Entramado vol. 20 Nº. 2 Julio - Diciembre de 2024, e-10840 (ISSN 1900-3803 / e-ISSN 2539-0279)

Optimizing sustainability in the specialty coffee supply chain *

Edgar Guillermo Rodríguez-Guevara
Full Professor at the Universidad del Valle, Cali - Colombia
edgar.rodriguez@correounivalle.edu.co

Diego Alonso García-Bonilla
Associate Professor at the Universidad del Valle, Cali - Colombia
diego.a.garcia@correounivalle.edu.co

Diana Lorena Pineda-Ospina
Full Professor at the Universidad del Valle, Cali - Colombia
diana.pineda@correounivalle.edu.co

KEYWORDS
Sustainability; specialty coffee; sustainable practices; innovation; quality
JEL CLASSIFICATION
D12,Q01,Q13,Q57

ABSTRACT

The development of the analysis focuses on identifying a set of effective practices that contribute to improving sustainability in the specialty coffee supply chain. Methodologically, the analysis is based on a thematic content analysis exercise in a corpus evaluated through a constructed indicator that allows measuring the structural impact of scientific articles in the Web of Science database. As a result, three categories of analysis were identified for the practices, which include multiple dimensions of analysis: Sustainable production technology and processes, environmental impact and coffee quality, and consumer behavior and added value. These findings contribute to answering the question of how production, marketing, and consumption practices of specialty coffees can be improved to achieve greater sustainability in the supply chain in the international market.

Received: 28/12/2023 Evaluated: 01/03/2024 Accepted: 05/05/2024

Funding sources: The article was written within the framework of the research project "CAFINNOVA VALLE," Strengthening the competitiveness of specialty coffees in the center of Valle del Cauca. This project was funded by the General Royalties System (DNP). It was carried out in collaboration with growers in the sector, specifically through the alliance with Caficentro in the center of Valle del Cauca, Colombia.

Author contributions

- Author 1: Conceptualization, data curation, formal analysis, and writing, review, and editing.
- Author 2: Methodology, investigation, formal analysis, and writing, review, and editing.
- Author 3: Conceptualization, methodology, formal analysis, and writing, review, and editing.

How to cite/ Como citar este artículo: RODRÍGUEZ-GUEVARA, Edgar Guillermo; GARCÍA-BONILLA, Diego Alonso; PINEDA-OSPINA, Diana Lorena. Optimizing sustainability in the specialty coffee supply chain. In: Entramado. July - December. 2024. vol. 20, no. 2 e-10840 p. 1-21.
https://doi.org/10.18041/1900-3803/entramado.2.10840

Optimización de la sostenibilidad en la cadena de suministro de cafés especiales

Resumen

El desarrollo del análisis se centra en identificar un conjunto de prácticas efectivas que contribuyan a mejorar la sostenibilidad en la cadena de suministro de cafés especiales. Metodológicamente, el análisis se fundamenta en un ejercicio de análisis de contenido temático en un corpus evaluado a través de un indicador construido que permite medir el impacto estructural de artículos científicos en la base de datos de Web of Science. Como resultado, se identificaron tres categorías de análisis para las prácticas que incluyen múltiples dimensiones de análisis: Tecnología y procesos de producción sostenible; Impacto ambiental y calidad del café; y, Comportamiento del consumidor y valor agregado. A partir de estos hallazgos, se contribuye a responder cómo se pueden mejorar las prácticas de producción, comercialización y consumo de cafés especiales para lograr una mayor sostenibilidad en la cadena de suministro en el mercado internacional.

Palabras clave
Sostenibilidad; café especial; prácticas sostenibles; innovación; Calidad
Clasificación JEL
D12,Q01,Q13,Q57

Otimização da sustentabilidade na cadeia de suprimentos de cafés especiais

Resumo

O desenvolvimento da análise se concentra na identificação de um conjunto de práticas eficazes que contribuem para melhorar a sustentabilidade na cadeia de suprimentos de cafés especiais. Metodologicamente, a análise baseia-se em um exercício de análise de conteúdo temático em um corpus avaliado por meio de um indicador construído para medir o impacto estrutural de artigos científicos na base de dados Web of Science. Como resultado, foram identificadas três categorias de análise para as práticas que incluem várias dimensões de análise: Tecnologia e processos de produção sustentáveis; Impacto ambiental e qualidade do café; e Comportamento do consumidor e valor agregado. Com base nessas descobertas, o estudo contribui para responder como as práticas de produção, marketing e consumo de cafés especiais podem ser aprimoradas para alcançar maior sustentabilidade na cadeia de suprimentos no mercado internacional.

Palavras-chave
Sustentabilidade; café especial; práticas sustentáveis; inovação; qualidade
Classificação JEL
D12,Q01,Q13,Q57

1. Introducción

In a global context of growing environmental and social awareness, the specialty coffee industry faces the challenge of how to achieve greater sustainability throughout the supply chain, given that the production, marketing, and consumption of specialty coffees are intrinsically interconnected activities whose impact transcends geographic and economic borders.

In this regard, the analysis developed below seeks to answer the following question: *How can production, marketing, and consumption practices of specialty coffees be improved to achieve greater sustainability in the supply chain*?, the general objective is to identify a set of effective practices that contribute to improving sustainability in the specialty coffee supply chain.

In this sense, findings derived from a multidisciplinary approach that addresses technical, economic, environmental, and social aspects will be presented in order to provide a solid basis for strategic decision-making aimed at transforming specialty coffee production into a reference model in global sustainability.

Methodologically, the development of the analysis is based on the configuration of a scientific corpus that brings together scientific literature in the field of sustainability in specialty coffees that allows the identification of best practices in the production, marketing, and consumption of specialty coffees, including sustainable cultivation methods, coffee processing techniques, effective marketing strategies and business models that promote sustainability; facilitating the assessment of environmental and social impact for the understanding of actions that can contribute to sustainability, whether by reducing the environmental footprint, improving the working conditions of farmers or promoting equity in the supply chain; and,

specifying the challenges and barriers that specialty coffee production units face in their search for sustainability. These challenges may include issues related to climate change, fluctuating coffee prices, and sustainability certification, among others.

To identify the scientific corpus, an impact indicator was designed using the citation indicators of the Web of Science (WOS) database, which focused on obtaining a complete understanding of the impact of scientific production, adjusting the relative importance of scientific articles, and reducing measurement bias through the incorporation of several indicators.

2. 2. Theoretical foundation

Sustainability in the specialty coffee supply chain has become a topic of growing interest in recent years due to environmental, economic, and social concerns. Investigate how production, marketing, and consumption practices of specialty coffees can be improved to achieve greater sustainability in the supply chain; it is necessary to identify the different analytical perspectives that allow identifying a set of effective practices that contribute to improving sustainability in the specialty coffee supply chain.

The literature review highlights seven analytical perspectives. The first, focused on sustainability in the coffee industry, highlights the need for this industry in light of the growing awareness of the need for sustainable practices. In this regard, sustainability has become a key factor in the production, marketing, and consumption of specialty coffees. This approach aligns with the vision of modernizing agricultural and commercial management, as outlined in the study by Kittichotsatsawat, Jangkrajarng and Tippayawong (2021), where they highlight the application of modern technologies and environmentally friendly practices in the coffee supply chain.

A second perspective is posed on the impact of crises and shocks, where the way in which the coffee supply chain has faced significant challenges is highlighted, as suggested by Rhiney et al. (2021), who highlights how economic crises and shocks, such as the covid-19 pandemic, can negatively affect coffee production and sourcing. It underscores the importance of improving sustainability in the supply chain as a strategy to address such challenges.

In contrast to the challenges, identifying sustainable business practices plays an essential role in promoting sustainability in the specialty coffee supply chain. Lin, Lin and Wang (2021) examine the relationship between social mission, service quality, and brand image in a social enterprise, illustrating how business practices can contribute to sustainability.

Another widely discussed theoretical perspective is on the selection of green suppliers in the coffee supply chain, as it is a critical aspect of improving sustainability. Nguyen, Lin and Dang (2021) focus on the evaluation of green suppliers using a multi-criteria approach, highlighting the importance of considering sustainable practices in the procurement of inputs.

Taking the perspective of consumers, the study of consumer demand for sustainable products has been increasing. Jaeger and Giacalone (2021) explore consumer perceptions of beverage alternatives, including sustainable options, indicating a growing awareness and preference for sustainable products. Finally, the prospects for sustainable ingredient development and the effectiveness of sustainability standards have gained relevance in the field. The development of sustainable plant-based ingredients is an important trend in the food industry. In this regard, Amagliani, Silva, Saffon and Dombrowski (2021) review the properties of plant-based ingredients used in food production, suggesting opportunities to substitute less sustainable ingredients in the coffee industry.

Taken together, this theoretical foundation provides a solid basis for addressing the research question and overall objective of identifying effective practices that contribute to improving sustainability in the specialty coffee supply chain. However, it highlights the need to expand the theoretical inquiry to answer how specialty coffee production, marketing, and consumption practices can be improved to achieve greater sustainability in the supply chain.

3. Methodology

For the development of the proposed analysis, five fundamental methodological criteria were established and designed to identify effective practices that drive sustainability in the specialty coffee supply chain. These criteria range from the formulation of a precise search equation to retrieve relevant literature to the development of a combined impact indicator

to assess the relevance of the articles. In addition, meticulous processing and organization of metadata, the creation of an analytical taxonomy to structure themes and sub-themes, and detailed analysis of the results to highlight practices that promote sustainable improvements were included. Table 1 summarizes these criteria, providing a clear overview of the methodological approaches employed in the study.

Table 1.
Central methodological criteria

Criterion	Description
1. Construction of search equation	The search equation was designed to retrieve relevant articles in the WOS database using key terms related to sustainability and specialty coffee. Filters were included by document type and specific thematic categories, as well as a range of years, to ensure the topicality of the articles. This systematic approach ensured the collection of a relevant corpus for analysis.
2. Formulation of the "Combined Impact Indicator"	The Combined Impact Indicator was constructed to assess the impact of the retrieved articles, combining two normalized usage indicators: "180 Day Usage Count" and "Since 2013 Usage Count". The formula adjusts the values of these indicators using z-scores and weighted coefficients to reflect their relative importance, providing a robust measure of the impact and relevance of each article in the corpus.
3. Metadata processing	In this phase, the metadata of the selected articles was processed to organize and analyze the information. Data preparation was performed, removing irrelevant information and coherently structuring the documents. Subsequently, the metadata was organized and categorized to identify recurring thematic patterns and prepare the corpus for detailed analysis.
4. Development of analytical taxonomy	The creation of the analytical taxonomy involved the interpretation and structuring of the recurring themes identified in the articles. Based on the content analysis, a hierarchical structure was developed to represent the themes and subthemes related to sustainable practices in specialty coffee production. This process facilitated a deeper understanding of the key themes in the corpus.
5. Analysis of results	In this final phase, the results were analyzed to identify the most effective practices in the sustainability of the specialty coffee supply chain. Practices related to coffee production, marketing, and consumption were evaluated, highlighting those that demonstrated a significant positive impact. This analysis provided a comprehensive view of best practices to improve sustainability.

