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Provision of Post-Harvest Coffee Technology and its Development Problems from the Perspectives of Ontology, Epistemology, and Axiology

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Abstract

The coffee industry in Indonesia has significant potential for growth; however, challenges in the provision of post-harvest technology remain a major obstacle. This article aims to examine the issues surrounding the development of coffee post-harvest technology through the perspectives of ontology, epistemology, and axiology. Ontology explores the essence of post-harvest technology as an integral part of the coffee production system, encompassing not only tools or machines but also the knowledge and practices related to coffee bean processing. Epistemology investigates how knowledge about this technology is constructed, disseminated, and applied by farmers, highlighting the gap between scientific research and field implementation. Axiology examines the values underlying the application of post-harvest technology, including its impact on environmental sustainability, economic efficiency, and farmer welfare. This study employs a qualitative approach with secondary data-based literature analysis. The findings reveal that innovations in coffee post-harvest technology have not fully considered local wisdom, farmers' capacities, and environmental sustainability. Therefore, this article recommends a holistic approach that integrates technical, social, and ethical aspects in the development of coffee post-harvest technology. These findings are expected to contribute significantly to the formulation of more inclusive and sustainable policies and practices in Indonesia's coffee sector.

Keywords: Axiology; Coffee; Epistemology; Ontology; Post-Harvest Technology.

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1. Introduction

Coffee is a strategic commodity that plays an important role in Indonesia's economy. Indonesia ranks as the 4th largest coffee producer in the world, following Brazil, Vietnam, and Colombia (Fitriani *et al.*, 2021). Coffee serves as a source of income for millions of farmers across various regions and contributes significantly to the country's foreign exchange earnings through exports (Innayatuhibbah *et al.*, 2024). However, despite its potential, the quality of Indonesian coffee often lags behind that of other producing countries. One of the main factors affecting coffee quality is the post-harvest process, which includes harvesting, processing, drying, fermentation, and storage of coffee beans (Amrulloh *et al.*, 2021; Mayrowani, 2013; Schroth *et al.*, 2014).

The post-harvest process significantly impacts the final quality of coffee products. Campos *et al.* (2022) emphasize that appropriate post-harvest technologies can enhance coffee bean quality, reduce damage levels, and extend product shelf life. However, in Indonesia, many coffee farmers still rely on traditional methods that are inefficient and susceptible to microbial contamination. For instance, the drying of coffee beans is often conducted manually under sunlight without adequate control over temperature and humidity, leading to risks of physical and biological damage, such as mold or excessive fermentation, which can diminish the economic value of the product (Situmeang *et al.*, 2023; Suprianto *et al.*, 2022). Research indicates that the drying process is critical; maintaining the grain temperature below 40°C and achieving a moisture content of around 12% is essential for preserving the quality of coffee beans (Coelho *et al.*, 2024; Jakkaew *et al.*, 2024). Furthermore, the use of controlled drying methods can mitigate the adverse effects associated with traditional practices, thereby improving the overall quality and marketability of Indonesian coffee (Barrios-Rodríguez *et al.*, 2020; Firdaus *et al.*, 2023).

The adoption of modern technology in the post-harvest process of coffee in Indonesia faces several challenges. Firstly, a significant portion of coffee farmers in Indonesia are smallholders with limited land and restricted access to capital, which hampers their ability to invest in advanced post-harvest technologies (Cofré-Bravo *et al.*, 2018). Secondly, there exists a

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knowledge gap between scientific research outcomes and practical field applications, often acting as a barrier to the implementation of new technologies (Sunanto *et al.*, 2024). This disconnect can lead to inefficiencies in the adoption of practices that could enhance coffee quality and productivity. Additionally, socio-cultural factors, such as traditional coffee processing habits, significantly influence farmers' acceptance of modern technologies (Nazaruddin *et al.*, 2023). These entrenched practices can create resistance to change, as farmers may prefer familiar methods over new approaches that require adjustments in their routines and beliefs (Kislali *et al.*, 2016).

