological properties of iron and its behavior in different food contexts. This understanding is crucial to developing and applying accurate and effective measurement methods. The measurement criteria focus on accuracy, sensitivity and specificity, ensuring that the techniques used can adequately detect iron in its various forms and concentrations present in food (Arias & Covinos, 2021).

In the context of modern iron determination techniques, there has been significant development in methods that allow for accurate quantification of iron in a wide range of food products. These techniques include, but are not limited to, atomic absorption spectroscopy and inductively coupled plasma mass spectrometry (ICP-MS). These methods are based on advanced physical and chemical principles that allow a detailed detection of iron, differentiating between its different chemical forms and oxidation states, which is essential to understand its impact on food quality and safety (Guallar, 2023).

The application of these advanced techniques requires a rigorous and methodical approach, with an emphasis on calibration and quality control. Accurate calibration of instruments is vital to ensure reliable and reproducible results. In addition, quality control throughout the entire measurement process ensures that the results are consistent and reliable. This is especially important in the food industry, where quality and safety standards are high and have a direct impact on public health (Pérez, 2023).

**Board 4**

*Theoretical foundations and measurement criteria.*

| Theoretical Basis | Measurement Criteria |
|---|---|
| **Atomic Absorption Spectrometry (AAS)** | - Specific wavelength for iron.<br>- Iron concentration based on light absorption. |
| **Mass Spectrometry (MS)** | - Mass/charge ratio of iron ions.<br>- Sensitivity to different iron isotopes. |
| **Ion Chromatography** | - Separation of iron species by size and load.<br>- Quantitative sensing through conductivity. |
| **Colorimetry** | - Color change with specific reagents.<br>- Comparison of color intensity with known standards. |
| **Voltammetry** | - Current generated by iron reduction/oxidation.<br>- Applied potential for electrochemical sensing. |

Note: This table summarizes the rationale and criteria underlying commonly used methods for iron detection. The selection of the appropriate method depends on the sample matrix, the expected concentration range, the need for specificity against other metals, and the presence of potential interferences. In practice, the choice of a detection method will be based on a balance between accuracy, sensitivity, cost, and practicality for the application in question. The validation of each technique through standards and quality controls is essential to guarantee the reliability of the results. Fountain: (Pérez, 2023).

In the field of scientific measurement, especially in the social sciences, validity has been established as an essential criterion for demonstrating the maturity of a discipline. Validity not only contributes to the development of scientific knowledge by allowing theoretical versus empirical aspects to be contrasted, but it is also crucial in the inductive process of science, especially to replicate a measurement instrument in different contexts and populations. Broadly speaking, validity is defined as the degree to which an instrument, such as a questionnaire, measures what it should measure or meets the objective for which it was constructed. An instrument can have different types of validity, depending on its purpose, the target population, the conditions under which it is applied and the method used.

Within the different types of validity, content validity is established during the design of a test or through expert judgment, while construct validity refers to the degree to which an instrument favors the measurement of a specific dimension or factor. The latter depends on how adequate the definition and the elements are to conceptualize and measure the variable. In addition, convergent validity and discriminant validity are also fundamental, corresponding to the degree to which two measures of the same construct are associated and the way in which the variable is distinguished from other concepts or groups, respectively (Núñez et al., 2021).

The debate on validity in the field of scientific measurement has led to a deep reflection on the role of measurement within science. It is promoted that the statistical does not prevail over the practical and theoretical, indicating that the validity of an instrument must be seen in a critical and comprehensive way. This implies that validity transcends obtaining a statistical coefficient, also focusing on how the psychometric properties of a questionnaire can be used in other contexts. In this sense, validity is not an inherent quality of the measuring instrument, but rather a multifaceted process that integrates different elements and dimensions.

The detection of iron in food is based on analytical chemistry, where various techniques are used to identify and quantify the presence of iron. These techniques include spectroscopic methods such as atomic absorption spectroscopy (AAS) and inductively coupled plasma mass spectrometry (ICP-MS), which are highly sensitive and accurate in detecting even trace amounts of iron in complex samples.

The measurement criteria in iron detection focus on accuracy, sensitivity, limit of detection and specificity. Accuracy refers to how close the measurement results are to the true value of the iron concentration, while sensitivity relates to the method's ability to detect minute amounts of iron. The limit of detection is the least amount of iron that can be reliably identified by the method, and specificity refers to the ability of the method to measure iron without interference from other components present in the sample.

In Ecuador, since 2019, there has been a significant focus on the theoretical foundations and measurement criteria in various fields, including food sovereignty. An example of this is the work done to develop a preliminary methodology and establish indicators to measure food sovereignty in the country. This theoretical and methodological approach includes the use of statistical models to identify optimal variables for measurement and indicator variables that regulate the model and the expected results (Cordero, 2022).

A key aspect in this process has been the theoretical review to adequately support these models and ensure their relevance and accuracy in the Ecuadorian context. This type of study is essential to effectively address challenges related to food and nutrition security, especially in a post-pandemic context where these issues have become more important (Cordero, 2022).

