REDUCING DEFECT RATES IN COFFEE SUPPLY CHAINS THROUGH UPSTREAM QUALITY MANAGEMENT: EVIDENCE AND STRATEGIC PRIORITIES FROM SMALLHOLDER FARMERS

Mochammad Robith Aizzurrohman
moch.robith97@gmail.com
Institut Teknologi Bandung

ABSTRAK

Rantai pasok kopi yang bergantung pada petani kecil sering menghadapi permasalahan kualitas yang berulang, terutama akibat terbentuknya cacat pada tahap hulu. Penelitian ini menganalisis pembentukan cacat dari perspektif manajemen kualitas hulu serta menentukan prioritas strategis untuk menurunkan tingkat cacat pada rantai pasok kopi berbasis petani kecil. Penelitian ini menggunakan pendekatan studi kasus dengan mengombinasikan analisis kualitatif terhadap praktik panen dan pascapanen dengan data kuantitatif tingkat cacat dari proses penilaian mutu green bean. Perbedaan praktik di tingkat petani dan koperasi dianalisis, kemudian alternatif intervensi perbaikan diprioritaskan menggunakan metode pengambilan keputusan multikriteria yang terstruktur. Hasil penelitian menunjukkan bahwa tingkat cacat bervariasi secara signifikan antar petani dan berkaitan erat dengan praktik penanganan di hulu. Panen selektif, pemrosesan tepat waktu, dan pengeringan dasar yang terkendali berhubungan dengan tingkat cacat yang lebih rendah. Hasil prioritisasi menegaskan bahwa intervensi preventif berbasis peningkatan kapabilitas perlu didahulukan dibandingkan solusi yang membutuhkan investasi infrastruktur besar.
Kata Kunci : Rantai Pasok Kopi Berbasis Petani Kecil, Manajemen Kualitas Hulu, Cacat Mutu Green Bean.

ABSTRACT

Coffee supply chains that depend on smallholder farmers often face persistent quality problems due to defects originating at the upstream level. This study examines defect formation from an upstream quality management perspective and identifies strategic priorities for defect reduction in a smallholder-based coffee supply chain. Using a case study approach, the research combines qualitative analysis of harvesting and post-harvest practices with quantitative defect rate data from green bean quality inspections. Differences in farmer- and cooperative-level practices are analyzed, and improvement interventions are prioritized using a structured multi-criteria decision-making method. The results show that defect rates vary significantly across farmers and are closely linked to upstream practices. Selective harvesting, timely processing, and basic drying control are associated with lower defect rates, while inconsistent handling leads to higher defects. The prioritization results indicate that preventive, low-cost, and capability-based interventions should be implemented before infrastructure-intensive solutions. This study contributes to supply chain quality management literature by operationalizing "quality at the source" through defect rate analysis and by providing practical guidance for prioritizing upstream quality interventions in smallholder coffee supply chains.
Keywords: *Smallholder-Based Coffee Supply Chain, Upstream Quality Management, Green Bean Quality Defects.*

INTRODUCTION

Coffee supply chains that rely on smallholder farmers often face persistent quality problems, especially in the form of high defect rates at the upstream level. In many producing countries, including Indonesia, coffee quality is strongly influenced by how cherries are harvested and handled during early post-harvest stages. When these activities are carried out with limited control and inconsistent practices, defects are formed and later appear in green coffee beans. Once defects occur at the farm level, they are difficult or

impossible to eliminate through downstream processing or sorting.

In practice, quality management in coffee supply chains is still largely reactive. Defects are mainly identified during grading and inspection at the cooperative or buyer level, after the coffee has already passed through harvesting, fermentation, drying, and hulling stages. At this point, quality control functions as damage assessment rather than defect prevention. As a result, downstream actors can only reject or downgrade defective coffee, while the root causes of quality problems remain unchanged upstream. This situation creates inefficiencies in the supply chain and places most of the economic risk on smallholder farmers, who receive lower prices when defects are detected.