In the context of coffee post-harvest technology development, it is essential to recognize that this advancement encompasses not only technical aspects but also deeper philosophical dimensions. The ontological perspective aids in understanding the essence of post-harvest technology as an integral component of the coffee production system, emphasizing its role in shaping the identity and practices within this sector (Ahmad *et al.*, 2023; Pavlovskaia, 2014). Furthermore, the epistemological perspective delves into how knowledge regarding these technologies is constructed, disseminated, and applied by farmers, highlighting the importance of local knowledge systems and educational frameworks in enhancing technological adoption (Rahmah, Mardawati, *et al.*, 2023; Rahmah, Purnomo, *et al.*, 2023). Meanwhile, the axiological perspective explores the underlying values associated with the implementation of such technologies, particularly their implications for environmental sustainability and the welfare of farmers, thereby addressing the ethical considerations that accompany technological advancements in coffee production (Ibnu, 2022; Trollman *et al.*, 2022). Collectively, these philosophical perspectives provide a comprehensive framework for understanding the multifaceted nature of coffee post-harvest technology development, ensuring that it aligns with sustainable practices and the well-being of all stakeholders involved.

Based on this background, several fundamental issues arise, including how the nature of post-harvest coffee technology is understood as part of the overall coffee production system, how knowledge about post-harvest coffee technology is constructed and disseminated to farmers, what values underpin the implementation of post-harvest coffee technology, and how this technology can support environmental sustainability and farmers' well-being. Therefore, these issues necessitate an examination of post-harvest coffee technology development through the perspectives of ontology, epistemology, and axiology.

2. Materials and Methods

2.1. Research Approach

This study employs a qualitative approach with a focus on literature analysis based on secondary data. The qualitative approach is chosen as the study aims to examine the development of post-harvest coffee technology through the perspectives of ontology, epistemology, and axiology. This approach enables the researcher to explore phenomena holistically, uncover meanings, and understand the social, cultural, and philosophical contexts underlying the implementation of post-harvest coffee technology.

Qualitative approaches are well-suited for research aimed at explaining complex phenomena through in-depth data interpretation, as they focus on understanding context, meaning, and the intricacies of human behavior (Eftenaru, 2022; Estera & Djaja, 2023). In this context, a literature analysis is conducted to identify trends, challenges, and potential solutions in the development of post-harvest coffee technology in Indonesia.

2.2. Data Sources

This study utilizes data sourced from secondary literature, encompassing several key categories. First, reputable scientific journals, including articles from journals indexed in Scopus, Web of Science, or SINTA 1-2, which cover topics related to post-harvest coffee technology, environmental sustainability, and the philosophy of science. Second, research reports from prominent research institutions such as the International Coffee Organization (ICO), the Indonesian Ministry of Agriculture, and leading universities. Third, official policy documents issued by government agencies or international organizations concerning agricultural technology development and coffee-related policies. Lastly, academic reference books discussing the philosophy of science (ontology, epistemology, and axiology) as well as modern agricultural technology. The selection of data sources was based on their relevance to the research topic, recent publication dates (within the last 5–10 years), and high academic reputation to ensure the quality and validity of the information used in this study.

2.3. Data Collection Techniques

The data collection technique in this study involves a systematic process consisting of several key steps. Initially, a literature search was carried out using academic databases such as Google Scholar, Scopus, ScienceDirect, and PubMed. The keywords used during the search included terms like "post-harvest technology," "coffee processing," "sustainability in agriculture," "ontology in agricultural technology," "epistemology of agricultural knowledge," and "axiology in farming practices" to ensure comprehensive coverage of relevant topics. Following this, a literature selection process was conducted, where articles and documents were chosen based on specific inclusion criteria: their relevance to the research topic, recent publication dates (within the last 5–10 years), and indexing in reputable journals such as Scopus, Web of Science, or SINTA 1-2. Finally, data extraction was performed by identifying and categorizing key information from each selected source into major themes, including post-harvest technology, ontology, epistemology, and axiology, to facilitate further analysis and discussion.

2.4. Data Analysis Techniques

Data analysis was carried out using thematic analysis, which involved several steps. The process of filtering secondary data involves several stages, starting from familiarization to interpretation, ensuring that only the most relevant and high-quality data is included in the analysis. Initially, during the familiarization stage, the researcher thoroughly reads and understands all the collected literature to identify patterns and key themes. From an initial pool of 150 articles retrieved through database searches, the researcher begins to exclude sources that do not align with the research focus. After this stage, approximately 100 articles remained, as 50 were deemed irrelevant or redundant.