Source: Prepared by the authors

In order to develop the methodological criteria described, the analysis was structured in three interrelated phases. Each phase was designed to address specific aspects of the study comprehensively. The stages of this methodological process are detailed below, offering a clear view of how each phase contributes to the overall objective of the analysis.

Phase 1: Elaboration of the scientific corpus through impact measurement

The objective of the first phase is to collect data and build a solid scientific corpus that serves as a basis for the analysis of sustainability practices in the specialty coffee supply chain. The following was established:

1. Construction of a search equation in the WOS database that would allow retrieving the scientific articles with the greatest impact according to the indexing indicators. The search equation (1) was built:
Ecuación 1:

> TI=("sustainability" OR "practices") AND TS=("specialty coffee" OR "coffee quality" OR "coffee certification" OR "sustainable coffee" OR "coffee varietals" OR "coffee roasting" OR "coffee origin" OR "coffee farming" OR "coffee processing" OR "coffee flavor profiles" OR "coffee sustainability practices" OR "sustainability practices" OR "sustainable coffee production" OR "sustainable coffee farming" OR "eco-friendly coffee practices" OR "environmentally friendly coffee practices" OR "green coffee practices" OR "ethical coffee practices" OR "responsible coffee practices") AND KP=("sustainability" OR "practices") AND PY=2018-

2022 AND DOCUMENT TYPES: (article) AND WC=("agriculture, dairy & animal science" OR "agricultural economics & policy OR "agricultural engineering" OR "agriculture, multidisciplinary" OR "biodiversity conservation" OR "business" OR "business, finance" OR "development studies" OR "economics" OR "food science & technology" OR "humanities, multidisciplinary" OR "engineering, manufacturing" OR "engineering, multidisciplinary" OR "engineering, industrial" OR "management" OR "microbiology" OR "social sciences, interdisciplinary" OR "water resources")

From this equation, 161 documents were retrieved, and a combined impact indicator was applied, as described below.

2. Construction of a Combined Impact Indicator (CII) to evaluate the impact of the retrieved articles. For the specificity of the analysis and the proposed objective, the Combined Impact Indicator described below was constructed based on what was proposed:

$$ICI = \alpha * Z1 + \beta * Z2$$

Where:

α and β are coefficients that you can adjust to reflect the relative importance of each indicator. A larger value for α or β means that indicator has a greater weight in the ICI.

Z1 and Z2 are the normalized z-scores for "180 Day Usage Count" and "Since 2013 Usage Count," respectively:

- Z1 = (180 Day Usage Count value - 180 Day Usage Count mean) / 180 Day Usage Count standard deviation
- Z2 = (Since 2013 Usage Count value - Since 2013 Usage Count mean) / Since 2013, the Usage Count standard deviation

This approach uses advanced statistics to normalize and weight the indicators before combining them. Z values allow for a comparison of the contribution of each indicator in terms of standard deviations from the mean, which can provide a more rigorous assessment of the impact of an article based on short- and long-term usage indicators. Finally, the coefficients α and β are adjusted according to preferences for the relative importance of each indicator. For the central objective, equal coefficients of 0.5 were assigned in order to weight both indicators equally.

Measuring the impact of each article by combining several weighted and normalized indicators contributes to the analysis by facilitating a more complete understanding of the impact, adjusting for relative importance, reducing biases, and gaining greater robustness.

Phase 2: Metadata processing and creation of analytical taxonomy of practices

The second phase focuses on processing the metadata of the articles identified through thematic content analysis. It is an approach that focuses on the identification and exploration of recurring themes and significant patterns within a set of textual data. This technique was used to identify underlying themes and understand the thematic structure in a corpus. To do so, the process focused on:

1. Formation of the corpus: To do so, the sample of 60 articles identified in the first phase was processed.

2. Data preparation: The data was prepared, eliminating non-relevant information from the documents and configuring a coherent and structured format for processing.

3. Reading, organization, and categorization of the metadata: The labels or thematic categories were organized based on the frequency and relevance of the themes identified in the documents.

4. Interpretation and generation of taxonomy: The taxonomy was structured to identify recurring themes and patterns in the data, interpret the results, and generate a hierarchical structure that represents the themes and subthemes related to sustainable practices in the production of specialty coffee.

Phase 3: Analysis of results

Finally, in the third phase, the results were analyzed to identify a set of effective practices that contribute to improving sustainability in the specialty coffee supply chain. Best practices were identified that have a significant positive impact on the sustainability of the supply chain. These practices relate to the production, marketing, or consumption of specialty coffees. Overall, this methodology provides a structured approach to address the research question and achieve the overall objective of the study. Each phase is designed to provide a solid basis for analysis and a synthesis of the identified practices.

4. Results

The application of the Combined Impact Indicator to assess the impact of the retrieved articles enabled the configuration of the corpus of scientific articles of 60 documents. This corpus was established as the fundamental basis for the content analysis for the construction of the taxonomy (Figure 1).

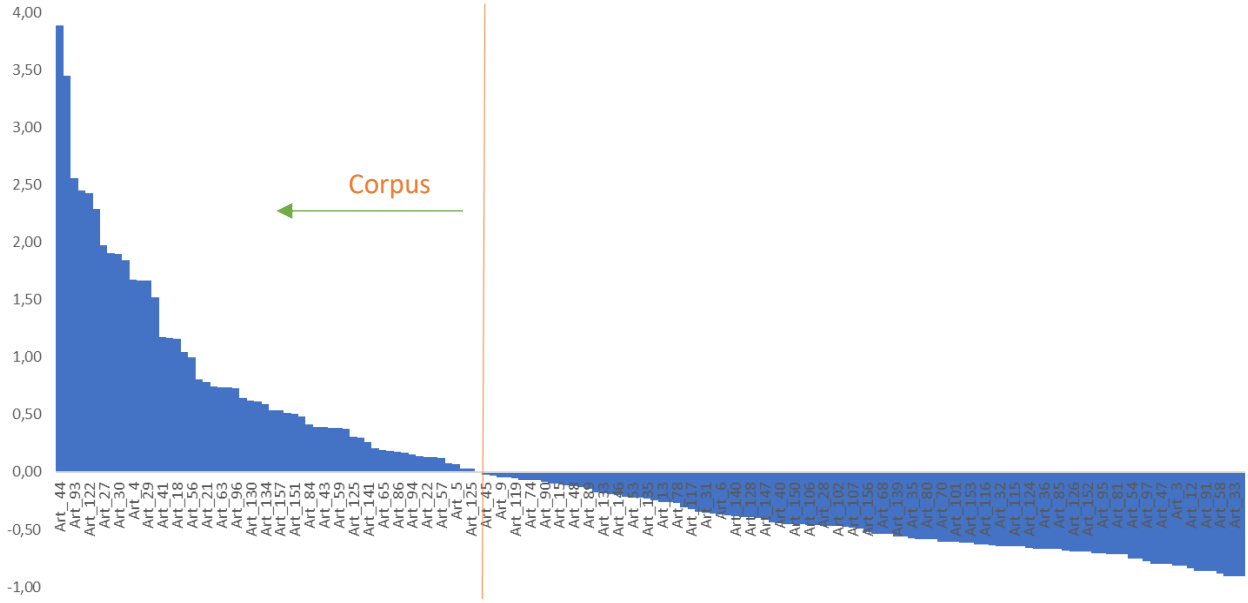

Figure 1. . Configuration of the scientific corpus based on the Combined Impact Indicator.
Source: Prepared by the authors based on calculations.

Based on the development of the analysis, a taxonomy was obtained that allowed structuring three categories of analysis according to Sustainable production technology and processes, with the dimensions of environmental sustainability in the production of specialty coffee, economic sustainability in coffee production, sustainability in the supply chain and social sustainability in the production of specialty coffee; Environmental impact and coffee quality, with the dimensions of the environmental impact of processing, improvement of coffee quality through microorganisms, microbiology, and wastewater treatment, sustainability in coffee production and wastewater treatment in the coffee industry; and, Consumer behavior and added value coffee quality and consumer preference, the dimensions of certification and sustainability labels, environmental impact of processing and processing and added value (Figure 2).

Define each of these; each analysis category and its dimensions are defined below:

1. Sustainable production technology and processes

The analysis category "Technology and sustainable production processes" highlights the importance of addressing sustainability from multiple perspectives to achieve a positive impact on the coffee sector and the environment in general. It addresses four major dimensions: the first, environmental sustainability, focuses on the analysis of processes and technologies that have a positive impact on waste reduction, efficiency in the use of natural resources, and mitigation of emissions; the second, social sustainability, aimed at exploring practices and technologies that benefit local communities,

farmers and workers in the coffee supply chain; the third, economic sustainability, dedicated to analyzing aspects related to the profitability and economic viability of the technologies and practices implemented in coffee production; and the fourth, sustainability in the supply chain, which discusses how technologies and practices impact the entire coffee supply chain, from production on the farm to the final consumer.