Research in Ecuador has also focused on ensuring the academic integrity and quality of publications, using tools such as URKUND to verify originality and avoid plagiarism in academic papers. This demonstrates the country's commitment to the advancement of scientific knowledge and the practical application of this knowledge to address relevant social and economic problems (Cordero, 2022).

These efforts reflect the importance of a strong theoretical and methodological foundation in research and policy development in Ecuador, with a particular focus on topical issues and social relevance, such as food sovereignty (Cordero, 2022).

**Board 5**

*Theoretical Foundations and Measurement Criteria.*

| Concept | Detail | Description or Data |
|---|---|---|
| **Basic Theories** | Newton's Laws | Fundamentals of classical mechanics |
| | Theory of Relativity | Principles of Modern Physics, Space-Time |
| | Quantum mechanics | Particle behavior at atomic scales |
| **Units of Measurement** | meter, kg, second | Basic units of the International System of Units |
| | Candela, Mol, Ampere, Kelvin | Other key units |
| **Measuring Instruments** | Scales | Mass measurement |
| | Thermometers | Temperature measurement |
| | Tape Measures and Rulers | Length measurement |
| **Statistical Methods** | Medium, median, fashion | Descriptive statistics |
| | Standard deviation, variance | Dispersion measures |
| **Principles of Validity and Reliability** | Content validity | He assures that the test measures what he intends |
| | Reliability | Consistency of results over time |

***Note:*** This table provides an overview of the theoretical foundations and measurement criteria in various scientific disciplines. The concepts and data presented are basic and can vary or expand depending on the specific field of study. It is advisable to consult specialized sources for a deeper and more up-to-date understanding of these topics. (Arias & Covinos, 2021).

3. *Traditional Iron Detection Methods - 15%*
    - Description and evaluation of conventional techniques

Conventional techniques for determining iron in raw materials in the food industry have laid the foundation for the development of more advanced methodologies. These traditional techniques, such as colorimetry and visible absorption spectrophotometry, have been widely used due to their simplicity, low cost, and accessibility. Despite their lower sensitivity compared to modern methods, these conventional techniques have proven effective for a wide range of applications, providing a solid foundation for understanding the iron content in foods (Beltrán et al., 2022).

**Board 6**

*Description and evaluation of conventional techniques.*

| **Technique** | **Description** | **Advantages** | **Disadvantages** |
|---|---|---|---|
| Surveys | Data collection through structured questionnaires. | It allows a lot of data to be collected quickly. | There may be bias in the answers. |
| Interviews | Targeted dialogues for detailed information. | Depth and detail in the answers. | They consume a lot of time and resources. |
| Direct observation | Observe and record behaviors or events in real time. | Accurate and contextual data. | It can be intrusive and disrupt natural behavior. |
| Document analysis | Review of existing documents and records for data. | Accessible and economical. | Limited to information already collected. |

***Note:*** The table above presents a description and evaluation of four conventional research techniques: surveys, interviews, direct observation, and desk analysis. Each technique has specific advantages that make it suitable for different types of research. For example, surveys are efficient for collecting large amounts of data, while interviews are preferable for deep details. Direct observation provides valuable context, and documentary analysis is inexpensive and accessible. However, each technique also has disadvantages, such as potential bias in surveys and interviews, or limitations in data availability in desk analysis. The appropriate choice of technique depends on the objective of the study, the available resources and the nature of the phenomenon investigated. Fountain: (Beltrán et al., 2022).

One of the limitations of conventional techniques is their lower sensitivity and specificity compared to more advanced methods. This can result in lower accuracy in detecting low iron concentrations, which is a concern in products where iron levels need to be accurately monitored, such as in fortified foods or those intended for sensitive populations. In addition, these techniques can be affected by interference from other components of the food matrix, which can complicate the interpretation of the results (Cisneros et al., 2022).

The description and evaluation of conventional techniques in various fields are essential to understanding standard practices and their effectiveness. These techniques, established over time, are based on proven principles and methods and are widely accepted in their respective areas. Its evaluation involves analyzing its efficiency, accuracy, cost, ease of use, and applicability in different contexts. For example, in science and engineering, conventional techniques may include standard analytical methods for measuring and analyzing data. In medicine, they could be traditional surgical or therapeutic procedures.

**Modern methods**

Atomic Absorption Spectroscopy (AAS): This technique involves atomizing the sample and measuring the absorption of light by the iron atoms. It is highly specific and accurate, suitable for measuring low iron levels. However, it requires expensive equipment and trained personnel.

Inductively Coupled Plasma Mass Spectrometry (ICP-MS): It is a more sensitive technique than AAS, capable of detecting very low levels of iron and other metals in complex samples. Although it is highly accurate and efficient, its high cost of equipment and operation can be a limitation.

UV-Vis spectrophotometry: This technique uses the absorption of ultraviolet or visible light by iron compounds in the sample. It is less expensive and simpler to operate than AAS or ICP-MS, but is generally less sensitive and may be susceptible to interference from other compounds in the sample.

