International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Food Degradation in Supply Chains: Implications for Sustainability and Food Security

Avi Jagota

ABSTRACT

Food degradation across supply chains is a common but often underestimated issue that affects how efficiently food systems function. From the point of production to final consumption, food is frequently exposed to poor handling practices, lack of proper storage, transportation delays, and unsuitable packaging. These factors gradually reduce food quality and, in many cases, lead to spoilage and waste. This paper examines the key stages of the food supply chain where degradation is most likely to occur and explains how losses at each stage contribute to rising levels of food waste. It also discusses the environmental impacts of degraded food, such as the unnecessary use of water, land, and energy, along with increased emissions linked to wasted production. In addition, the study highlights how food degradation weakens food security by limiting availability and increasing pressure on already stressed food systems, especially in developing countries. The paper argues that reducing food degradation requires improvements across the entire supply chain rather than isolated solutions at individual stages.

KEYWORDS: Food degradation, supply chain losses, food waste, sustainability, environmental impact, food security.

INTRODUCTION

Food is produced in large quantities across the world, yet a considerable part of it does not reach people in a usable form. In many cases, food quality reduces as it moves from farms to markets and finally to households. This reduction in quality, known as food degradation, happens due to several reasons such as rough handling, poor storage conditions, transport delays, and exposure to unsuitable temperatures. When food degrades, it often becomes unsafe or unacceptable for consumption, leading to waste.

The issue of food degradation is closely linked with the structure of supply chains. In developing countries especially, food passes through multiple stages before reaching consumers, and each stage increases the risk of damage or spoilage. Studies show that a large share of food losses occurs after harvesting and during storage and transportation rather than at the consumer level (FAO, 2011). Perishable items like fruits, vegetables, milk, and meat are more likely to degrade when proper infrastructure such as cold storage and efficient logistics is missing.

Food degradation also has serious environmental effects. Producing food requires land, water, energy, and labour. When degraded food is thrown away, all these resources are wasted as well. The United Nations Environment Programme points out that food waste contributes significantly to greenhouse gas emissions, especially when wasted food decomposes in landfills (UNEP, 2021). This makes food degradation an environmental issue, not just a problem of inefficiency.

Apart from environmental concerns, food degradation directly affects food security. When food is lost within supply chains, the amount of food actually available for consumption decreases. This can lead to higher food prices and reduced access, particularly for poorer households. Research suggests that reducing losses in supply chains can improve food availability without increasing production pressure (Gustavsson et al., 2011). Therefore, addressing food degradation is important for ensuring stable and equitable food systems.

This paper examines the major stages at which food degradation occurs in the supply chain and analyses how losses at each stage contribute to food waste and environmental stress. By focusing on degradation rather than only production, the study highlights the importance of improving supply- chain practices to support sustainability and long-term food security.

LITERATURE REVIEW

Research on food degradation and food loss has grown steadily over the past two decades, particularly as concerns about sustainability and food security have intensified. Early studies largely focused on measuring the scale of food losses rather than explaining how and where degradation occurs within supply chains. One of the most widely cited reports by the Food and Agriculture Organization estimated that nearly one-third of global food production is lost or wasted annually, drawing attention to inefficiencies beyond agricultural production itself (FAO, 2011). This report highlighted that food losses are not evenly distributed across regions and supply-chain stages.

Several studies have shown that food degradation is strongly linked to post-harvest handling and storage conditions, especially in developing countries. Gustavsson et al. (2011) observed that in low- and middle-income countries, losses mainly occur during harvesting, storage, and transportation due to poor infrastructure, lack of refrigeration, and limited access to modern logistics. These findings
suggest that food degradation is less about consumer behaviour in such contexts and more about systemic supply-chain weaknesses.

Other researchers have focused on the role of temperature and storage environments in accelerating food degradation. Kader (2005) emphasized that inappropriate temperature control leads to faster microbial growth and physical damage, particularly for fresh fruits and vegetables. Studies on cold- chain management further confirm that even small breaks in temperature control during transport or storage can significantly reduce shelf life and increase spoilage rates (Aung & Chang, 2014). These findings underline the importance of storage and transportation as critical stages where degradation occurs.