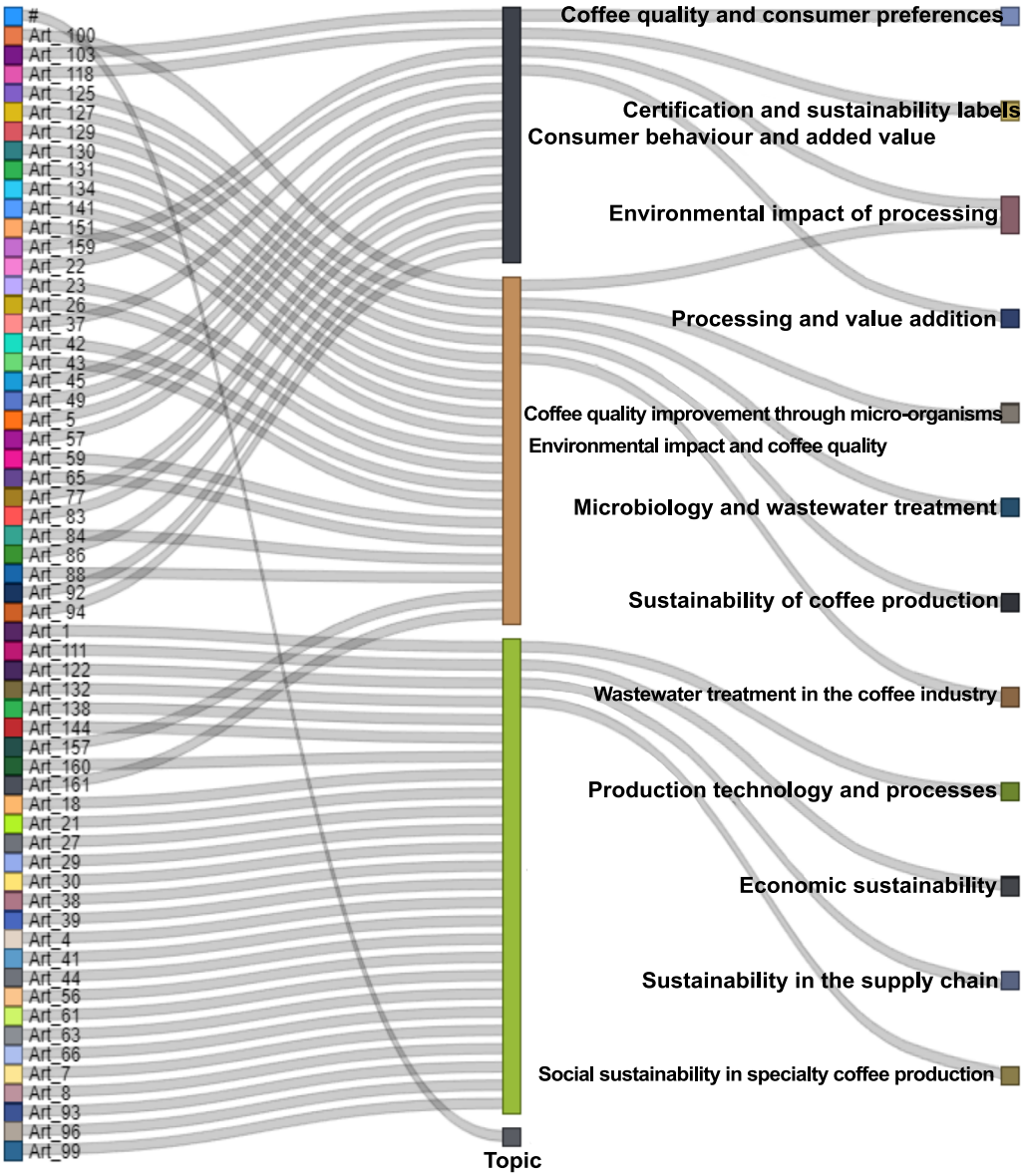

Figure 2. Articles according to the constructed analytical taxonomy
Source: Prepared by the authors based on calculations.

a. Environmental sustainability in specialty coffee production

In the field of coffee production, evidence highlights significant progress towards environmental sustainability through innovative practices and technologies. This dimension focuses on addressing the dimension of environmental sustainability with a focus on natural resource conservation, energy efficiency, and waste minimization.

Zhai et al. (2022) highlight the implementation of the "ultrasound-assisted cold brewing" method for coffee preparation, which significantly reduces extraction time and, therefore, energy consumption compared to traditional methods. Thus,

this advance has a positive impact on energy efficiency and the reduction of resource consumption, thus contributing to environmental sustainability. Chen et al. (2019) address the use of coffee waste, such as coffee grounds, for the preparation of activated carbon for the adsorption of CO2 under flue gas conditions. For the authors, this strategy demonstrates how byproducts of coffee production can be sustainably reused to reduce greenhouse gas emissions, a key component of environmental sustainability.

On the other hand, authors such as Costa et al. (2018) focus on studying the chemical composition of coffee production waste, specifically "coffee silverskin," and how these wastes can be sustainably harnessed to obtain beneficial compounds, such as dietary fiber and antioxidants. In this way, the authors determine that the reuse of byproducts contributes significantly to waste reduction and the efficient use of resources, thus promoting environmental sustainability.

Bolka and Emire (2020) highlight the application of technologies, such as drones and image analysis, to monitor coffee plantations and their variability. The authors claim that this precise monitoring of plantations improves resource management and reduces environmental impact by optimizing agricultural processes, ultimately contributing to environmental sustainability.

Lachenmeier et al. (2018) aanalyze the presence of contaminants, including acrylamide, in coffee and reveal an inverse relationship between the degree of roasting and acrylamide. It underscores the importance of controlling the roasting process to reduce this contaminant. Furthermore, the authors mention that other contaminants, such as furfuryl alcohol and furan, are more prominent in darker roasts, emphasizing the need to address all of these contaminants to achieve environmental sustainability.

Regarding the research conducted by Spreng et al. (2021) on non-volatile reaction products formed from free amino acids during early coffee roasting, the authors identified eleven pyrazine structures, some of which had not been previously identified in other foods. The authors highlight that sucrose is an important precursor of these pyrazines, suggesting the importance of managing ingredients in the roasting process to reduce environmental impact.

In a study validating a biomimetic coffee production technique, Poisson, Pittet, Schaerer, Mestdagh and Davidek (2020) highlight how this technique can help understand the formation of aromatic compounds during roasting. The results indicate that this technique can help improve efficiency in coffee production, which could reduce energy and resource consumption, contributing to environmental sustainability.

Pantaleo, Fordham, Oyewunmi, De Palma and Markides (2018) compare intermittent waste heat recovery using thermal energy storage and organic Rankine cycles to combine heat and power generation in a coffee roasting plant. The results highlight the importance of energy efficiency in coffee production and how heat management decisions can impact environmental sustainability.

Leme, da Silva, Barbosa, Borem and Pereira (2019) for their part, propose a computer vision model to assess the degree of roasting of coffee based on the color of the beans. For the authors, the use of this technology could help control and optimize the roasting process, which would reduce coffee waste and energy consumption, contributing to environmental sustainability.

Finally, Caudill, Osborne, Sandeep, Simunovic and Harris (2022) compare different coffee preparation methods, including cold brew coffee. In their study, they show that a brief heat treatment before cold brewing accelerates the cold brew coffee production process, which may have implications for the energy efficiency of large-scale production and the reduction of resource consumption. Overall, the findings highlight a constantly evolving landscape and progress towards more environmentally friendly practices in this industry. These investigations have shed light on various facets that contribute to environmental sustainability, such as energy efficiency, waste minimization, pollutant control, and biomimetic research.

b. Sostenibilidad social en la producción de café especial

The "Social sustainability in specialty coffee production" dimension focuses on assessing the impact of coffee production on local communities and society at large. This analysis covers critical aspects such as improving working conditions, supporting local communities, and implementing agricultural practices that benefit the people involved.

Le, Cowal, Jovanovic and Le (2021) highlight the implementation of regenerative agriculture and the transformation of conventional coffee farms into organic shade farms as a way to empower local communities by improving soil quality and strengthening the regional economy. In addition, these authors underline the need to address obstacles, such as the threat of coffee rust, in the process of transitioning to more sustainable practices, which attests to a genuine commitment to social sustainability.

From another perspective, Brenes-Peralt, De Menna and Vittuari (2022) analyze in depth how social and economic factors influence farmers' decisions regarding the adoption of more sustainable practices in coffee production. In this sense, the importance of demonstrating economic and environmental benefits to stimulate the transition towards regenerative agriculture is highlighted, which ultimately contributes to social sustainability by improving farmers' living conditions.

Overall, social sustainability in coffee production stands out for its focus on the direct impact this industry has on local communities and society as a whole, showing a significant commitment to improving the living conditions of farmers and strengthening regional economies.

c. Sostenibilidad económica en la producción de café

The "Economic sustainability in coffee production" dimension covers a spectrum of fundamental aspects of the financial viability of this industry. Through the approaches analyzed, the commitment to improve the competitiveness of companies, optimize coffee quality, and ultimately promote economic sustainability in this key sector is evident.

Pascucci (2018) highlights the assessment of the competitiveness of Italian coffee roasting companies in the international market and underlines the challenges they face in a globalized environment. For the author, this focus on competitiveness reflects the constant need for innovation and adaptation to ensure the economic sustainability of these companies.

On the other hand, Maksimowski, Pachura, Oziemblowski, Nawirska-Olszanska and Szumny (2022) destacan cómo las técnicas de extracción en frío pueden influir en la calidad del café y, en consecuencia, en su valor económico. Este enfoque en la tecnología y la calidad demuestra el potencial de mejorar la rentabilidad tanto para los productores como para la industria en general.

Finally, Barbosa et al. Souza et al. (2021) highlight the use of advanced technologies, such as drones and image analysis, for monitoring coffee plantations. According to the authors, this technology can optimize supply chain management and have a positive economic impact on coffee production by improving resource efficiency.
Overall, the analysis highlights a continued commitment by the coffee industry to address economic challenges and improve financial sustainability. To this end, the implementation of innovative and technological strategies is essential to ensure that this industry can maintain its competitiveness in the global market while promoting a more sustainable approach in its practice and production.

d. Sustainability in the supply chain

The "Sustainability in the supply chain" dimension addresses the efficient and meticulous management of the coffee value chain, from its cultivation to the enjoyment of the final consumer. This perspective contemplates multiple facets that crucially impact the achievement of a sustainable supply chain, including, but not limited to, the optimization of coffee quality, rigorous supervision of plantations, the influence of specific fermentation processes, and decision-making supported by verifiable data.

For Wang et al. (2019) lthe fermentation controlled by microorganisms and its influence on the quality of coffee become the central focus of the analysis; this is addressed in a conscientious way how the implementation of specific fermentation practices exerts a direct and measurable impact on the quality of the product throughout the entire supply chain journey, from cultivation to the consumer's cup. According to the authors, this analysis strongly highlights the preponderant relevance of sustainability in each of the links of the coffee supply chain.

Mahingsapun et al. (2022) further assess the impact of controlled fermentation on coffee quality. They also suggest that specific microbial strains have the potential to enrich and improve product quality significantly. This finding extends to

the supply chain sphere by providing critical insights on how to improve coffee quality during the production phase. This contribution consolidates the sustainability perspective within the supply chain.