Next, during the coding stage, the remaining data is systematically coded based on major themes such as "ontology of post-harvest technology," "knowledge dissemination," "values in technology," and "development challenges." At this point, another round of filtering occurs, where articles that lacked sufficient depth or failed to meet the inclusion criteria (e.g., outdated publications or non-indexed journals) were excluded. This reduced the number of articles to around 60, as 40 additional sources did not meet the quality or thematic requirements.

In the theme identification stage, similar codes are grouped into broader themes, such as "the nature of post-harvest technology," "knowledge gap," and "sustainability principles." Here, further refinement takes place, and only articles that strongly contribute to these overarching themes are retained. After this step, approximately 40 articles remained, as 20 more were excluded for not fitting into the identified themes or lacking relevance to the research questions.

Finally, during the interpretation stage, the identified themes are analyzed and interpreted to answer the research questions and provide new insights into the development of post-harvest coffee technology. By the end of this process, a total of 30 articles were selected for the final analysis, as they provided the most robust and relevant data to support the study's objectives. Thus, out of the initial 150 articles, 30 were ultimately included after a rigorous filtering process based on the established exclusion criteria.

2.5. Validity and Reliability of Data

To ensure the validity and reliability of the data, this study employs several strategies. First, source triangulation is utilized by gathering data from a variety of sources, including scientific journals, research reports, and policy documents. This approach ensures that the information used is both comprehensive and free from bias, as it draws on multiple perspectives. Second, the study incorporates peer review, where the initial draft of the article is evaluated by experts in agricultural technology and the philosophy of science. This step helps to verify the accuracy and rigor of the analysis. Finally, the study prioritizes the use of recent references, with all sources being credible and published within the last 5–10 years, ensuring that the data reflects current conditions and remains relevant to contemporary issues. Through these strategies, the study aims to maintain high standards of validity and reliability in its findings.

2.6. Conceptual Framework

The conceptual framework of this study is based on three philosophical perspectives, namely ontology, epistemology, and axiology. Below is the conceptual framework presented in the form of a schema or concept map based on the three elements of the philosophy of science (ontology, epistemology, and axiology) as described in figure 1. This framework integrates technical, social, and ethical aspects in the development of post-harvest coffee technology.