From a supply chain quality management perspective, this reactive approach contradicts the principle of "quality at the source," which emphasizes that quality should be controlled as early as possible in the supply chain. In agricultural commodities such as coffee, early-stage practices play a critical role in determining final quality outcomes. Differences in harvesting discipline, cherry selection, drying methods, and basic handling practices can lead to significant variation in defect rates across farmers. However, despite the importance of these upstream activities, empirical studies that link specific farmer-level practices to measurable defect outcomes remain limited.

Existing research on coffee quality has largely focused on technical aspects of post-harvest processing or on downstream grading systems. Other studies discuss farmer empowerment or sustainability issues without clearly connecting daily operational practices to defect formation and quality performance. As a result, there is a gap in the literature between descriptive analyses of processing practices and actionable strategies for reducing defects at the upstream level. In addition, few studies go beyond identifying problems to evaluate which improvement interventions should be prioritized when resources and managerial attention are limited.

To address this gap, this study examines defect formation in coffee supply chains from an upstream quality management perspective. Using a case study of smallholder farmers supplying a coffee trading company, the research analyzes how differences in farmer and cooperative processing practices affect defect rates in green coffee beans. Defect rate is used as the main performance indicator because it directly reflects the effectiveness of harvesting and early post-harvest handling practices.

Beyond identifying quality problems, this study also aims to support managerial decision-making. Based on empirical findings, several upstream improvement interventions are evaluated and prioritized using a structured multi-criteria approach. The focus is placed on preventive strategies that strengthen farmer-level capabilities and reduce defect formation before coffee reaches downstream quality control stages. By combining defect rate analysis with strategic prioritization, the study provides practical guidance for improving supply chain performance through upstream quality management.

The contribution of this study is twofold. First, it provides empirical evidence on how upstream processing practices contribute to defect rate differences in smallholder-based coffee supply chains. Second, it offers a structured prioritization of strategic interventions that can support more effective and sustainable quality management at the source. These findings are relevant for supply chain managers, cooperatives, and buyers seeking to reduce quality risk while maintaining stable and sustainable smallholder sourcing.

RESEARCH METHODOLOGY

This study adopts a case study research design with a mixed-method approach. The case study method is appropriate because the research aims to examine quality problems within their real operational context and to understand how upstream practices influence

defect formation in a specific supply chain setting (Yin, 2018). A mixed-method approach is used to combine qualitative insights on processing practices with quantitative analysis of defect rates, allowing for a more comprehensive assessment of upstream quality management.

The research focuses on a coffee supply chain involving smallholder farmers and a buying organization. This context is suitable for examining upstream quality issues because smallholder farmers are directly responsible for harvesting and early post-harvest handling activities, where most defects originate. The case study design enables an in-depth analysis of these practices and supports the identification of targeted improvement strategies.

LITERATURE REVIEW AND CONCEPTUAL BACKGROUND

Supply Chain Quality Management and Defect Prevention

Supply Chain Quality Management (SCQM) refers to the coordination of quality-related activities across different actors in the supply chain to ensure consistent product performance (Flynn & Flynn, 2005). Unlike traditional quality control, which focuses on inspection and rejection at the final stage, SCQM emphasizes preventive actions and process control throughout the supply chain. One of the central ideas within this approach is the concept of "quality at the source," where quality problems are addressed at the point of origin rather than corrected downstream (Foster, 2008).

In agricultural supply chains, preventive quality management is particularly critical due to the biological nature of products and their sensitivity to early handling practices (Trienekens & Zuurbier, 2008). Defects formed during production and early post-harvest stages are often irreversible, making downstream inspection insufficient as a quality improvement strategy. From an SCQM perspective, upstream actors therefore play a decisive role in determining final product quality.