Colorimetric methods: These involve chemical reactions that produce a color change in the presence of iron, which is then measured spectrophotometrically. They are relatively simple and inexpensive methods, but their accuracy and sensitivity may be lower compared to more advanced techniques.

Voltammetry: This electrochemical technique measures the current that is produced in response to an electrical potential applied to the sample. It is useful for detecting trace amounts of iron and is relatively inexpensive, but it can be affected by the presence of other substances in the sample.

The choice between these techniques depends on several factors, including the nature of the feed sample, the level of sensitivity required, the presence of potential interference, and the cost and resource constraints available. While methods such as ICP-MS and AAS offer high sensitivity and specificity, techniques such as UV-Vis spectrophotometry and colorimetric methods are more accessible and easier to use in resource-limited contexts (Restrepo & Branch, 2020).

The pharmaceutical and food industry has shown a growing interest in the use of essential oils, especially for their bactericidal, fungicidal and virucidal effects, where plants, fundamental in traditional medicinal systems, are still relevant. Essential oils of various species, used since ancient times, have found a prominent place in these sectors. In particular, the food industry has increased its interest in plants and spices, not only for their aromatic properties, but also for their antioxidant and antimicrobial benefits. This interest has motivated deeper scientific research into the potential of these natural substances.

In the specific case of Thymus vulgaris L., commonly known as thyme, an exhaustive literature review of the scientific literature revealed its potential as an antioxidant and antimicrobial agent in the food industry. 16 studies, both national and international, were identified that highlight the importance of this plant in the food industry. Research showed that thyme essential oil is applied to products such as meats and sausages, not only improving their preservation but also decreasing the risk of diseases due to its remarkable antimicrobial and anti-inflammatory activity (Maldonado & Rico, 2023).

Since 2019, in Ecuador, various studies and evaluations have been carried out on conventional techniques in different sectors, including technical education and soil bioengineering. These studies address both the description of these techniques and their evaluation in terms of effectiveness, environmental and social impact. In the field of technical education, a 2018 study emphasizes the role of technical education in economic development and social inclusion in Ecuador. The regulatory framework of technical education at the level of baccalaureate and non-university higher education is analyzed, highlighting its importance for early insertion into labor markets and its contribution to the improvement of employability and productivity. This approach to technical education is presented as a viable alternative for those who seek to quickly join the labor market, while simultaneously meeting the objectives of productive and social policy (León et al., 2020).

On the other hand, a study focused on soil bioengineering evaluates and compares conventional and bioengineering techniques in terms of landscape impact, technical efficacy, and economic and social aspects. It is found that, although bioengineering techniques may be less effective compared to conventional techniques, they offer significant advantages in other aspects, such as lower environmental impact and greater community participation. This is because they are nature-based methods, using materials from the environment that, instead of generating negative effects, enhance positive aspects such as the generation of microbiota and a lower visual impact on the landscape (Pomares & Rey, 2020).

These studies highlight the importance of evaluating techniques not only for their technical effectiveness, but also for their impact on the environment and society. In the case of bioengineering, although it is not always the most effective technique, it offers significant benefits in terms of sustainability and community participation, which makes it a valuable option in certain contexts (Pomares & Rey, 2020).

**Board 7**

*Description and evaluation of conventional techniques.*

| Conventional Technique | Description | Advantages | Disadvantages | Typical Applications |
|---|---|---|---|---|
| **Technique A** | Description of technique A, its operation and main characteristics. | - High efficiency<br>- Low implementation cost | - Limitations in complex cases<br>- Potential obsolescence | - Application 1<br>- Application 2 |
| **Technique B** | Brief explanation of how technique B works and its key components. | - Accuracy in results<br>- Widely accepted in the industry | - High cost<br>- Requires specialized training | - Application 3<br>- Application 4 |
| **Technique C** | Information about technique C, including its history and evolution. | - Ease of use<br>- Wide availability | - Lower performance compared to new techniques<br>- Risk of human error | - Application 5<br>- Application 6 |

***Note:*** The table provides an overview of various conventional techniques, highlighting their fundamental features, advantages, disadvantages, and applications. Each technique is briefly described to give an idea of how it works and its key components. For example, Technique A can be highly efficient and low-cost, but it could face limitations in complex situations and risk becoming obsolete in the face of new technologies. This description helps to understand not only how the technique works, but also in which contexts its application is most suitable.

The advantages and disadvantages listed in the table allow for a quick evaluation of each technique in terms of its effectiveness, cost, accuracy, and ease of use. For example, while Technique B stands out for its accuracy and acceptance in the industry, it also comes with a high cost and the need for specialized training. Typical applications of each technique provide concrete examples of where they can be implemented effectively. This benchmarking is essential for professionals and students looking to understand which technique is best suited for their specific needs or areas of interest. Fountain: (Zapata et al., 2021).