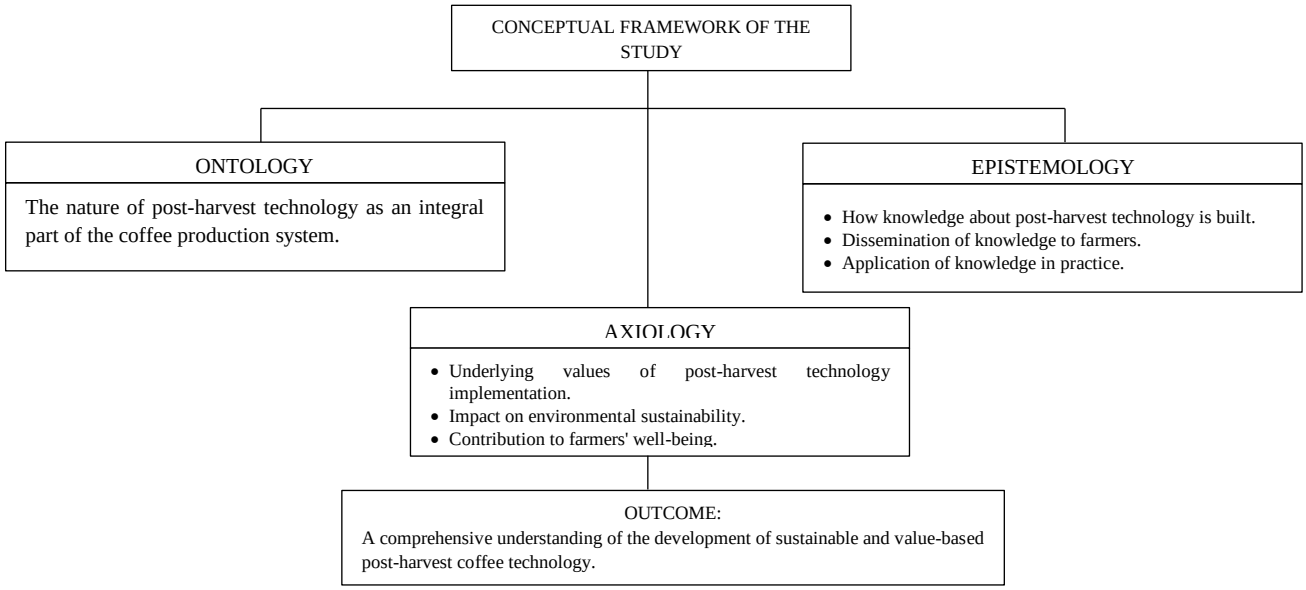

Figure 1 Conceptual Framework of this Study

2.7. Research Limitations

This study is subject to several limitations that should be acknowledged. Firstly, the research relies exclusively on secondary data, with no primary data collected directly from farmers or the coffee industry, which may limit the depth of field-specific insights. Secondly, the analysis is centered on the context of Indonesia, meaning that the findings might not be fully applicable or generalizable to other countries with different conditions or practices. Lastly, the study was carried out within a limited timeframe and with constrained resources, which may have restricted the breadth of literature reviewed and the overall scope of the analysis. These limitations highlight areas for potential improvement in future research endeavors.

3. Results and Discussion

Based on the analysis of the data, the articles that have been determined are grouped into sub-topics that will be discussed following the research theme. The following is a table of the distribution of review articles based on the topics discussed, which is fully displayed in table 1.

Table 1 Article cited and topic discussions

Discussion Topic	Cited Articles
3.1. Ontology: The Nature of Post-Harvest Coffee Technology	Estera & Djaja (2023), Putri & Sokarina (2024), Antón-Solanas et al. (2022), Pötschke (2018), Nazaruddin et al. (2023), Abimbola (2014), Hidayati et al. (2020), Oktavianti et al. (2020)
3.2. Epistemology: Dissemination of Post-Harvest Technology Knowledge	Alixandre et al. (2023), Nazaruddin et al. (2023), Parfitt et al. (2010), Sun et al. (2022), Ma et al. (2024), Sutarsyah et al. (2022)
3.3. Axiology: Values in the Application of Post-Harvest Technology	Krishnan & Patnam (2013), Lamontagne-Godwin et al. (2016), Duhan & Singh (2017), Chimoita et al. (2017), Musa et al. (2013), Silamat et al. (2024), Avoga et al. (2023)
3.4. Challenges in the Development of Post-Harvest Technology	Liu & Liu (2024), Wei et al. (2021)
3.5. Potential Solutions to Overcome Challenges	Polanía et al. (2024), Vale et al. (2024)

3.1. Ontology: The Nature of Post-Harvest Coffee Technology

Ontology examines the essence of existence, in this case, post-harvest coffee technology. Post-harvest technology is not merely a set of tools or machines used to process coffee beans but also encompasses knowledge systems and practices related to overall coffee processing. Post-harvest technology represents the interaction between humans, nature, and technology in efforts to enhance the efficiency and quality of coffee production, as qualitative approaches are particularly effective in exploring and interpreting the complexities of such phenomena (Estera & Djaja, 2023; Putri & Sokarina, 2024).

In the Indonesian context, many coffee farmers still perceive post-harvest technology as an additional, non-essential element. This perception is influenced by several factors. One of the primary factors is local wisdom, where many farmers in Indonesia maintain traditional practices in coffee processing, such as manual sun drying. These methods are often perceived as "safer" due to their long-standing use. However, they are vulnerable to weather changes and microbial contamination, potentially diminishing product quality. Qualitative research effectively explores the complexities of such phenomena through in-depth analysis (Antón-Solanas *et al.*, 2022; Pötschke, 2018).

Another significant factor is the limitation of understanding among farmers regarding the benefits of modern technology in enhancing the quality and economic value of their products. For instance, the use of automatic drying machines can reduce drying time and the risk of damage from rain. However, the high initial investment costs pose a significant barrier for smallholder farmers (Nazaruddin *et al.*, 2023).