Although SCQM has been widely discussed in manufacturing contexts, its application in smallholder-based agricultural supply chains remains limited (Robinson & Malhotra, 2005). Many studies focus on standards, certification, or compliance mechanisms, while fewer examine how daily operational practices at the farm level translate into measurable quality outcomes such as defect rates. This indicates a need for empirical studies that operationalize SCQM principles using concrete performance indicators.

Defect Formation in Coffee Post-Harvest Processing

Coffee quality is strongly influenced by harvesting and early post-harvest handling activities. Defects such as black beans, broken beans, sour beans, and mold damage are commonly associated with improper cherry selection, delayed processing, inconsistent drying, and poor storage conditions (Wintgens, 2009). These defects typically originate at the farm level and persist throughout the supply chain, even after grading and sorting.

Previous studies highlight the importance of selective harvesting, controlled fermentation, and uniform drying in reducing defect formation (Viani & Horman, 2011). For example, harvesting unripe or overripe cherries increases the likelihood of physical and sensory defects, while inadequate drying can lead to moisture imbalance and microbial growth. Once these defects are formed, downstream actors have limited ability to restore quality.

Despite this knowledge, smallholder farmers often apply heterogeneous post-harvest practices due to limited access to training, infrastructure, and standardized procedures (Neilson, 2008). As a result, defect rates may vary significantly among farmers operating within the same supply chain. This variation suggests that managerial and operational practices, rather than environmental factors alone, are key contributors to quality inconsistency.

Smallholder Farmers and Upstream Capability Development

Smallholder farmers play a central role in global coffee production, yet they often face constraints related to skills, knowledge, and resources (Donovan & Poole, 2014). In the context of supply chain quality management, these constraints can limit farmers' ability to implement consistent and preventive handling practices. As a result, quality management tends to remain reactive, with defects identified only after coffee reaches downstream actors.

Much of the existing literature discusses farmer empowerment in terms of income, social welfare, or market access (Barrett et al., 2012). While these perspectives are important, they do not fully explain how farmer-level capabilities influence operational quality outcomes. From an SCQM perspective, capability development refers to improving farmers' skills, routines, and decision-making related to production and post-harvest handling processes.

Cooperatives and buying firms can support upstream capability development through training programs, standard operating procedures, and basic quality monitoring systems (Trienekens, 2011). However, because financial and organizational resources are limited, not all interventions can be implemented simultaneously. This creates a managerial challenge in deciding which upstream quality interventions should be prioritized to achieve meaningful defect reduction.

Research Gap and Analytical Focus

Based on the reviewed literature, several gaps can be identified. First, although defect formation in coffee has been widely acknowledged, empirical studies that link specific upstream practices to measured defect rates remain scarce. Second, SCQM concepts are often discussed at a conceptual level but are rarely operationalized in smallholder-based coffee supply chains using concrete quality indicators. Third, few studies provide structured guidance on how upstream quality interventions should be prioritized under resource constraints.

This study addresses these gaps by examining defect rates as a direct outcome of upstream quality management practices in smallholder coffee supply chains. Using empirical evidence from farmers and cooperatives, the research analyzes how differences in handling practices contribute to defect formation. Furthermore, a structured prioritization approach is applied to evaluate alternative upstream interventions, providing practical guidance for managers seeking to improve quality performance through preventive supply chain strategies.

RESULT AND DISCUSSISON

Upstream Practices as the Main Source of Defect Formation

The findings of this study confirm that defect formation in coffee supply chains is largely determined by upstream processing practices at the farm level. Differences in harvesting discipline, processing timeliness, and drying methods are associated with clear variations in defect rates among smallholder farmers. This supports the supply chain quality management principle that quality outcomes are shaped early in the production process rather than at downstream inspection stages.