The environmental impacts of food degradation and waste have also received increasing attention in the literature. According to the United Nations Environment Programme, wasted food contributes substantially to greenhouse gas emissions when production, transport, and disposal are considered together (UNEP, 2021). Hall et al. (2009) argued that food waste represents a hidden loss of resources, including water, land, and energy, which intensifies environmental stress. This perspective shifts the discussion from food loss as an economic issue to a broader sustainability concern.

Food degradation has also been examined in relation to food security. Parfitt, Barthel, and Macnaughton (2010) noted that reducing food losses along supply chains can be an effective way to improve food availability without increasing agricultural output. Similarly, FAO (2019) argued that tackling food loss is essential for ensuring stable food supplies, especially in regions facing resource constraints and climate-related risks. These studies highlight that food security is not only about producing more food but also about preserving what is already produced.

Despite the growing body of research, gaps remain in the literature. Many studies examine food loss at isolated stages of the supply chain, without linking degradation across stages to environmental and food security outcomes in an integrated manner. There is also limited empirical work connecting physical degradation processes directly with broader sustainability indicators. This paper builds on existing literature by examining food degradation across multiple supply-chain stages and linking these losses to environmental stress and food security concerns.

METHODOLOGY

This paper follows a **theoretical and descriptive research approach**. It is based entirely on the review and interpretation of existing studies and reports related to food degradation, food supply chains, sustainability, and food security.

The material used in this paper was collected from secondary sources such as books, academic journal articles, and reports published by organisations like the Food and Agriculture Organization (FAO) and the United Nations Environment Programme (UNEP). These sources were chosen because they provide detailed discussions on food loss, supply-chain inefficiencies, and environmental impacts at both global and regional levels.

The review of literature was carried out in a simple manner. First, studies explaining different stages of the food supply chain were examined to identify where food degradation is most likely to occur. Second, existing research was reviewed to understand the main reasons behind food degradation, such as poor storage, lack of cold-chain facilities, transportation delays, and handling practices. Third, the literature was used to link food degradation with environmental stress and food security concerns.

Based on this review, the paper develops a conceptual understanding of how food degradation at various stages of the supply chain leads to food waste and broader sustainability challenges. Since the study is theoretical in nature, the focus is on explaining relationships and patterns rather than measuring them numerically. This approach helps in presenting a clear and integrated view of the issue using already available knowledge.

DISCUSSION

The review of existing studies shows that food degradation happens gradually across the supply chain rather than at one fixed point. Most of the literature points towards early stages such as post- harvest handling, storage, and transportation as major areas where food quality begins to decline (FAO, 2011; Gustavsson et al., 2011). This is especially visible in developing countries, where storage facilities are limited and transport systems are often slow or unreliable (FAO, 2019). These findings support the approach taken in this paper, which looks at degradation as a process spread across multiple stages rather than a single event.

The causes of food degradation discussed in the literature are largely structural in nature. Poor storage conditions, lack of cold-chain infrastructure, unsuitable packaging, and long transport times appear repeatedly across studies (Kader, 2005; Aung & Chang, 2014). These issues are not always the result of poor decision-making but are often linked to financial and institutional limitations within food systems. Because of this, degradation becomes a routine part of how supply chains operate, rather than an exception. This helps explain why food loss continues despite improvements in agricultural productivity (Parfitt et al., 2010).

Environmental impacts also emerge clearly in the discussion of food degradation. When food

deteriorates and is discarded, the resources used to produce it are wasted as well. Several studies emphasise that food waste represents a loss of water, land, and energy, along with added pressure on the environment through emissions from production and disposal (Hall et al., 2009; UNEP, 2021). This supports the idea that food degradation should be treated as an environmental issue and not just as a supply-chain inefficiency.