The ontological views of farmers regarding post-harvest technology are influenced by socio-cultural factors, such as traditional practices and limited access to information; therefore, the development of post-harvest technology must consider local contexts to ensure acceptance among farmers (Abimbola, 2014; Hidayati *et al.*, 2020; Oktavianti *et al.*, 2020).

3.2. Epistemology: The Dissemination of Post-Harvest Coffee Technology Knowledge

Epistemology examines the sources, methods, and validity of knowledge. In the context of post-harvest coffee technology, epistemology is used to analyze how knowledge about this technology is constructed, disseminated, and applied by farmers.

Knowledge about post-harvest coffee technology often originates from scientific research conducted by research institutions and universities; however, there exists a significant gap between the knowledge generated by these institutions and the knowledge applied by farmers in the field, which can hinder effective implementation of beneficial practices (Alixandre et al., 2023; Nazaruddin et al., 2023). This is due to several factors:

a. Limited Access to Information: Many coffee farmers in Indonesia live in remote areas with restricted access to the internet, printed media, or formal training programs.
b. Complex Technical Language: Scientific publications often use technical language that is difficult for farmers without formal education backgrounds to understand.

c. Lack of Continuous Mentoring: Training programs are often incidental and not followed by continuous mentoring and support.

An inclusive and participatory communication approach can help bridge the knowledge gap regarding post-harvest technology among farmers. For instance, the use of visual media, field demonstrations, and the involvement of community leaders in disseminating knowledge can enhance farmers' understanding of post-harvest technologies (Parfitt *et al.*, 2010; Sun *et al.*, 2022). Additionally, training programs designed inclusively, followed by ongoing mentorship, can ensure that farmers not only comprehend but also effectively implement these technologies (Ma *et al.*, 2024; Sutarsyah *et al.*, 2022).

3.3. Axiology: Values in the Application of Post-Harvest Coffee Technology

Axiology examines the values that underpin actions or decisions. In the context of post-harvest coffee technology, the values underlying its implementation include environmental sustainability, economic efficiency, and farmers' well-being. Technologies that prioritize productivity without considering environmental impacts can lead to long-term issues such as soil degradation, water pollution, and loss of biodiversity (Krishnan & Patnam, 2013; Lamontagne-Godwin *et al.*, 2016). For example, excessive use of chemical fertilizers and pesticides disrupts ecosystems and harms soil health, ultimately threatening agricultural sustainability (Duhan & Singh, 2017). Thus, it is essential to adopt environmentally friendly practices that balance productivity with ecological preservation (Chimoita *et al.*, 2017; Musa *et al.*, 2013). Therefore, the development of post-harvest technology must consider sustainability principles, such as:

a. Use of Renewable Energy: Utilizing solar energy to power drying machines can help reduce environmental impact.
b. Eco-Friendly Waste Management: Waste from the fermentation process can be repurposed as organic fertilizer to enhance soil fertility.
c. Natural Resource Conservation: Developed technologies should prioritize the preservation of natural resources to ensure the sustainability of coffee production in the future.

Social values must be considered in the implementation of post-harvest technology, as expensive and complex technologies often do not align with the capacities of smallholder farmers in Indonesia. Ideal technologies should not only enhance productivity but also improve farmers' welfare by increasing income and reducing labor burdens (Silamat *et al.*, 2024). For instance, accessible and user-friendly technologies can significantly contribute to the economic stability of farmers while ensuring that they can effectively adopt and benefit from these innovations (Avoga *et al.*, 2023).

3.4. Challenges in the Development of Post-Harvest Coffee Technology in Indonesia

Although post-harvest coffee technology has great potential to improve product quality and economic value, its development in Indonesia still faces various challenges. Some of the main challenges include:

a. Limited Capital: Many coffee farmers in Indonesia are smallholders with limited land and restricted access to capital for purchasing modern technology.
b. Knowledge Gap: There is a significant gap between the knowledge produced by research institutions and the knowledge applied by farmers in the field.
c. Socio-Cultural Factors: Traditional coffee processing habits often hinder farmers' acceptance of new technologies.
d. Lack of Infrastructure: Adequate infrastructure, such as electricity and transportation, is often unavailable in coffee-producing regions.