Code	Criterion	Description	Weight
C1	Expected Impact on Defect Reduction	Degree to which the intervention is expected to reduce defect formation, particularly at harvesting and early post-harvest stages	**0.35**
C2	Feasibility	Practical ease of implementation considering existing farmer capabilities, institutional support, and operational constraints	**0.20**

C3	Empowerment Potential	Extent to which the intervention strengthens farmer knowledge, autonomy, and long-term quality awareness	**0.20**
C4	Time to Implement	Expected speed at which the intervention can be executed and begin generating quality improvements	**0.15**
C5	Scalability	Potential for the intervention to be replicated and expanded across a broader farmer base	**0.10**
	Total		**1.00**

The results reinforce the concept of "quality at the source," which argues that preventive actions are more effective than corrective measures. In the studied supply chain, downstream grading and sorting are unable to eliminate defects that originate from poor upstream handling. Instead, these activities mainly function as screening mechanisms that identify quality problems after value has already been lost. This explains why defect rates remain persistent despite the presence of downstream quality control systems.

Preventive versus Reactive Quality Management in Coffee Supply Chains

The dominance of reactive quality management practices observed in the case reflects a common pattern in smallholder-based agricultural supply chains. Quality control is often concentrated at the buyer or exporter level, where defects are detected and classified rather than prevented. The findings of this study suggest that such an approach is insufficient for improving overall quality performance.

By linking upstream practices to measurable defect outcomes, this study demonstrates that preventive quality management offers a more effective pathway for defect reduction. Simple actions such as selective harvesting, same-day processing, and basic drying standardization show a strong association with lower defect rates. These results highlight that quality improvement does not necessarily require complex technology but depends on consistent operational discipline at the farm level.

Strategic Prioritization as a Managerial Response to Quality Problems

Beyond identifying quality problems, this study contributes by showing how strategic prioritization can support managerial decision-making in resource-constrained contexts. The prioritization results indicate that interventions focused on farmer capability development and basic handling practices should be implemented before capital-intensive solutions. This finding aligns with supply chain management literature that emphasizes feasibility and impact as key considerations in operational improvement initiatives.

The use of a structured prioritization method helps translate empirical evidence into actionable strategy. Instead of treating all quality problems as equally urgent, managers can focus on interventions that offer the highest potential impact on defect reduction within realistic cost and time constraints. This approach reduces the risk of ineffective investments and supports more systematic quality improvement planning.

Implications for Sustainable Smallholder Sourcing

Although this study does not directly measure environmental or social outcomes, the findings have important implications for sustainable smallholder sourcing. Reducing defect rates at the upstream level improves supply chain efficiency by lowering rejection rates and minimizing quality losses. This, in turn, contributes to more stable relationships between buyers, cooperatives, and farmers.

By focusing on preventive quality management and capability development, supply chain actors can support smallholder participation without relying solely on price incentives or certification schemes. Improved handling practices increase the likelihood that farmers meet quality requirements, which can enhance income stability and reduce waste. In this sense, upstream quality management functions as a practical mechanism that supports

sustainability objectives through operational improvement rather than normative claims.

CONCLUSION

This study examines defect formation in coffee supply chains from an upstream quality management perspective. Focusing on smallholder farmers, the research analyzes how differences in harvesting and early post-harvest practices influence defect rates and identifies strategic priorities for quality improvement. By combining defect rate analysis with a structured prioritization approach, the study provides both empirical evidence and actionable guidance for supply chain decision-making.

The findings show that defect rates are strongly associated with upstream operational practices. Farmers who apply selective harvesting, timely processing, and basic drying control tend to produce coffee with lower defect rates. In contrast, mixed harvesting, delayed processing, and inconsistent drying are linked to higher levels of physical and biological defects. These results confirm that quality problems in coffee supply chains originate primarily at the farm level and cannot be effectively resolved through downstream inspection alone.

Beyond identifying the sources of defects, this study highlights the importance of strategic prioritization in addressing quality problems under resource constraints. The prioritization results indicate that preventive, low-cost, and capability-based interventions should be implemented before infrastructure-intensive solutions. Training related to harvesting discipline and early handling practices emerges as the most effective starting point for defect reduction, followed by basic drying standardization and supportive cooperative-level quality controls.