Macheiner, Schmidt, Karpf and Mayer (2021) rhighlight the strategic use of drone technology and image analysis as cutting-edge tools for monitoring coffee plantations. This technological innovation provides an invaluable resource for supply chain management, allowing for real-time information on the status of crops and early detection of any irregularities. According to the authors, the application of such technologies represents a significant advance that unequivocally contributes to promoting sustainability in the coffee supply chain.

Overall, the aspects analyzed underline the critical importance of sustainability in the coffee supply chain. From the influence of microorganism-controlled fermentation on coffee quality to the role of microbial strains in improving quality and the implementation of advanced technologies such as drones and image analysis for monitoring plantations, the need to rigorously and technically address the challenges and opportunities surrounding sustainability in this value chain is emphasized. These findings support the premise that sustainability is an imperative need in the coffee supply chain. Adopting evidence-based approaches, advanced technology, and constant quality improvement are critical elements to ensuring a coffee supply that is both economically viable and environmentally responsible.

2. Environmental impact and coffee quality

The "Environmental Impact and Coffee Quality" analysis category addresses key aspects related to the dimensions of environmental impact and coffee quality, including wastewater treatment, sustainability in production, microbiology involved in coffee fermentation, and the influence of microorganisms on coffee flavor.

a. Microbiology and wastewater treatment

The "Microbiology and Wastewater Treatment" dimension of analysis focuses on the investigation of the influence of the microbial community and wastewater treatment in the context of the coffee industry. This dimension involves the study of the microbiology present in wastewater treatment systems used in coffee production and processing, as well as its impact on treatment efficiency and treated water quality. In addition, microbial dynamics in processes such as anaerobic digestion are investigated, and how certain microorganisms can contribute to the degradation of specific compounds, such as caffeine, in coffee wastewater is analyzed.

Lei et al. (2019) investigate the efficiency of an anaerobic co-digestion system that treats wastewater from canned coffee processing and activated sludge using an anaerobic membrane bioreactor. In this sense, the authors analyze the microbial composition and identify the dominant bacteria involved in the hydrolysis and fermentation processes, as well as the caffeine degradation in the system.

On the other hand, Botello et al. (2018) evaluate the effect of organic loading on the performance and microbial composition of a two-stage UASB system treating coffee processing wastewater. In the study, the predominant microorganisms are identified, and methane production is monitored, which has important implications for wastewater treatment in the coffee industry.

Authors such as Berego, Sota, Ulsido and Beyene (2022) developed an experimental study to evaluate the effectiveness of natural and constructed wetland systems in the treatment of coffee wastewater. The study analyzes the physicochemical parameters and the removal of contaminants and compares the performance of both types of wetlands in the purification of coffee wastewater.

Finally, Gloess, Yeretzian, Knochenmuss and Groessl (2018) perform an online analysis of coffee roasting and investigate the formation of volatile organic compounds during this process. Although wastewater is not directly addressed, the results offer information on the release of compounds during coffee production that may be related to the generation of wastewater in the industry.

Together, these studies provide a comprehensive view of how microbiology and wastewater treatment are approached in the coffee industry, highlighting the importance of understanding the microbial community and its role in water treatment and quality processes in specialty coffee production.

b. Sustainability in specialty coffee production

The "Sustainability in coffee production" dimension of analysis focuses on the evaluation of practices, programs, and policies related to specialty coffee production, the main objective of which is to promote sustainability in economic, social, and environmental terms. This dimension involves the consideration of factors such as the adoption of sustainable agricultural practices, the certification of coffee with sustainability labels, the impact of agricultural management and policies on social equity, and the efficiency of water use in coffee production.

Jezeer, Verweij, Boot, Junginger and Santos (2019) investigate how farmers' livelihood assets, risk perception, and unexpected impacts influence the choice of unconventional agricultural practices by small coffee farmers in San Martín, Peru. Within that framework, the authors analyze how these factors affect the sustainability of coffee production and how contradictory decisions can arise due to the influence of different types of livelihood assets.

Rich et al. (2018) examine the role of certification programs in promoting environmental conservation and protection on coffee farms in the Coorg region of India. In this analysis, coffee farmers' perceptions of certification and its relationship to environmental conservation are assessed, highlighting the importance of sustainability in coffee production.

Maguire-Rajpaul, Rajpaul, McDermott and Pinto (2020) address the relationship between compliance with social performance criteria and management criteria in certification programs and their impact on social equity at farm and landscape levels, highlighting the importance of management requirements in improving smallholder social performance and the role of certification in promoting equity.

Thong, Viet and Wilson (2022) analyze the effect of sustainability certification on water use efficiency in coffee production, considering different irrigation technologies used by farmers, examining how certification influences water efficiency, and highlighting advanced irrigation technologies as a means to improve water use sustainability.

Kwon et al. (2022) present an unusual focus on the sustainability of coffee production by exploring how water-soluble components of green coffee beans and roasted coffee residue affect lettuce growth in hydroponic systems. In their findings, the authors posit that water-soluble components of green coffee beans inhibit lettuce growth, while roasted coffee residues facilitate its growth.

This finding highlights the complexity of the effects of coffee by-products on the environment and suggests the possibility of recycling and reusing roasted coffee residues as crop growth stimulants. This innovative approach shows how sustainability in coffee production can go beyond agriculture itself and have implications for waste management and the circular economy.

Finally, Douangphachanh, Idrus, Phommavong and Jaquet (2021) explore the impact of economic liberalization and women's participation in decision-making on coffee production in the Bolaven Plateau in Laos. They analyze how the change in coffee production affects women's participation and decision-making power, highlighting the importance of considering gender equity in the sustainability of coffee production.

In general, this dimension of analysis focuses on promoting practices and policies that guarantee sustainability in coffee production from multiple perspectives, including economic, social, and environmental, with the aim of improving the quality of life of producers and preserving the environment.

c. Wastewater treatment in the coffee industry

The "Wastewater treatment in the coffee industry" dimension of analysis focuses on assessing how the coffee industry manages and treats its wastewater, as well as understanding the environmental impacts and implications for sustainability.

Dadi et al. (2018) reveals that effluents from traditional specialty coffee wet processing plants in Ethiopia have a significant impact on water quality in nearby rivers and streams. Water quality parameters such as organic content and acidity are severely affected by these effluents. It raises concerns about eutrophication risks and the health of aquatic ecosystems in the region, underlining the need for proper treatment of coffee waste.

On the other hand, Magalhães et al. (2021) focus on fermentation in coffee processing and how the use of bioreactors and starter cultures could influence coffee quality and, therefore, its economic value. The authors raise the possibility that treatment practices may have a direct impact on the economic sustainability and quality of coffee.

Mutarutwa et al. (2020) explore the relationship between the concentration of certain substances in green coffee and the occurrence of a flavor defect in the coffee. The treatment and quality of coffee beans can influence the perception of quality and, therefore, the economic sustainability of the industry.

Finally, Orfanou, Dermesonlouoglou and Taoukis (2019) focus on the aging of coffee during home storage and how factors such as temperature and water activity affect its quality, being relevant both for product quality and for reducing food waste. Overall, the findings address issues related to the treatment of processing effluents, the influence of fermentation and other processes on coffee quality, and quality management during home storage. These aspects are fundamental to ensure the environmental and economic sustainability of the coffee industry.

d. Improving coffee quality through microorganisms

The analysis dimension "Improving coffee quality through microorganisms" focuses on the influence of microorganisms on coffee quality. This approach involves the identification and evaluation of microorganisms that can have a positive impact on coffee flavor and aroma. Through isolation techniques, identification, and evaluation of microorganisms present in the coffee fermentation process, the aim is to determine their ability to improve coffee quality. Results may include the identification of microorganisms that produce enzymes relevant to the degradation of compounds in coffee, as well as their influence on the sensory characteristics of coffee.

Krajangsang et al. (2022) identify and evaluate microorganisms isolated from the coffee fermentation process with the aim of improving coffee quality through pectin degradation and its impact on coffee flavor and aroma. On the other hand, Batista da Mota, Dias and Schwan (2022), investigate coffee fermentation under anaerobic conditions and how this can influence the sensory characteristics of coffee. Although they do not directly mention the influence of microorganisms, the coffee fermentation process involves microorganisms that can affect the final quality of the product.

Traore, Wilson and Fields (2018) explore how quality attributes, both material and symbolic, impact specialty coffee scores and prices in the context of the Cup of Excellence program, a relevant aspect for understanding how coffee quality is valued in terms of flavor and aroma.

Finally, Maciel, Teixeira, Della Lucia and Saraiva (2022), investigate the influence of additives such as maltodextrin and whey protein isolate on coffee properties such as foam formation and sensory quality, contributing to the quest to improve coffee quality through the manipulation of its physical and sensory properties.

Taken together the findings offer a comprehensive view of how coffee quality improvement is approached from different perspectives. Studies analyzing the influence of microorganisms on the degradation of compounds and the creation of unique sensory profiles are on the rise. It provides coffee producers and roasters with new tools to improve quality and differentiate their products in a highly competitive market. Understanding coffee microbiology is playing a crucial role in the evolution of the industry toward the production of high-quality coffees and distinctive flavors.

3. Consumer behavior and added value

The "Consumer Behavior and Added Value" analysis category focuses on how aspects of quality, certification, processing, and consumer preferences can influence the sustainability of the specialty coffee industry. These factors are essential to understanding how the industry can move towards more sustainable practices and how consumers can play a role in this process.

a. Coffee quality and consumer preference

The "Coffee Quality and Consumer Preference" analysis dimension is essential in specialty coffee production. This dimension focuses on understanding the factors that influence coffee quality and how these qualities are perceived and preferred

by consumers. The studies identified in this field address coffee quality from different perspectives, including chemical composition, sensory evaluation, the influence of bean maturation, and the relationship between perceived quality and consumer preference.

Sittipod, Schwartz, Paravisini and Peterson (2019) highlight the importance of chemical composition in coffee quality, identifying chemical compounds that have a positive impact on cup scores according to the Specialty Coffee Association, through mass spectrometry analysis and sensory testing to identify and isolate compounds that improve coffee quality.

On the other hand, Bemfeito et al. (2021) highlight the relationship between consumers' perceived quality and the information provided about coffee, including details about roast type and price, demonstrating that perceived quality of specialty coffees can influence consumers' preference and willingness to pay more. Pereira et al. (2022) investigate the influence of coffee bean maturation and the application of a fungus on coffee quality. Although the results show no significant differences in quality due to the application of the fungus, they highlight the importance of environmental conditions on coffee quality.