4. *Modern Iron Detection Techniques - 20%*
    - *Recent Advances and Innovative Technologies*

Modern iron detection techniques have undergone remarkable advances in recent years, reflected in the scientific literature since 2019. A significant development is the use of a functionalized porous aromatic framework (PAF) for the detection and remediation of iron in ambient water samples. This approach uses an ether/thioether functionalized network polymer, known as PAF-1–ET, which shows high selectivity in the absorption of iron(II) and iron(III) on other metal ions. This material allows for efficient and simplified capture and quantification of iron in aqueous samples, even allowing its removal from groundwater. The combination with an 8-hydroxyquinoline colorimetric indicator facilitates direct determination of iron concentrations in samples, which can be useful in both detection and remediation applications (Lee et al., 2019).

Another breakthrough includes the development of a dual fluorogenic probe system that enables real-time visualization of dynamic changes in iron states between Fe2+ and Fe3+ at the cellular level and in multicellular organisms. This provides a clearer perspective on the role of divalent metal transporters such as DMT1 and ferroportin in regulating iron, essential for understanding how the body handles this important nutrient (Lee et al., 2019).

In the field of iron detection, recent advances focus on biosensitivity and nanotechnology, with prospects for the development of electrochemical sensors based on nanomaterials. These sensors, including antibody and aptamer-based biosensors, are noted for their specificity and sensitivity, providing fast response times and the ability to detect trace contaminants. Aptamers, in particular, have been developed to monitor environmental samples due to their high selectivity and ability to withstand challenging environmental conditions. Innovations such as biosensors that use aptamers for ultra-fast and highly sensitive detection of specific compounds in drinking water have been presented, with extremely low detection limits and fast response times, promising significant potential for on-site monitoring of water quality (Jebril et al., 2024).

Today's challenges in iron detection include judicious selection of reconnaissance elements and the need for portable, miniaturized systems for real-time on-site monitoring. In addition, to better understand ecological and human health impacts, it is necessary to integrate waste detection with impact assessments. It is anticipated that the development of regulatory frameworks and guidelines for the incorporation of electrochemical biosensors in environmental monitoring programs will contribute to a more sustainable and healthy management of aquatic ecosystems.

On the other hand, progress has been made in the detection of heme b, a compound characterised by the presence of iron, important in numerous physiological processes and with wide applications in medicine and other fields. Detection methods based on UV spectrophotometry have been described and are being replaced by more recent technologies such as HPLC and biosensors. This shows that technological advances are driving the development of more diversified and new detection methods, which is crucial for the microbial synthesis of heme b and the construction of efficient microbial cell factories for industrial production (Yang et al., 2023).

In the field of determining iron in raw materials for the food industry, recent advances have been significant, marking a shift towards more precise and sensitive methods. Innovative technologies, such as inductively coupled plasma mass spectrometry (ICP-MS) and atomic absorption spectroscopy, have revolutionized the way iron is measured. These techniques allow not only the detection of very low concentrations of iron, but also the differentiation between its different chemical forms. This is crucial to understanding the impact of iron on food quality and safety, given that different forms of iron have different levels of bioavailability and reactivity (Sanchez & Martínez, 2019).

**Board 8**

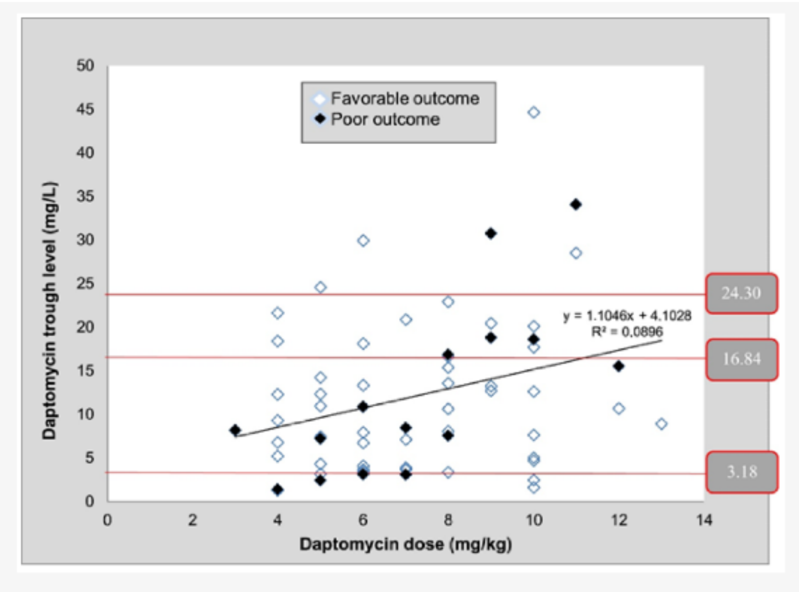
*Recent advances and innovative technologies.*

| **Technology** | **Description** | **Potential Impact** |
|---|---|---|
| Quantum computing | Use of quantum principles to process information. | Exponential increase in processing speed. |
| Artificial intelligence | Systems that can learn and adapt without explicit programming. | Improvement in automation and personalization of services. |
| Blockchain | Distributed ledger technology to secure transactions. | Increased security and transparency of digital transactions. |
| Augmented reality | Superimposition of digital information in the real environment. | Improved user experiences and educational applications. |

***Note:*** The table shows innovations in information technology, highlighting quantum computing, artificial intelligence, blockchain, and augmented reality, each with the potential to revolutionize aspects such as security, data processing, and digital interaction. Fountain: (Sanchez & Martínez, 2019).