Collaboration among the government, research institutions, the coffee industry, and farmers is essential for addressing these challenges. For instance, the government can provide subsidies or soft loans to farmers for purchasing modern technology, while research institutions can develop environmentally friendly and affordable technologies for smallholder farmers (Liu & Liu, 2024). This partnership can enhance the capacity of farmers, ensuring they have access to the necessary resources and knowledge to improve their productivity and sustainability (Wei *et al.*, 2021).

3.5. Potential Solutions to Overcome Challenges

To address these challenges, several potential solutions can be proposed:

a. Holistic Approach: The development of post-harvest technology should adopt a holistic approach that considers technical, social, and ethical aspects.
b. Sustainable Training and Mentorship Programs: Training programs should be designed inclusively and followed by continuous mentoring to ensure that farmers fully understand and can effectively implement the technology.
c. Collaboration Among Stakeholders: Collaboration between the government, research institutions, the coffee industry, and farmers is crucial to ensure that the developed technology aligns with field needs and conditions.
d. Development of Affordable and Eco-Friendly Technology: The technology should be environmentally friendly, easy to use, and affordable for smallholder farmers.

The development of selected microbial fermentation technologies and the use of solar energy for drying coffee beans can serve as potential solutions to address these challenges. For instance, utilizing coffee by-products as a medium for microbial inoculation can enhance the fermentation process, leading to improved coffee quality (Polanía *et al.*, 2024). Additionally, the integration of solar energy for drying can provide an efficient and sustainable method to reduce post-harvest losses while minimizing environmental impacts (Vale *et al.*, 2024).

4. Conclusions and Recommendations

The development and implementation of post-harvest coffee technology in Indonesia require a comprehensive approach that integrates ontology, epistemology, and axiology. Ontologically, post-harvest coffee technology is not merely a physical tool but also represents knowledge and practices deeply embedded in the coffee production system. However, Indonesian farmers' limited perception of this technology, shaped by traditional habits and insufficient understanding of its benefits, remains a significant barrier. Epistemologically, there is a notable gap between scientific research findings and their practical application in the field. This gap arises from limited access to information, complex technical language, and a lack of continuous mentorship for farmers. Axiologically, the application of post-harvest technology must align with values such as environmental sustainability, economic efficiency, and farmers' well-being. Technologies that are environmentally harmful or financially unattainable for smallholder farmers risk being underutilized or rejected.

To improve the development and implementation of post-harvest coffee technology in Indonesia, several recommendations can be considered for different stakeholders. For the government, subsidies and incentives should be provided to make modern technologies, such as automatic drying machines or controlled fermentation systems, more affordable for farmers. Additionally, improving basic infrastructure like electricity and transportation in coffee-producing regions is crucial to support the adoption of these technologies. The government should also offer inclusive and continuous training programs that involve community leaders and utilize visual media to enhance farmers' understanding. For research institutions and academics, efforts should focus on developing locally-oriented post-harvest technologies that are environmentally friendly and affordable for smallholder farmers. Scientific findings need to be translated into simpler formats, such as brochures, tutorial videos, or field demonstrations, to bridge the gap between research and practice. Collaboration with the coffee industry is also essential to create technologies that meet global market demands, such as microbial-based fermentation systems that produce unique flavor profiles. For farmers, gradual adoption of post-harvest technologies is recommended, starting with simple and affordable solutions before transitioning to more advanced systems. Farmers should actively participate in training and mentorship programs to build their capacity and understanding of modern technologies while integrating these innovations with traditional agricultural practices that have proven effective. Finally, for the coffee industry, investment in the supply chain, such as providing shared processing facilities at the farmer level, can significantly aid technology adoption. Implementing blockchain technology to ensure product certification and traceability will enhance consumer trust and help meet international standards. Through these collaborative efforts, the development and implementation of post-harvest coffee technology in Indonesia can be significantly improved, benefiting both farmers and the broader coffee industry.

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Ethical considerations

Not applicable.

Conflict of Interest

The authors declare no conflicts of interest.

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