The literature further shows that food degradation has direct implications for food security. When edible food is lost before reaching consumers, the actual availability of food decreases. This can affect prices and access, particularly for low-income groups (FAO, 2019). The discussion suggests that reducing degradation along supply chains could improve food availability without increasing production, which is especially important in a context of limited resources and growing environmental constraints (Gustavsson et al., 2011).

Overall, the discussion highlights that food degradation is closely linked with sustainability and food security outcomes. The theoretical approach used in this paper helps in bringing together different strands of research and shows that addressing food degradation requires coordinated improvements across the entire supply chain. Isolated solutions at individual stages are unlikely to be effective unless broader structural issues are also addressed (Parfitt et al., 2010).

ANALYSIS

The discussion of food degradation across supply chains highlights an important shift in how food loss should be understood. Rather than viewing food waste as a problem occurring mainly at the consumer level, the literature clearly shows that degradation begins much earlier in the supply chain. This suggests that policies and interventions focused only on consumer behaviour are unlikely to address the root causes of the problem. Instead, food degradation must be analysed as a systemic issue shaped by infrastructure, logistics, and institutional capacity (FAO, 2011).

The structural nature of food degradation is particularly significant. Factors such as inadequate storage facilities, lack of cold-chain infrastructure, and inefficient transportation systems are not easily corrected through individual action. These problems are embedded within broader economic and governance conditions, especially in developing countries. As a result, food degradation persists even when agricultural output increases, indicating that production growth alone cannot ensure food availability or efficiency (Gustavsson et al., 2011). This analysis reinforces the argument that improving supply-chain systems is as important as improving farm-level productivity.

From an environmental perspective, the analysis shows that food degradation contributes indirectly but substantially to environmental stress. When degraded food is discarded, the environmental costs of production such as water use, land conversion, and energy consumption are incurred without delivering nutritional or economic benefits. This makes food degradation a hidden driver of environmental degradation and climate change (UNEP, 2021). Analysing food loss through this lens shifts the debate from waste management to resource efficiency and sustainability.

The link between food degradation and food security also becomes clearer through analysis. Losses within supply chains reduce the effective supply of food, which can increase pressure on markets and affect prices. For vulnerable populations, even small reductions in availability can have serious consequences. The literature suggests that reducing food degradation could improve food access without expanding agricultural land or intensifying resource use, which is particularly relevant under current environmental constraints (FAO, 2019). This highlights food degradation as a critical but often

overlooked barrier to achieving food security.

Overall, the analysis indicates that food degradation operates at the intersection of supply-chain inefficiency, environmental sustainability, and food security. Addressing it requires coordinated, long-term approaches that strengthen infrastructure, improve logistics, and support institutional capacity.

The theoretical approach adopted in this paper allows these interconnections to be examined together, offering a more integrated understanding of food degradation and its broader implications.

CONCLUSION AND POLICY IMPILICATIONS

This paper highlights that food degradation is a gradual process that occurs at multiple stages of the supply chain, from post-harvest handling to storage, transportation, and retail. The analysis shows that the main causes of degradation are often structural, including poor storage facilities, lack of cold-chain infrastructure, inefficient transportation, and inadequate packaging. These issues lead to significant food waste, loss of resources, and environmental impacts, while also reducing food availability and affecting food security, especially for vulnerable populations (FAO, 2011; Gustavsson et al., 2011; UNEP, 2021).

From a policy perspective, the findings suggest that addressing food degradation requires coordinated action across the entire supply chain rather than isolated interventions. Policies should focus on improving storage infrastructure, investing in cold-chain technologies, strengthening transportation systems, and providing training for proper food handling practices. Governments and organisations can also encourage investment in logistics solutions and supply-chain monitoring to reduce losses at critical stages (Kader, 2005; FAO, 2019).

Furthermore, reducing food degradation has broader sustainability benefits. By preventing unnecessary waste, resources such as water, land, and energy can be used more efficiently, and greenhouse gas emissions from food production and disposal can be reduced. This makes food degradation not only a supply-chain issue but also an environmental and social priority.