In contrast, Agnoletti et al. (2022) propose using instrumental methods together with sensory evaluations to predict coffee quality. This approach seeks to objectify sensory evaluation and highlights volatile compounds as predictors of quality. Lee, Jung and Moon (2022) address the relationship between coffee quality and brand preference and loyalty, focusing on Starbucks and examining how attributes such as taste and price influence consumer loyalty.

Wuepper, Clemm and Wree (2019) focus on the influence of sustainability labels on consumer choice of coffee. To do so, they use an online choice experiment to assess the effect of water-saving labels on consumer preference. Their results suggest an increase in the likelihood of choice and willingness to pay for coffee labeled as "water-saving," showing how sustainability labels can influence consumer preference.

Marcus, Sisli-Ciamarra and McGinnis (2023) address sensory quality and its impact on specialty coffee auctions. They argue that sensory quality scores can lead to inequitable auction outcomes and propose interventions to standardize quality rating protocols. It is relevant to understanding how perceived quality can influence prices and consumer preferences in the specialty coffee market.

Hu, Liu, Jiang, Zhang and Zhang (2021) focus on the level of acrylamide in robust coffee beans during the roasting process, showing how roasting temperature affects the formation of acrylamide, a chemical compound related to coffee flavor. It illustrates the importance of roasting on perceived quality and consumer preference in terms of flavor.

For their part, Liu, Chen and Chen (2019) explore the importance that consumers place on sustainability certifications in their choice of coffee beans, highlighting the relevance of traceability, organic certification, and other certification attributes in consumer preference and their willingness to pay more for certified products, demonstrating how sustainability labels can influence consumer choice and preference.

Finally, Cabrera, Caldarelli and da Camara (2020) perform a bibliometric analysis of the scientific production of certified coffee. Although it does not directly address consumer preference, it highlights the growing attention to sustainability in coffee research, indicating the importance of these topics in consumer perception and coffee quality.

Together, these findings provide a comprehensive view of how coffee quality and consumer preference are influenced by chemical, sensory, environmental, and sustainability labeling factors. Understanding these aspects is critical for sustainable production and successful marketing of specialty coffee since coffee quality is a multidimensional issue encompassing chemical composition, sensory evaluation, bean maturation, and consumer perception. Understanding how these aspects relate to and affect consumer preference is essential for sustainable specialty coffee production and marketing strategy in the industry.

b. Certification and sustainability labels

The "Sustainability Certification and Labels" dimension of analysis focuses on the importance of sustainability-related certifications and labels in the coffee industry. These certifications and labels serve as essential tools for consumers to

evaluate the food safety, health concerns, and environmental friendliness of products. Furthermore, this dimension focuses on consumer perception and preference regarding these certifications, as well as their willingness to pay for certified products, which allows an understanding of how sustainability certifications and labels influence consumer choice and preference in the coffee market.

Liu, Chen and Chen (2019) highlight the relevance of sustainability certification labels in evaluating the food safety, health, and environmental friendliness of products, focusing on the attention consumers pay to sustainability information when choosing coffee certification attributes. The findings reveal consumers' preferences in terms of certification attributes, with traceability, organic, grade, environmental friendliness, and fair trade occupying priority positions in their willingness to pay.

Cabrera, Caldarelli and da Camara (2020) developed a bibliometric analysis that maps the scientific production related to certified coffee and its sustainability theme. In this study, the authors provide an overview of how research in this field has increased but also highlight the lack of significant collaboration networks and the concentration of research in a limited number of journals, highlighting that sustainability and environmental studies play a prominent role in the scientific literature, underlining the importance of sustainability in the coffee industry.

Overall, the dimension focuses on the fundamental role of sustainability certifications and labels in consumer evaluation and preference in the coffee industry, as well as the growing academic attention to this topic. These elements are crucial to understanding how consumers perceive and choose certified coffee products and how sustainability influences their decision-making.

c. Environmental impact of processing

The "Environmental impact of processing" analysis dimension focuses on the assessment of how coffee processing affects the ambient environment, specifically in terms of emissions of volatile and semi-volatile organic compounds, as well as water quality in the surrounding areas.

Moreira et al. (2019), presents a novel dynamic approach to profiling emissions of volatile and semi-volatile organic compounds during the coffee roasting process, where they use two different sorbents to collect substances released during the roasting process and are analyzed using advanced gas chromatography techniques. In their results, the authors show the ability of one of the sorbents to capture both volatile and semi-volatile compounds, providing a detailed understanding of the compounds released during the roasting process and how they evolve.

Complementarily, Dadi et al. (2018) assesses the impact of effluents from wet coffee processing plants on water quality in Ethiopia by collecting water samples in rivers/streams near these plants during peak coffee processing and analyzing water quality parameters. The authors found that effluents from these plants have an acidic pH and contain high levels of organic matter, which depletes oxygen content and poses a risk of eutrophication. It suggests a significant environmental impact on nearby water bodies and ecosystems.

In conclusion, this dimension focuses on understanding how coffee processing impacts the environment, from emissions of compounds during roasting to water quality in processing areas. These findings underline the importance of sustainably addressing environmental aspects in coffee production and the need to implement appropriate practices and technologies to mitigate these impacts.

d. Processing and added value

The "Processing and added value" analysis dimension focuses on the study of coffee processing and how this process adds value to the final product, influencing its quality and sensory characteristics, highlighting relevant aspects of coffee processing methods and how these methods can improve the quality and value of coffee.

Cassimiro et al. (2023) investigate the impact of inoculation of lactic bacteria and yeasts during the wet fermentation process of Coffea canephora coffee. Through the monitoring of various microbial strains, the production of acids and volatile compounds during fermentation is analyzed. Their results suggest how the inoculation of Leuconostoc mesenteroides improves the quality of coffee, generating caramel, fruity, and spicy notes in the drink, which adds sensory value to the final product.

Perez-Miguez, Castro-Puyana, Sanchez-Lopez, Plaza and Marina (2020) use a metabolomics strategy to study the coffee roasting process, analyzing green and roasted coffee beans at different degrees and identifying key metabolites that act as biomarkers of the roasting process. Their results allow us to understand how the roasting process adds value to coffee by generating specific compounds that contribute to its unique flavor and aroma.

Finally, Ut-tha, Lee and Chung (2021) reassess consumers' willingness to pay for sustainable coffee and investigate its determinants through the contingent valuation method to estimate consumers' willingness to pay for sustainable coffee in Thailand. The authors show that attitude, prior experience, and other factors influence consumers' willingness to pay, demonstrating how the perception of sustainability adds value to coffee and affects the willingness to pay a premium price for it.

Overall, the dimension focuses on how processing practices, fermentation, roasting, and perceived sustainability add value to coffee, both in terms of sensory quality and consumers' willingness to pay – essential aspects for the successful production and marketing of high-quality coffee.

5. Discussion

The different findings highlight key aspects related to sustainability in the coffee industry, including coffee quality, wastewater treatment, sustainability in production, the influence of microorganisms, consumer behavior, and added value. In this regard, the discussion can be expanded in five specific dimensions.

The studies highlight the importance of coffee quality in consumer preference and willingness to pay a premium price. Coffee quality refers to flavor and aroma and factors such as the chemical composition and ripeness of the beans. Improving sustainability is essential to focusing on the production of high-quality coffee, which will attract consumers who are willing to pay more and, therefore, benefit farmers.

The results address wastewater management in the coffee industry, highlighting its impact on water quality in the surrounding areas. Improving environmental sustainability is essential to implementing effective wastewater treatment systems that reduce adverse effects on aquatic ecosystems and prevent eutrophication. It will contribute to more sustainable coffee production from an environmental perspective.

The studies also analyze how factors such as farmers' livelihood assets and sustainability certifications influence production practices. Promoting sustainable farming practices, coffee certifications with sustainability labels, and training programs for farmers can improve economic and social sustainability. Furthermore, water use efficiency in coffee production is essential to ensure the sustainability of water resources.

The study of how microorganisms can influence coffee quality offers opportunities to improve the flavor and aroma of the final product. Identifying beneficial microorganisms and using them in the fermentation process can be an effective strategy to differentiate coffee in the market and increase its value.

Finally, the results reveal that consumers value sustainability certification and are willing to pay more for certified products. It highlights the importance of promoting and communicating sustainable practices in the coffee supply chain to attract a sustainability-conscious market segment. Comprehensive measures must be taken to address coffee quality, water management, environmental impact, and social equity. It involves collaboration between producers, roasters, certifiers, and consumers to promote sustainable practices and ensure high-quality coffee that is economically viable and environmentally responsible. Furthermore, continued research into the influence of microorganisms and consumer behavior can guide effective strategies to improve sustainability in the specialty coffee industry.

6. Methodological limitations

The analysis of coffee quality, consumer behavior, sustainability certifications, and the environmental impact of processing reveals several key dimensions that influence coffee production and marketing. However, it is crucial to identify and consider methodological limitations that may affect the interpretation of the results and conclusions drawn from the reviewed studies.

First, several studies have focused on specific geographical contexts, such as Ethiopia (Dadi et al., 2018) or Thailand (Ut-tha et al., 2021). This regional focus may limit the generalizability of the findings to other coffee-producing regions. Climatic conditions, agricultural practices, and processing methods vary significantly between countries and regions, which may affect the applicability of the results to different contexts.

Furthermore, most of the reviewed studies come from countries with high coffee production, such as Brazil, Colombia, and Ethiopia. It leaves out emerging or less represented regions in global production, which could lead to a biased view that needs to reflect the challenges and realities of less prominent producing countries.

There is also a tendency to prioritize studies that present positive or innovative results. It may lead to the omission of studies that found no significant improvements or that presented neutral or negative results, both of which are equally important for a complete understanding of the topic.

Most of the studies reviewed focus on quantitative and experimental methods, which could exclude valuable insights offered by qualitative research. Methodologies such as interviews and focus groups could provide a deeper understanding of the factors that influence consumer preferences and behaviors.

On the other hand, the diversity in the methodologies used to evaluate coffee quality, from chemical analysis to sensory and instrumental tests, can complicate the comparison and integration of results. The lack of standardization in evaluation techniques can lead to discrepancies in findings and conclusions about coffee quality.

Finally, some studies may have yet to fully control external factors such as climatic conditions, agricultural management, and processing methods. These factors can have a significant impact on coffee quality and study results, limiting the ability to attribute quality improvements solely to the interventions or techniques analyzed.