From a theoretical perspective, this study contributes to the supply chain quality management literature by operationalizing the concept of “quality at the source” using defect rate as a measurable performance indicator. The findings extend existing research by linking upstream practices directly to quality outcomes and by demonstrating how structured prioritization tools can support preventive quality strategies in smallholder-based agricultural supply chains.

From a managerial perspective, the results offer practical guidance for cooperatives, buyers, and supply chain managers. Rather than relying solely on downstream grading and rejection, quality improvement efforts should focus on strengthening upstream handling practices and farmer capabilities. The prioritization framework used in this study can assist managers in allocating limited resources more effectively and in designing quality improvement programs that address the root causes of defects.

This study has several limitations. The analysis is based on a single case, which may limit the generalizability of the findings. In addition, the study focuses on defect rates as the primary quality indicator and does not explicitly measure economic, environmental, or social outcomes. Future research could examine multiple cases across different regions, incorporate longitudinal data, and explore the broader sustainability impacts of upstream quality interventions.

In conclusion, this study demonstrates that reducing defect rates in coffee supply chains requires a shift from reactive quality control to preventive upstream quality management. By providing empirical evidence and strategic priorities, the research supports more effective and sustainable approaches to managing quality in smallholder-based coffee supply chains.

DAFTAR PUSTAKA

Barrett, C. B., Bachke, M. E., Bellemare, M. F., Michelson, H. C., Narayanan, S., & Walker,

T. F. (2012). Smallholder participation in agricultural value chains: Comparative evidence from three continents. World Development, 40(4), 715–730. https://doi.org/10.1016/j.worlddev.2011.10.006

Donovan, J., & Poole, N. (2014). Changing asset endowments and smallholder participation in higher value markets: Evidence from certified coffee producers in Nicaragua. Food Policy, 44, 1–13. https://doi.org/10.1016/j.foodpol.2013.10.010

Edwards, W., & Barron, F. H. (1994). SMARTS and SMARTER: Improved simple methods for multiattribute utility measurement. Organizational Behavior and Human Decision Processes, 60(3), 306–325. https://doi.org/10.1006/obhd.1994.1087

Flynn, B. B., & Flynn, E. J. (2005). Synergies between supply chain management and quality management: Emerging implications. International Journal of Production Research, 43(16), 3421–3436. https://doi.org/10.1080/00207540500118076

Foster, S. T. (2008). Towards an understanding of supply chain quality management. Journal of Operations Management, 26(4), 461–467. https://doi.org/10.1016/j.jom.2007.06.003

Neilson, J. (2008). Global private regulation and value-chain restructuring in Indonesian smallholder coffee systems. World Development, 36(9), 1607–1622. https://doi.org/10.1016/j.worlddev.2007.09.005

Robinson, C. J., & Malhotra, M. K. (2005). Defining the concept of supply chain quality management and its relevance to academic and industrial practice. International Journal of Production Economics, 96(3), 315–337. https://doi.org/10.1016/j.ijpe.2004.06.055

Saunders, M., Lewis, P., & Thornhill, A. (2019). Research methods for business students (8th ed.). Pearson Education.

Trienekens, J. H. (2011). Agricultural value chains in developing countries: A framework for analysis. International Food and Agribusiness Management Review, 14(2), 51–82.

Trienekens, J. H., & Zuurbier, P. J. P. (2008). Quality and safety standards in the food industry: Developments and challenges. International Journal of Production Economics, 113(1), 107–122. https://doi.org/10.1016/j.ijpe.2007.02.050

Viani, R., & Horman, I. (2011). Post-harvest processing and quality control in coffee production. In J. N. Wintgens (Ed.), Coffee: Growing, processing, sustainable production (2nd ed., pp. 443–465). Wiley-VCH.

Wintgens, J. N. (Ed.). (2009). Coffee: Growing, processing, sustainable production (2nd ed.). Wiley-VCH.

Yin, R. K. (2018). Case study research and applications: Design and methods (6th ed.). SAGE Publications.