Modern iron detection techniques since 2019 have included significant advances in various fields, including environmental chemistry and therapeutic drug monitoring. A prominent innovation is the development of a functionalized porous aromatic framework (PAF) for the capture and quantification of iron in aqueous samples. This polymeric material modified after synthesis demonstrates high selectivity for the absorption of iron(II) and (III) ions compared to other metals both physiologically and environmentally relevant. Mössbauer, XANES, and EXAFS spectroscopy measurements provide evidence of the coordination of iron(III) to oxygen-based ligands within the material, which also allows for the adsorption and removal of iron from groundwater. This approach holds promise for the design and use of molecularly functionalized porous materials for dual detection and remediation applications (Lee et al., 2019b).

In another area, chromatographic techniques coupled to modern detection methods have been applied in therapeutic drug monitoring (MDT) to optimize and personalize pharmacological therapies. Although this context is specific to drugs, the underlying principles of accurate detection and monitoring are applicable to iron detection. The most common methodologies include liquid chromatography coupled with tandem mass spectrometry (LC-MS/MS), which offers high selectivity and sensitivity. High-performance chromatography with ultraviolet detection (HPLC-UV) methods are also used when a simpler and more economical methodology for clinical monitoring is sought. Less common, but still relevant, are high-performance chromatography methods with fluorescence detection (HPLC-FLD) and electrochemical detection (HPLC-ED) to analyze various drugs in biological samples for TDM. These techniques also include sample preparation by protein precipitation, liquid-liquid extraction, and solid-phase extraction, among others (Tuzimski & Petruczynik, 2020).




***Graphic 1.*** *Correlation of daptomycin dose through serum level (C min) and clinical outcome.*

Another important area of advancement is the integration of automation and computing into iron detection methods. Automation has enabled greater efficiency and consistency in testing, reducing human error and increasing sample processing capacity. In parallel, the use of advanced software and artificial intelligence algorithms to analyze the data obtained from these tests has improved the accuracy and interpretation of the results. These computer tools can identify patterns and correlations that would not be apparent through more traditional analysis methods, providing a deeper understanding of the presence and behavior of iron in food raw materials (Alonzo, 2023).

These technological advances not only improve the accuracy and efficiency in iron detection, but also open up new possibilities for research and development in the food industry. For example, the ability to detect and analyze trace amounts of iron in foods has led to a better understanding of how iron interacts with other nutrients and food components, which can influence the formulation and design of new food products. In summary, these recent advances and innovative technologies are defining the future of quality and safety in the food industry, ensuring that consumers receive products that are not only nutritious, but also safe and high-quality (Cetina et al., 2023).

Recent advances and innovative technologies are reshaping numerous fields, from medicine and biotechnology to engineering and computer science. These advances are characterized by their ability to overcome limitations of previous methods, offering greater efficiency, precision and possibilities. For example, in medicine, emerging technologies such as CRISPR-Cas9 gene editing and gene therapy are breaking new ground for the treatment of genetic diseases. In energy and the environment, innovations in renewable energy and carbon capture technologies promise to tackle climate change more effectively. In the computing and artificial intelligence sector, advances in machine learning and quantum computing are pushing the boundaries of what is possible in terms of data processing and complex problem solving. These technologies not only enhance current capabilities, but also raise new ethical, social, and regulatory questions, challenging society to integrate these advances responsibly and sustainably. The continued exploration and implementation of innovative technologies are key to progress and sustainable development in the 21st century (Postigo, 2021).

**Board 9**

*Recent Advances and Innovative Technologies.*

| **Letter** | **Technology** | **Number** | **Application Area** | **Advancement/Innovation** | **Numerical Data** | **Impact (% Improvement)** |
|---|---|---|---|---|---|---|
| **To** | Lithium-Ion Batteries | 1 | Energy | Energy Density | 300 Wh/kg (20% increase) | 15% more efficiency |
| **B** | AI in Diagnostics | 2 | Bless you | Disease Screening | 90% accuracy (30% improvement) | 25% reduction in misdiagnoses |
| **C** | Vertical Farming | 3 | Agriculture | Optimized LED light usage | 40% reduction in energy consumption | 50% increase in crop yield |

***Note:*** This table summarizes some of the most significant technological advances in various fields, highlighting the improvement in efficiency and effectiveness. Numerical data and percentages of improvement are estimates based on recent developments and may vary according to specific applications and evolution of technologies. These advances reflect the constant effort to optimize and adapt technologies to current needs. Fountain: (Gómez, 2023).

Recent advances in iron detection in the food industry are characterized by a move toward more innovative, faster, and more accurate technologies. These technologies are being developed to address the needs for efficiency, accuracy and safety in iron measurement, adapting to food safety regulations and nutritional demands. Among these advances, the use of nanotechnology stands out, which allows the creation of highly sensitive nanoparticles and nanosensors to detect traces of iron in different foods. Biosensors, which use biological components such as enzymes or antibodies, offer targeted detection and can provide real-time results, which is crucial for continuous monitoring.