Overall, while the reviewed studies provide valuable insights into coffee quality, consumer behavior, sustainability certifications, and the environmental impact of processing, it is critical to acknowledge these methodological limitations. Addressing these limitations in future research will contribute to a more comprehensive and accurate understanding of the factors that influence coffee production and marketing.

7. Practical limitations of the findings

The findings provide an empirical basis for improving coffee quality and encouraging sustainable practices in the industry. However, to advance in this field, future research is required in three dimensions. First, it is central to explore new sustainable practices that could optimize both coffee quality and its environmental impact. Second, it is necessary to evaluate the effectiveness of current recommendations in real practice, ensuring that proposed solutions translate into tangible improvements. Third, the implementation of studies on microbial diversity, energy efficiency in processing, and the relationship between coffee quality and consumer health should be considered. How these findings can be complemented by future research and their practical implications will be discussed below.

The focus on new sustainable practices could contribute to technological innovation in the coffee industry. Although current studies have identified significant impacts of coffee processing on the environment, innovations that reduce these effects need to be explored. Research on emerging technologies, such as the use of bio-products for effluent management and greener roasting processes, could offer effective solutions. Evaluating the effectiveness of these new practices in terms of reducing emissions and improving coffee quality will be critical to their widespread adoption.

Furthermore, integrating sustainable practices from cultivation to processing can optimize both coffee quality and sustainability. Future research could focus on how to combine organic farming practices with advanced fermentation and processing techniques. This integrated approach can improve coffee quality and minimize environmental impact, offering a viable model for producers seeking to adopt more sustainable practices.

Evaluating the effectiveness of recommendations in practice is essential to ensure that the proposed solutions are truly applicable. Although studies have provided recommendations based on experiments, the implementation of these recommendations in real-world contexts needs to be evaluated through case studies or pilots. For example, the inoculation

of microorganisms in coffee fermentation, as recommended by research, needs to be tested in production practices to confirm its impact on product quality and viability in the field.

Furthermore, the effectiveness of sustainability certifications needs to be investigated in practice. Although certifications influence consumer preference, their actual impact on production practices and environmental and social benefits needs further evaluation. Investigating how these certifications actually impact production and tangible outcomes can provide a more complete view of their value in the industry.

The practical implications of these findings are significant. Adopting new sustainable technologies and practices can improve coffee quality and differentiate products in a competitive market. For producers and roasters, this suggests the need to keep up with innovations and best practices. Training and education on new techniques, such as fermentation with specific microorganisms and sustainable processing, are crucial to implement these practices effectively.

Finally, future research could explore microbial diversity in different regions and growing conditions to customize fermentation processes and improve the sensory profile of coffee. Assessing energy efficiency in processing can also contribute to economic and environmental sustainability while studying the relationship between coffee quality and consumer health can influence demand and marketing strategies.

In conclusion, while the current findings offer a solid foundation, future research can expand and deepen this understanding. Addressing identified limitations and exploring new areas will enable more effective application of sustainable practices and emerging technologies in coffee production and marketing.

8. Conclusions

The findings of the analysis highlight the importance of key factors to improve sustainability in the specialty coffee supply chain: coffee quality, natural resource management, sustainable agricultural practices, sustainability certifications and labels, and consumer education. These elements are interconnected and play a crucial role in the production, marketing, and consumption of specialty coffees. From these aspects, significant conclusions can be drawn.

First, quality is fundamental to sustainability. Studies show that coffee quality attracts consumers willing to pay higher prices and ensures the economic viability of farmers and the long-term success of the industry. High-quality coffee can justify premium prices, thus ensuring consistent demand. The relationship between quality and sustainability suggests that efforts to maintain and improve coffee quality can result in significant economic and environmental benefits. Implementing quality control processes and investing in technologies that improve the sensory profile of coffee is crucial to sustaining this balance.

Second, water management is critical. Proper management of water resources, both on coffee farms and in processing facilities, is essential to minimize environmental impact and ensure long-term water availability. Water management practices should include the implementation of effective wastewater treatment systems and technologies for reducing water use. Evaluating current practices and adopting innovative solutions for recycling and reusing water are critical steps toward more sustainable production. Research into advanced wastewater treatment and management techniques may offer new strategies to mitigate the negative impacts associated with coffee processing.

Third, sustainable certifications and practices are valuable. Sustainability certifications, such as fair trade and organic, and the adoption of responsible agricultural practices can improve farmers' profitability and encourage responsible practices throughout the supply chain. Consumers are increasingly inclined to value products with sustainability labels, making these certifications key differentiators in the marketplace. Encouraging the adoption of sustainable practices at the production level and promoting greater transparency and traceability in the supply chain is essential to meeting consumer expectations and improving the overall sustainability of the industry. Fourth, microorganisms can improve coffee quality. Research on the influence of microorganisms on coffee fermentation offers promising opportunities to improve the flavor and aroma of the final product. The identification of beneficial microbial strains and the application of controlled fermentation techniques can generate unique sensory profiles and improve coffee quality. Exploiting coffee microbiology to develop innovative and effective fermentation methods is an area of great potential that can contribute to the differentiation and valorization of specialty coffee in the market.

Finally, consumer education is essential. Consumer behavior plays a crucial role in the sustainability of the coffee industry. Education about the importance of supporting sustainable practices and the willingness to pay a premium price for certified products can drive positive change in the industry. Informed consumers are more likely to choose products that meet sustainability standards, which in turn can incentivize producers to adopt more responsible practices. Promoting awareness and understanding of the benefits of sustainability in coffee can lead to increasing demand for products that respect these principles.

To achieve greater sustainability in the specialty coffee supply chain, it is central to fostering ongoing collaboration between producers, traders, and consumers. It involves supporting sustainable agricultural practices, implementing efficient water management systems, and reducing environmental impact at all stages of production and processing. The constant pursuit of excellence in coffee quality must be a priority, as it ensures consistent demand and improves profitability for farmers. Furthermore, promoting social equity in the supply chain and ensuring that producers are fairly compensated for their work is essential for the sustainable development of the sector.

Ultimately, consumer education plays a crucial role in sustainability. Greater consumer understanding and appreciation of sustainability enables informed decisions and contributes to the drive for high-quality and sustainable coffee globally. Integrating these elements into practice can lead to a more efficient and environmentally friendly supply chain, ensuring a viable future for the coffee industry and benefiting all actors involved. The findings underline the need to adopt effective practices and collaborate at all levels to improve sustainability in the specialty coffee supply chain, thereby ensuring balanced and sustainable development across the industry.

The findings of the analysis also allow for the formulation of new hypotheses that could deepen our understanding of sustainability in specialty coffee production. One possible hypothesis is that integrating advanced water management and wastewater treatment practices on coffee farms could significantly reduce the environmental impact and improve the economic sustainability of coffee production.

This hypothesis is based on the observation that inadequate water management and pollution from coffee processing are critical concerns. Future studies could explore how different wastewater treatment technologies affect water quality in surrounding areas and the profitability and sustainability of coffee farms. Specific research could include evaluating innovative treatment systems, such as biological filters and water recycling technologies, and their impact on reducing the water footprint of coffee.

Another emerging hypothesis is that combining advanced fermentation techniques with sustainable agricultural practices could result in coffees with distinctive sensory profiles that could influence consumer preferences and their willingness to pay premium prices. Since microorganisms play a crucial role in coffee fermentation and the sensory quality of the final product, additional studies could investigate how the selection of specific microbial strains and controlled fermentation techniques can generate unique flavor profiles that respond to sustainable consumption trends.

Future projects could examine the interaction between sustainable agricultural practices, such as the use of organic fertilizers and environmentally friendly cultivation techniques, and their impact on coffee fermentation. In addition, market studies could be conducted to assess how these unique sensory profiles affect consumers' willingness to pay more for coffees with distinctive, sustainable characteristics.

These new hypotheses and specific studies provide a clear perspective for future research, helping to more effectively address challenges and opportunities in the production and marketing of sustainable specialty coffees. By exploring these topics, researchers can contribute to the implementation of innovative and sustainable practices in the coffee industry, promoting a more balanced and responsible future throughout the supply chain.

Conflict of interest

The authors declare no conflict of interest.