Overall, the study underscores that improving supply-chain efficiency, reducing food losses, and strengthening infrastructure are key steps toward achieving both food security and environmental sustainability. Coordinated policy interventions that address these challenges can create more resilient, equitable, and sustainable food systems.

REFERENCES

1. FAO. (2011). *Global food losses and food waste: Extent, causes and prevention*. Food and Agriculture Organization of the United Nations.
2. Gustavsson, J., Cederberg, C., Sonesson, U., van Otterdijk, R., & Meybeck, A. (2011). *Global food losses and food waste*. FAO.
3. UNEP. (2021). *Food Waste Index Report 2021*. United Nations Environment Programme.
4. Aung, M. M., & Chang, Y. S. (2014). Temperature management for the quality assurance of a perishable food supply chain. *Food Control*, 40, 198–207.
5. FAO. (2011). *Global food losses and food waste: Extent, causes and prevention*. Food and Agriculture Organization of the United Nations.
6. FAO. (2019). *The state of food and agriculture: Moving forward on food loss and waste reduction*. Food and Agriculture Organization of the United Nations.
7. Gustavsson, J., Cederberg, C., Sonesson, U., van Otterdijk, R., & Meybeck, A. (2011). *Global food*

losses and food waste. FAO.
8. Hall, K. D., Guo, J., Dore, M., & Chow, C. C. (2009). The progressive increase of food waste in America and its environmental impact. *PLoS ONE*, 4(11).
9. Kader, A. A. (2005). Increasing food availability by reducing postharvest losses of fresh produce. *Acta Horticulturae*, 682, 2169–2176.
10. Parfitt, J., Barthel, M., & Macnaughton, S. (2010). Food waste within food supply chains:
11. Quantification and potential for change. *Philosophical Transactions of the Royal Society B*, 365(1554), 3065–3081.
12. UNEP. (2021). *Food Waste Index Report 2021*. United Nations Environment Programme.
13. Aung, M. M., & Chang, Y. S. (2014). Temperature management for the quality assurance of a perishable food supply chain. *Food Control*, 40, 198–207.
14. FAO. (2011). *Global food losses and food waste: Extent, causes and prevention*. Food and Agriculture Organization of the United Nations.
15. FAO. (2019). *The state of food and agriculture: Moving forward on food loss and waste reduction*. Food and Agriculture Organization of the United Nations.
16. Gustavsson, J., Cederberg, C., Sonesson, U., van Otterdijk, R., & Meybeck, A. (2011). *Global food losses and food waste*. FAO.
17. Hall, K. D., Guo, J., Dore, M., & Chow, C. C. (2009). The progressive increase of food waste in America and its environmental impact. *PLoS ONE*, 4(11).
18. Kader, A. A. (2005). Increasing food availability by reducing postharvest losses of fresh produce. *Acta Horticulturae*, 682, 2169–2176.
19. Parfitt, J., Barthel, M., & Macnaughton, S. (2010). Food waste within food supply chains:
20. Quantification and potential for change. *Philosophical Transactions of the Royal Society B*, 365(1554), 3065–3081.
21. UNEP. (2021). *Food Waste Index Report 2021*. United Nations Environment Programme.
22. FAO. (2011). *Global food losses and food waste: Extent, causes and prevention*. Food and Agriculture Organization of the United Nations.
23. FAO. (2019). *The state of food and agriculture: Moving forward on food loss and waste reduction*. Food and Agriculture Organization of the United Nations.
24. Gustavsson, J., Cederberg, C., Sonesson, U., van Otterdijk, R., & Meybeck, A. (2011). *Global food losses and food waste*. FAO.
25. Kader, A. A. (2005). Increasing food availability by reducing postharvest losses of fresh produce. *Acta Horticulturae*, 682, 2169–2176.
26. UNEP. (2021). *Food Waste Index Report 2021*. United Nations Environment Programme.