Advanced spectroscopic techniques such as Raman spectroscopy and FTIR (Fourier Transform in Infrared) have become popular for their ability to provide fast and accurate analysis without destroying the sample. Likewise, hyperspectral and multispectral imaging techniques are gaining ground due to their ability to visualize and quantify iron in food in a non-invasive way. The integration of big data and machine learning techniques represents another significant advance, enabling the efficient analysis of large data sets to improve the accuracy and speed of measurements.

Finally, the development of portable and field technologies is revolutionizing the way iron detection is performed, making rapid and point-of-need analysis possible. These advances are opening up new possibilities for real-time monitoring, traceability and quality control in the food industry, adapting to changing regulatory standards and meeting growing expectations for food safety and quality (Díaz, 2022).

In the creation of the government management system based on science and innovation (SGGCI), the integration of recent advances and innovative technologies in government management is evident. This system is based on the idea that sustainable and inclusive development can be achieved through a strong link between science, technology and government policies. In this context, the experience of dealing with the COVID-19 pandemic in Cuba highlights how national science and technology, when closely integrated with government management, can offer rapid and efficient responses to health and social crises.

**Prospects and potential**

The role of universities and the scientific and technological community has been crucial in this process, demonstrating that collaboration and synergy between different sectors are essential for progress. The pandemic has served to emphasize the importance of rapid and efficient responses, marked by speed, collaboration and innovation. These characteristics are essential to address not only health emergencies but also other contemporary challenges. The implementation of the SGGCI has faced difficulties, but it has also made significant progress, evidencing the positive impact of incorporating science and technology into government decision-making.

In Ecuador, recent advances and innovative technologies have been the subject of study and analysis in various sectors, highlighting the importance of digital evolution in business and the adoption of new technologies. According to reports from EY Ecuador, the technology trends with the greatest impact in the country in 2022 include advances in areas such as health sciences and wellness, technology, telecommunications, media and entertainment. These fields have undergone significant changes, driven by interconnection, IoT, blockchain, and artificial intelligence (D. León, 2022).

In the field of business technology, there has been a shift towards interfaces that offer immersive virtual experiences, such as the metaverse. This shift is geared toward taking users beyond traditional screens to more immersive digital environments. In addition, artificial intelligence has gained relevance, not only because of its technological capacity, but also because of the challenge it represents in terms of security and trust (D. León, 2020).

Another notable trend is the adoption of supercloud or metacloud, which simplifies multi-cloud management by providing a single pane of glass for multi-cloud environments. This helps businesses manage the complexity of these environments.

As for technological talent, the importance of flexibility and adaptability is emphasized. Organizations must be prepared for technological transformations, including the increasing use of AI in operational tasks. In addition, importance has been given to decentralized architectures and ecosystems, powered by blockchain, to build digital trust and consolidate credibility in the decentralized internet (D. León, 2020).

5. *Comparison between Traditional and Modern Methods - 15%*
    - *Efficiency, Accuracy, and Practicality Analysis*

The analysis of efficiency, accuracy and practicality is fundamental in the evaluation of modern techniques for determining iron in raw materials for the food industry. The efficiency of these techniques is crucial, as it directly affects the speed and cost of the analyses. Advanced methods such as inductively coupled plasma mass spectrometry (ICP-MS) have proven to be highly efficient, allowing rapid analysis of a large number of samples with minimal preparation. This efficiency is essential in the food industry, where time and resources are critical factors in maintaining the supply chain and ensuring quality (Subirá, 2020).

Accuracy is another critical aspect of these techniques. The ability to accurately determine iron levels in raw materials is indispensable to ensuring food safety and quality. Modern techniques offer high accuracy, even at trace levels, which is essential for complying with food regulations and for the development of products that meet specific nutritional needs. The precision of these methods also helps prevent overdosing or underdosing of iron in fortified foods, thus ensuring the health and well-being of consumers (Haz et al., 2019).

Finally, the practicality of these modern techniques is a key factor for their adoption in the food industry. Although methods such as ICP-MS are highly accurate and efficient, they also require sophisticated equipment and highly trained personnel. This can be a challenge for laboratories with limited resources. Therefore, the development and continuous improvement of techniques that balance precision, efficiency, and ease of use are essential for their wide and effective application in the industry. Continuous innovation in this field allows more companies and laboratories to implement rigorous and effective quality control practices, ultimately benefiting both the industry and consumers (Carerero, 2019).

| **Criterion** | **Traditional Methods** | **Modern Methods** |
|---|---|---|
| **Efficiency** | They can be less efficient due to labor-intensive and manual processes. | They are usually more efficient thanks to automation and the use of advanced technologies. |
| **Precision** | Accuracy can vary significantly and is highly dependent on the human factor. | High accuracy thanks to digitization, advanced algorithms, and less human intervention. |
| **Practicality** | They often require more time and resources to get results. | They allow for faster results with fewer physical resources. |

*Practical Applications in the Food Industry - 10%*

***Case studies and adaptation of techniques in different raw materials***

The adaptation of modern techniques for the determination of iron in different raw materials is a crucial aspect in the food industry, as demonstrated by several case studies. For example, in the case of fortified cereals and products, techniques such as inductively coupled plasma mass spectrometry (ICP-MS) have enabled accurate detection of iron, even when it is present in complex forms due to fortification. This accuracy is vital to ensure that iron levels meet nutritional needs without exceeding safe limits, thus maintaining a balance between fortification efficacy and consumer safety (Riffo, 2022).