References

1. AGNOLETTI, Barbara Zani; FOLLI, Gabriely Silveira; PEREIRA, Lucas Louzada; PINHEIRO, Patricia Fontes; GUARCONI, Rogerio Carvalho; DA SILVA OLIVEIRA, Emanuele Catarina; FILGUEIRAS, Paulo Roberto. Multivariate calibration applied to study of volatile predictors of arabica coffee quality. In: Food Chemistry. 2022. vol. 367, p. 130679. https://doi.org/10.1016/j.foodchem.2021.130679
2. AMAGLIANI, Luca; SILVA, Juliana V. C.; SAFFON, Maxime; DOMBROWSKI, Jannika. On the foaming properties of plant proteins: Current status and future opportunities. In: Trends in Food Science & Technology. 2021. vol. 118, p. 261-272. https://doi.org/10.1016/j.tifs.2021.10.001
3. BATISTA DA MOTA, Marcela Caroline, et al. Impact of microbial self-induced anaerobiosis fermentation (SIAF) on coffee quality. In: Food Bioscience. 2022. vol. 47, p. 101640. https://doi.org/10.1016/j.fbio.2022.101640
4. BEMFEITO, Carla Martino; GUIMARAES, Angelica Sousa; DE OLIVEIRA, Alberto Lima; ANDRADE, Bruna Fernandes; AMARAL FROSSARD DE PAULA, Luiza Maria; PIMENTA, Carlos Jose. Do consumers perceive sensory differences by knowing information about coffee quality? In: LWT. 2021. vol. 138, p. 110778. https://doi.org/10.1016/j.lwt.2020.110778
5. BEREGO, Yohannes Seifu; SOTA, Solomon Sorsa; ULSIDO, Mihret Dananto; BEYENE, Embialle Mengistie. Treatment Performance Assessment of Natural and Constructed Wetlands on Wastewater From Kege Wet Coffee Processing Plant in Dale Woreda, Sidama Regional State, Ethiopia. In: Environmental Health Insights. 2022. vol. 16, p. 117863022211427. https://doi.org/10.1177/11786302221142749
6. BOLKA, Muluken; EMIRE, Shimelis. Effects of coffee roasting technologies on cup quality and bioactive compounds of specialty coffee beans. In: Food Science & Nutrition. 2020. vol. 8, no. 11, p. 6120-6130. https://doi.org/10.1002/fsn3.1904
7. BOTELLO-SUAREZ, Wilmar Alirio; VANTINI, Juliana da Silva; DUDA, Rose Maria; GIACHETTO, Poliana Fernanda; CINTRA, Leandro Carrijo; TIRABOSCHI-FERRO, Maria Ines; DE OLIVEIRA, Roberto Alves. Predominance of syntrophic bacteria, Methanosaeta and Methanoculleus in a two-stage up-flow anaerobic sludge blanket reactor treating coffee processing wastewater at high organic loading rate. In: Bioresource Technology. 2018 vol. 268, p. 158–168. https://doi.org/10.1016/j.biortech.2018.06.091
8. BRENES-PERALTA, Laura; DE MENNA, Fabio; VITTUARI, Matteo. Interlinked driving factors for decision-making in sustainable coffee production. In: Environment, Development and Sustainability. 2022. https://doi.org/10.1007/s10668-022-02821-6
9. CABRERA, Lilian Cervo; CALDARELLI, Carlos Eduardo; DA CAMARA, Marcia Regina Gabardo. Mapping collaboration in international coffee certification research. In: Scientometrics. 2020. vol. 124, no. 3, p. 2597-2618. https://doi.org/10.1007/s11192-020-03549-8
10. CASSIMIRO, Debora Mara de Jesus; BATISTA, Nadia Nara; FONSECA, Hugo Calixto; NAVES, Jose Augusto Oliveira; COELHO, Jussara Moreira; BERNARDES, Patricia Campos; DIAS, Disney Ribeiro; SCHWAN, Rosane Freitas. Wet fermentation of Coffea canephora by lactic acid bacteria and yeasts using the self-induced anaerobic fermentation (SIAF) method enhances the coffee quality. In: FOOD MICROBIOLOGY. 2023. vol. 110. https://doi.org/10.1016/j.fm.2022.104161
11. CAUDILL, Morgan; OSBORNE, Jason; SANDEEP, K. P.; SIMUNOVIC, Josip; HARRIS, Gabriel Keith. Viability of microwave technology for accelerated cold brew coffee processing vs conventional brewing methods. In: Journal of Food Engineering. 2022. vol. 317, p. 110866. https://doi.org/10.1016/j.jfoodeng.2021.110866
12. CHEN, Zhaojie; SONG, Shiming; MAO, Lianying; WEI, Jie; LI, Yuanfu; TAN, Huihua; LI, Xuesheng. Determinations of dinotefuran and metabolite levels before and after household coffee processing in coffee beans using solid-phase extraction coupled with liquid chromatography-tandem mass spectrometry. In: Journal of the Science of Food and Agriculture. 2018. vol. 99, no. 3, p. 1267-1274. https://doi.org/10.1002/jsfa.9300
13. COSTA, Anabela S. G.; ALVES, Rita C.; VINHA, Ana F.; COSTA, Elisio; COSTA, Catarina S. G.; ANTONIA NUNES, M.; ALMEIDA, Agostinho A.; SANTOS-SILVA, Alice; OLIVEIRA, M. Nutritional, chemical and antioxidant/pro-oxidant profiles of silverskin, a coffee roasting by-product. In: Food Chemistry. 2018. vol. 267, p. 28-35. https://doi.org/10.1016/j.foodchem.2017.03.106
14. DADI, Dessalegn; MENGISTIE, Embialle; TEREFE, Gudina; GETAHUN, Tadesse; HADDIS, Alemayehu; BIRKE, Wondwossen; BEYENE, Abebe; LUIS, Patricia; VAN DER BRUGGEN, Bart. Assessment of the effluent quality of wet coffee processing wastewater and its influence on downstream water quality. In: Ecohydrology & Hydrobiology. 2018. vol. 18, no. 2, p. 201-211. https://doi.org/10.1016/j.ecohyd.2017.10.007
15. DOUANGPHACHANH, Maliphone; IDRUS, Rusaslina; PHOMMAVONG, Saithong; JAQUET, Stephanie. AGRICULTURE TRANSITION AND WOMEN'S DECISION-MAKING POWER IN COFFEE-FARMING HOUSEHOLDS IN LAO PDR. In: Jati. 2021. vol. 26, no. 1, p. 49–71. https://doi.org/10.22452/jati.vol26no1.3
16. GLOESS, A. N.; YERETZIAN, C.; KNOCHENMUSS, R.; GROESSL, M. On-line analysis of coffee roasting with ion mobility spectrometry–mass spectrometry (IMS–MS). In: International Journal of Mass Spectrometry. 2018. vol. 424, p. 49–57. https://doi.org/10.1016/j.ijms.2017.11.017
17. HU, Huihui; LIU, Xiaoling; JIANG, Lian; ZHANG, Qi; ZHANG, Haide. The relationship between acrylamide and various components during coffee roasting and effect of amino acids on acrylamide formation. In: Journal of Food Processing and Preservation. 2021. vol. 45, no. 5. https://doi.org/10.1111/jfpp.15421
18. JAEGER, Sara R.; GIACALONE, Davide . Barriers to consumption of plant-based beverages: A comparison of product users and non-users on emotional, conceptual, situational, conative and psychographic variables. In: Food Research International. 2021. vol. 144, p. 110363. https://doi.org/10.1016/j.foodres.2021.110363

19. JEZEER, Rosalien E.; VERWEIJ, Pita A.; BOOT, Rene G.A.; JUNGINGER, Martin; SANTOS, Maria J. Influence of livelihood assets, experienced shocks and perceived risks on smallholder coffee farming practices in Peru. In: Journal of Environmental Management. 2019. vol. 242, p. 496–506. https://doi.org/10.1016/j.jenvman.2019.04.101
20. KITTICHOTSATSAWAT, Yotsaphat; JANGKRAJARNG, Varattaya; TIPPAYAWONG, Korrakot Yaibuathet. Enhancing Coffee Supply Chain towards Sustainable Growth with Big Data and Modern Agricultural Technologies. In: Sustainability. 2021 vol. 13, no. 8, p. 4593. https://doi.org/10.3390/su13084593
21. KRAJANGSANG, Sukhumaporn, et al. New approach for screening of microorganisms from Arabica coffee processing for their ability to improve Arabica coffee flavor. In: 3 BIOTECH. 2022. vol. 12, no. 7. https://doi.org/10.1007/s13205-022-03203-5
22. KWON, Sumin; YOON, Ho Young; PHONG, Nguyen Thanh; LEE, Gyu Young; JANG, Kyoung-Soon; JOE, Eun-Nam; LEE, Yesol; JEON, Jong-Rok. Humic-like crop stimulatory activities of coffee waste induced by incorporation of phytotoxic phenols in melanoidins during coffee roasting: Linking the Maillard reaction to humification. In: Food Research International. 2022. vol. 162, p. 112013. https://doi.org/10.1016/j.foodres.2022.112013
23. LACHENMEIER, Dirk W.; SCHWARZ, Steffen; TEIPEL, Jan; HEGMANNS, Maren; KUBALLA, Thomas; WALCH, Stephan G.; BREITLING-UTZMANN, Carmen M. Potential Antagonistic Effects of Acrylamide Mitigation during Coffee Roasting on Furfuryl Alcohol, Furan and 5-Hydroxymethylfurfural. In: Toxics. 2018. vol. 7, no. 1, p. 1. https://doi.org/10.3390/toxics7010001
24. LE, Quan Vu; COWAL, Sanya; JOVANOVIC, Grace; LE, Don-Thuan. A study of regenerative farming practices and sustainable coffee of ethnic minorities farmers in the central highlands of Vietnam. In: Frontiers in Sustainable Food Systems. 2021. vol. 5. https://doi.org/10.3389/fsufs.2021.712733
25. LEE, Won Seok; JUNG, Jiwoo; MOON, Joonho. Exploring the antecedents and consequences of the coffee quality of Starbucks: a case study. In: British Food Journal. 2021. vol. 124, no. 4, p. 1066–1080. https://doi.org/10.1108/bfj-04-2021-0442
26. LEI, Zhen; ZHI, Li; JIANG, Hongyu; CHEN, Rong; WANG, Xiaochang; LI, Yu-You. Characterization of microbial evolution in high-solids methanogenic co-digestion of canned coffee processing wastewater and waste activated sludge by an anaerobic membrane bioreactor. In: Journal of Cleaner Production. 2019. vol. 232, p. 1442–1451. https://doi.org/10.1016/j.jclepro.2019.06.045
27. LEME, Dimas Samid; DA SILVA, Sabrina Alves; GROENNER BARBOSA, Bruno Henrique; BOREM, Flavio Meira; FONSECA ALVARENGA PEREIRA, Rosemary Gualberto. Recognition of coffee roasting degree using a computer vision system. In: Computers and Electronics in Agriculture. 2019. vol. 156, p. 312–317. https://doi.org/10.1016/j.compag.2018.11.029
28. LIN, Yi-Hsin; LIN, Feng-Jyh; WANG, Kuo-Hsiung . The effect of social mission on service quality and brand image. In: Journal of Business Research. 2021b. vol. 132, p. 744–752. https://doi.org/10.1016/j.jbusres.2020.10.054
29. LIU, Chun-Chu; CHEN, Chu-Wei; CHEN, Han-Shen Measuring consumer preferences and willingness to pay for coffee certification labels in Taiwan. In: Sustainability. 2019. vol. 11. no. 5, p. 1297. https://doi.org/10.3390/su11051297
30. LIU, Chun-Chu; CHEN, Chu-Wei; CHEN, Han-Shen. Measuring consumer preferences and willingness to pay for coffee certification labels in Taiwan. In: Sustainability. 2019. vol. 11, no. 5, p. 1297. https://doi.org/10.3390/su11051297
31. MACHEINER, Lukas; SCHMIDT, Anatol; KARPF, Franz; MAYER, Helmut K. A novel UHPLC method for determining the degree of coffee roasting by analysis of furans. In: Food Chemistry, 2021. vol. 341, p. 128165. https://doi.org/10.1016/j.foodchem.2020.128165
32. MACIEL, Katia Silva; TEIXEIRA, Luciano Jose Quintao; LUCIA, Suzana Maria Della; SARAIVA, Sergio Henriques. Optimization of foam mat drying for instant coffee processing and its effect on drying kinetics and quality characteristics. In: Drying Technology. 2021. vol. 40, no. 9, p. 1866–1880. https://doi.org/10.1080/07373937.2021.1887210
33. MAGALHÃES-JUNIOR, Antonio Irineudo; NETO, Dao Pedro de Carvalho; PEREIRA, Gilberto Vinicius de Melo; VALE, Alexander da Silva; MEDINA, Jesus David Coral; DE CARVALHO, Julio Cesar; SOCCOL, Carlos Ricardo. A critical techno-economic analysis of coffee processing utilizing a modern fermentation system: Implications for specialty coffee production. In: FOOD AND BIOPRODUCTS PROCESSING. 2021. vol. 125, p. 14-21. https://doi.org/10.1016/j.fbp.2020.10.010
34. MAGUIRE-RAJPAUL, Victoria A.; RAJPAUL, Vinesh M.; MCDERMOTT, Constance L.; GUEDES-PINTO, Luis Fernando. Coffee certification in Brazil: compliance with social standards and its implications for social equity. In: Environment, Development and Sustainability. 2018. vol. 22, no. 3, p. 2015–2044. https://doi.org/10.1007/s10668-018-0275-z
35. MAHINGSAPUN, Rattiyakorn; TANTAYOTAI, Prapakorn; PANYACHANAKUL, Titiporn; SAMOSORN, Siritron; DOLSOPHON, Kulvadee; JIAMJARIYATAM, Rossaporn; LORLIAM, Wanlapa; SRISUK, Nantana; KRAJANGSANG, Sukhumaporn. Enhancement of Arabica coffee quality with selected potential microbial starter culture under controlled fermentation in wet process. In: Food Bioscience. 2022. vol. 48, p. 101819. https://doi.org/10.1016/j.fbio.2022.101819
36. MAKSIMOWSKI, Damian; PACHURA, Natalia; OZIEMBLOWSKI, Maciej; NAWIRSKA-OLSZANSKA, Agnieszka; SZUMNY, Antoni. Coffee roasting and extraction as a factor in cold brew coffee quality. In: Applied Sciences. 2022. vol. 12, no. 5, p. 2582. https://doi.org/10.3390/app12052582
37. MARCUS, Benjamin; SISLI-CIAMARRA, Elif; MCGINNIS, Lee Phillip. Winner-takes-all no more: radical transparency for sustainable specialty coffee value chains. In: Journal of Agribusiness in Developing and Emerging Economies. 2022. vol. 13, no. 3, p. 490–503. https://doi.org/10.1108/jadee-07-2021-0186