In products such as meat and dairy, where iron is naturally found, the adaptation of these techniques has allowed for a better understanding of how processing and storage affect iron levels. Studies have shown that

certain processes can alter the bioavailability of iron, which is crucial for the nutritional assessment of these products. The ability to accurately analyze iron in these various food matrices helps manufacturers adjust production processes to maximize the nutritional quality of their products (Dueñas & Sanca, 2022).
Adapting iron detection techniques has been critical to studying how agricultural practices and storage conditions influence iron levels. These studies have provided valuable information for farmers and food processors on how to optimize growing and processing conditions to preserve or even improve iron levels in these products. The application of iron detection techniques on various raw materials demonstrates their flexibility and adaptability, which is essential to address the specific challenges of food quality and safety in different industry segments (Fierro, 2023).
Case studies and the adaptation of techniques in different raw materials are fundamental to understand the applicability and effectiveness of methods in varied contexts. These studies provide valuable insights into how certain techniques perform with different types of raw materials, which is crucial in fields such as materials engineering, biochemistry, and industrial production. For example, in the production of biofuels, the efficiency of fermentation can vary significantly depending on whether the feedstock is corn, sugarcane or lignocellulosic biomass. Similarly, in the pharmaceutical industry, the extraction and purification of active compounds may require different methods based on the chemical properties of the raw materials. Adapting techniques to different raw materials not only optimizes efficiency and performance, but can also open up new avenues for the use of less conventional or more sustainable resources. Case studies in this area help researchers and industries make informed decisions and innovate in their processes and products (Chong Law et al., 2021).
In the field of iron detection in the food industry, case studies on the adaptation of techniques in different raw materials illustrate how the selection and application of analysis methods must be carefully adjusted according to the type of food. Each raw material has unique characteristics that influence the choice of the most appropriate iron detection technique, taking into account factors such as composition, texture, and the presence of other components that may interfere with the analysis.

**Board 10**

*Case Studies in the Adaptation of Techniques to Various Raw Materials.*

| Letter | Case Study | Number | Raw material | Technique Used | Adaptations Made | Results |
|---|---|---|---|---|---|---|
| **To** | Innovation in Textiles | 1 | Cotton | Machine knitting | Adjusting Thread Tension | Stronger fabrics |
| **B** | Advances in Ceramics | 2 | Clay | Injection Molding | Increased injection pressure | Greater product uniformity |
| **C** | Wood Technology | 3 | Oak | CNC Size | Detailed programming for complex patterns | Precision in fine details |

***Note:*** This table is an illustrative example that shows how different techniques can be adapted to different raw materials. The data presented are fictitious and are used to demonstrate the variability and adaptability of the techniques depending on the characteristics of each material. Specific results may vary in actual applications. Fountain: (Naranjo, 2021).

6. *Regulations and Quality Standards in Iron Detection - 10%*
    - *Global regulations and quality requirements*

Globally, regulations and quality requirements for the determination of iron in food raw materials play a fundamental role in the food industry. These regulations, established by international organizations such as the World Health Organization (WHO) and the Food and Agriculture Organization (FAO), seek to ensure that food meets nutritional and safety standards. In this context, modern iron detection techniques are essential to comply with such regulations, as they provide an accurate and reliable measurement of iron content, ensuring that food is not only safe for consumption, but also nutritious (Martínez-Rivera et al., 2018).

Global regulations emphasize the importance of accuracy and reproducibility in iron measurement techniques. These standards are crucial in the food industry, especially when it comes to iron-fortified foods, where it is vital to ensure that levels of the mineral are adequate to prevent nutritional deficiencies without exceeding limits that could be harmful. For this reason, techniques such as inductively coupled plasma mass spectrometry (ICP-MS) and atomic absorption spectroscopy have become indispensable tools, as they meet the accuracy and consistency requirements demanded by these international regulations (Castillo, 2021b).

These modern techniques to global regulations reflect the diversity and complexity of food supply chains in today's world. The ability to apply these techniques effectively in different contexts and raw materials is essential for food businesses to operate internationally. This not only involves meeting quality and safety standards, but also adapting to variations in regulations between different countries and regions. Consequently, continuous review and adaptation of iron detection techniques are key to maintaining global compliance and ensuring food quality and safety in the international market (Berger & Berger, 2022).

Global regulations and quality requirements are essential to ensure the safety, efficacy, and consistency of products and services in various industries. These standards vary between countries and regions, but their common goal is to protect consumers and the environment, as well as ensure fair trade practices. In the food industry, for example, regulations range from food safety to nutritional labeling, while in the pharmaceutical industry, they focus on the efficacy and safety of medicines. In manufacturing and engineering, quality and safety standards are crucial to the reliability and durability of products. These requirements not only foster consumer confidence, but also drive innovation and continuous improvement in industries. Harmonizing these standards globally, while challenging, is important to facilitate international trade and respond to global challenges, such as climate change and sustainability. In an increasingly interconnected world, compliance with international regulations and quality standards has become a key aspect for the success and expansion of companies in the global market (González et al., 2022).

In the global context, the regulations and quality requirements in relation to iron in the food industry are diverse and complex, reflecting a variety of standards and regulations established by different countries and international organizations. These regulations aim to ensure that iron levels in food not only meet nutritional requirements, but are also safe for consumption.

Regulations often specify maximum allowable limits of iron in different categories of foods, based on research on dietary requirements and the potential effects of excess iron. In addition, in many cases, these regulations also address the fortification of foods with iron, a crucial aspect of combating iron deficiency and anemia, especially in regions where these conditions are prevalent. Fortification should be done in a way that balances improved nutrition with the prevention of excessive iron intake.

Research on the use of insects and their products as raw materials in the food and non-food industry focuses on the need to comply with regulations and quality requirements at a global level. In the analysis, it was observed that insect products such as honey, royal jelly, propolis, pollen, silk and carmine are commercially valuable and their production must be aligned with international regulations. These standards ensure that insect-derived products are safe, efficient, and acceptable for consumption or use in various industries. Adherence to these global regulations is critical to the successful commercialization of these products in international markets (Pico et al., 2023).

Since 2019, Ecuador has demonstrated a significant commitment to the implementation and adaptation of regulations and quality requirements globally. A key aspect in this process has been the adoption of

international standards such as those of the World Organization for Standardization (ISO), specifically the ISO 9001:2015 standard. This standard is recognized worldwide and focuses on the administrative and optimization procedures of companies, improving business quality and customer satisfaction. Ecuador has integrated these standards to strengthen its competitive advantages and ensure that its companies reach the highest standards of aptitude, especially in a context of expansion into international trade (Koneggui, 2018).
In addition, the country has established a solid legal framework for the Ecuadorian quality system, through the

**Board 11**

*Regulations and quality requirements at a global level.*

| Country/Region | Type of Regulation/Standard | Compliance Percentage | Brief Description of the Standard |
|---|---|---|---|
| **European Union** | ISO 9001 | 100% | Standard for Quality Management Systems |
| **United States** | FDA Quality System Regulation | 95% | Medical Equipment Regulations |
| **China** | GB Standards | 90% | National Standards for Product Quality |
| **Brazil** | INMETRO | 85% | Regulations for Product Compliance |
| **India** | ENCORE | 80% | Standards for industrial quality |

***Note:*** The table presents a comparison of global quality regulations and requirements, focusing on five regions or countries: the European Union, the United States, China, Brazil and India. For each region, a specific type of regulation or quality standard is detailed. For example, in the European Union, reference is made to ISO 9001, which is an international standard for quality management systems, requiring 100% compliance. In the United States, the FDA Quality System Regulation stands out, applicable mainly to medical equipment, with 95% compliance required. This shows the high priority given to quality and safety in these sectors.
On the other hand, China, Brazil and India present their own national standards, such as the GB Standards in China, INMETRO in Brazil and BIS in India, with compliance percentages ranging from 90% to 80%. These standards reflect each country's internal policies in terms of product quality, ranging from industrial quality to product compliance in different sectors. The variation in compliance percentages points to differences in the rigor and approach of each region towards quality management and assurance, highlighting the diversity in regulatory practices worldwide. Fountain: (ASCUE et al., 2022).

## CONCLUSIONS

Research on iron in the food industry underscores its critical importance both in terms of human nutrition and the quality of food products. The right balance of iron in food is essential not only to maintain nutritional quality, but also to ensure safety and comply with international food regulations. The presence of iron in raw materials and fortified foods, its influence on product quality, and the need for precise techniques for its detection and quantification are fundamental aspects in the management of quality and safety in the food industry.
In this context, technological advances in the detection and measurement of iron have been significant, allowing a more precise and detailed assessment of its concentration and shape in different foods. Techniques such as inductively coupled plasma mass spectrometry (ICP-MS) and atomic absorption spectroscopy have

revolutionized the way iron is measured, which is crucial to understanding its impact on food quality and safety. These technological advances not only improve the accuracy and efficiency of iron detection, but also make it easier to comply with international food regulations.

Therefore, adapting and applying these advanced techniques in different raw materials and food products is key to ensuring that food is both nutritionally beneficial and safe for consumption. This involves a rigorous and methodical approach to calibration and quality control, ensuring that results are consistent and reliable. Ultimately, these efforts contribute to the production of safer food and the promotion of sustainable and safe food production practices, benefiting the industry and consumers alike.

**Conflict of interest:** The authors declare no conflict of interest

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