38. MOREIRA-NOVAES, Fabio Junior; DA SILVA JUNIOR, Ademario Iris; KULSING, Chadin; NOLVACHAI, Yada; BIZZO, Humberto Ribeiro; DE AQUINO NETO, Francisco Radler; REZENDE, Claudia Moraes; MARRIOTT, Philip John. New approaches to monitor semi-volatile organic compounds released during coffee roasting using flow-through/active sampling and comprehensive two-dimensional gas chromatography. In: Food Research International. 2019. vol. 119, p. 349–358. https://doi.org/10.1016/j.foodres.2019.02.009
39. MUTARUTWA, Delvana; NAVARINI, Luciano; LONZARICH, Valentina; CRISAFULLI, Paola; COMPAGNONE, Dario; PITTIA, Paola. Determination of 3-Alkyl-2-methoxypyrazines in Green Coffee: A Study To Unravel Their Role on Coffee Quality. In: Journal of Agricultural and Food Chemistry. 2019. vol. 68, no. 17, p. 4743–4751. https://doi.org/10.1021/acs.jafc.9b07476
40. NGUYEN, Ngoc Bao Tu; LIN, Gu-Hong; DANG, Thanh-Tuan . A two phase integrated Fuzzy Decision-Making framework for green supplier selection in the coffee bean supply chain. In: Mathematics. 2021. vol. 9, no. 16, p. 1923. https://doi.org/10.3390/math9161923
41. ORFANOU, Foteini; DERMESONLOUOGLOU, Efimia K.; TAOUKIS, Petros S. Greek coffee quality loss during home storage: Modeling the effect of temperature and water activity. In: Journal of Food Science. 2019. vol. 84, no. 10, p. 2983–2994. https://doi.org/10.1111/1750-3841.14756
42. PANTALEO, Antonio M.; FORDHAM, Julia; OYEWUNMI, Oyeniyi A.; DE PALMA, Pietro; MARKIDES, Christos N. Integrating cogeneration and intermittent waste-heat recovery in food processing: Microturbines vs. ORC systems in the coffee roasting industry. In: Applied Energy. 2018 vol. 225, p. 782–796. https://doi.org/10.1016/j.apenergy.2018.04.097
43. PASCUCCI, Federica. The export competitiveness of Italian coffee roasting industry. In: British Food Journal. 2018. vol. 120, no. 7, p. 1529–1546. https://doi.org/10.1108/bfj-05-2017-0306
44. PEREIRA, Karoline Cristina; REZENDE DE MELO, Bruno Manoel; FERREIRA, Sindynara; DOS SANTOS, Telma Miranda; SOUZA, Vitor Marinello; SALOMAO LEME, Raissa Lima. Coffee quality at different maturation stages, due to the application of Cladosporium cladosporioides. In: Nativa. 2022. vol. 10, no. 3, p. 351–355. https://doi.org/10.31413/nativa.v10i3.13426
45. PEREZ-MIGUEZ, Raquel; CASTRO-PUYANA, Maria; SANCHEZ-LOPEZ, Elena; PLAZA, Merichel; LUISA MARINA, Maria. Untargeted HILIC-MS-Based Metabolomics approach to evaluate coffee roasting process: contributing to an Integrated metabolomics multiplatform. In: Molecules. 2020. vol. 25, no. 4, p. 887. https://doi.org/10.3390/molecules25040887
46. POISSON, Luigi; PITTET, Jonathan; SCHAERER, Anja; MESTDAGH, Frederic; DAVIDEK, Tomas. Quantitative validation of the In-Bean approach in coffee roasting. In: Journal of Agricultural and Food Chemistry. 2019. vol. 68, no. 17, p. 4732–4742. https://doi.org/10.1021/acs.jafc.9b05436
47. RHINEY, Kevon; GUIDO, Zack; KNUDSON, Chris; AVELINO, Jacques; BACON, Christopher M.; LECLERC, Gregoire; AIME, M. Catherine; BEBBER, Daniel P. Epidemics and the future of coffee production. Proceedings of the National In: Academy of Sciences of the United States of America. 2021. vol. 118, no. 27. https://doi.org/10.1073/pnas.2023212118
48. RICH, Karl M.; CHENGAPPA, P. G.; MUNIYAPPA, Arun; YADAVA, C. G.; MANJYAPURA, Gana Shruthy; BABU, B. N. Pradeepa; SHUBHA, Y. C.; RICH, Magda. Coffee certification in India: Awareness, practices, and sustainability perception of growers. In: Agroecology and Sustainable Food Systems. 2017. vol. 42, no. 4, p. 448–474. https://doi.org/10.1080/21683565.2017.1361497
49. SITTIPOD, Sichaya; SCHWARTZ, Eric; PARAVISINI, Laurianne; PETERSON, Devin G. Identification of flavor modulating compounds that positively impact coffee quality. In: Food Chemistry. 2019. vol. 301, p. 125250. https://doi.org/10.1016/j.foodchem.2019.125250
50. SOUZA BARBOSA, Brenon Diennevam; FERRAZ, Gabriel Araujo e Silva; DOS SANTOS, Luana Mendes; SANTANA, Lucas Santos; MARIN, Diego Bedin; ROSSI, Giuseppe; CONTI, Leonardo. Application of RGB Images Obtained by UAV in Coffee Farming. In: Remote Sensing. 2021. vol. 13, no. 12, p. 2397. https://doi.org/10.3390/rs13122397
51. SPRENG, Stefan; SCHAERER, Ania; POISSON, Luigi; CHAUMONTEUIL, Matthieu; MESTDAGH, Frederic; DAVIDEK, Tomas. Discovery of Polyhydroxyalkyl Pyrazine Generation upon Coffee Roasting by In-Bean Labeling Experiments. In: Journal of Agricultural and Food Chemistry. 2021. vol. 69, no. 23, p. 6636–6649. https://doi.org/10.1021/acs.jafc.1c01894
52. THONG-QUOC, Ho; VIET-NGU Hoang; WILSON, Clevo. Sustainability certification and water efficiency in coffee farming: The role of irrigation technologies. In: Resources, Conservation and Recycling. 2022. vol. 180, p. 106175. https://doi.org/10.1016/j.resconrec.2022.106175
53. TRAORE, Togo M.; WILSON, Norbert L.W.; FIELDS, Deacue, III. WHAT EXPLAINS SPECIALTY COFFEE QUALITY SCORES AND PRICES: A CASE STUDY FROM THE CUP OF EXCELLENCE PROGRAM. In: Journal of Agricultural and Applied Economics, 2018. vol. 50, no. 3, p. 349–368. https://doi.org/10.1017/aae.2018.5
54. UT-THA, Veenarat; LEE, Pai-Po; CHUNG, Rebecca. Willingness to pay for sustainable coffee: a case of Thai consumers. In: Sage Open. 2021. vol. 11. no. 4, p. 21582440211052956. https://doi.org/10.1177/21582440211052956
55. WANG, Chenhui; SUN, Jingcan; LASSABLIERE, Benjamin; YU, Bin; ZHAO, Feifei; ZHAO, Fangju; CHEN, Ying; LIU, Shao Quan. Potential of lactic acid bacteria to modulate coffee volatiles and effect of glucose supplementation: fermentation of green coffee beans and impact of coffee roasting. In: Journal of the Science of Food and Agriculture. 2018. vol. 99, no. 1, p. 409–420. https://doi.org/10.1002/jsfa.9202
56. WUEPPER, David; CLEMM, Alexandra; WREE, Philipp. The preference for sustainable coffee and a new approach for dealing with hypothetical bias. Journal of Economic Behavior and Organization. 2019. vol. 158, p. 475–486. https://doi.org/10.1016/j.jebo.2018.12.012
57. ZHAI, Xingchen; YANG, Mengnan; ZHANG, Jing; ZHANG, Lulu; TIAN, Yarong; LI, Chaonan; BAO, Lina; MA, Chao; ABD EL-ATY, A. M. Feasibility of Ultrasound-Assisted extraction for accelerated cold brew coffee processing: Characterization and comparison with conventional brewing methods. In: Frontiers in Nutrition. 2022. vol. 9. https://doi.org/10.3389/fnut.2022.849811