International Journal of Lean Six Sigma

327

Received 17 September 2025
Revised 4 February 2026
13 April 2026
Accepted 23 June 2026

The role of lean, Six Sigma, and lean Six Sigma in driving sustainability through a circular economy framework in agribusiness: a systematic literature review

R.A.S.A Perera and Eric Ng
School of Business, Laws, Humanities and Pathways, University of Southern Queensland, Toowoomba, Australia, and

Rumman Hassan
School of Business, Laws, Humanities and Pathways, University of Southern Queensland, Springfield, Australia

Abstract

Purpose – This study aims to identify different applications of Lean, Six Sigma and Lean Six Sigma (LSS) and how they are used to support circular economy (CE) principles in agribusiness. It seeks to understand how the different applications contribute to sustainability within a CE framework. It also helps to bridge the theoretical and practical gaps between operational excellence and circular regenerative and sustainability approach systems in the agribusiness sector.

Design/methodology/approach – This paper presents a systematic literature review using the PRISMA framework, analysing 36 peer-reviewed articles to examine how Lean, Six Sigma and LSS contribute to sustainability in agribusiness through CE principles. The ReSOLVE framework was used to evaluate the CE principles addressed across the various applications of Lean, Six Sigma and LSS.

Findings – It is revealed that Lean and Six Sigma are often implemented as a combined approach, particularly in the agribusiness food processing sector. This approach supports the LSS principles of waste elimination and continuous improvement, which are the two most addressed in agribusiness. “Optimisation” is often considered as a key CE principle that helps agribusinesses to increase productivity, reduce waste and cost savings, whereas other principles “Loop”, “Share”, “Virtualisation” and “Regenerate” are less commonly observed. The review also highlights the alignment of Lean and Six Sigma practices with sustainability pillars, with the economic pillar receiving the most attention, with the aim of reducing emissions and promoting reuse and recovery.

Research limitations/implications – This study contributes to expanding the existing knowledge on the different applications of Lean, Six Sigma and LSS towards sustainability in agribusiness, and the inter-relationship between the applications, sustainability and CE in agribusiness. Further theoretical understanding of the utilisation of the ReSOLVE framework in measuring CE principles.

Practical implications – It also offers insights to agribusinesses on the role that Lean Six Sigma and LSS play in the implementation of the CE principles to achieve sustainability.

International Journal of Lean Six Sigma
Vol. 17 No. 8, 2026
pp. 327-358
Emerald Publishing Limited
2040-4166
DOI 10.1108/IJLSS-09-2025-0260

Originality/value – This paper offers new insights into how Lean and Six Sigma support the CE and sustainability in agribusiness and identifies strategic directions for future research.

Keywords Lean six sigma, Agribusiness, Sustainability, Circular economy, Systematic literature review

Paper type Literature review

1. Introduction

The circular economy (CE) model is described as an economic system that replaces the traditional production and consumption model "take-make-disposal" with a strategy of reuse, recycling and remanufacturing to optimise the resources efficiently (Dennison *et al.*, 2024). This model seeks to extend the product life cycles with the aim to reduce waste and its environmental impact (Basile *et al.*, 2024; Jerome and Ljunggren, 2025). CE is widely discussed in the contemporary business field on economic growth, leading to sustainability (Voulvoulis, 2022), balancing ecological resilience (Kennedy and Linnenluecke, 2022) and promoting long-term economic, social and environmental benefits (Yin *et al.*, 2023). The concept of CE encourages the mitigation of resource scarcity, minimises waste and fosters innovations towards sustainable production and consumption, and is based on several key principles (e.g. reducing resource usage, reusing materials, recycling waste, regenerating natural systems and enhancing the product lifestyle) (Velenturf and Purnell, 2021). These principles are evident in agribusiness through the practice of waste valorisation, regenerative farming, producing innovative products and closed-loop supply chains activities (Cahyadi *et al.*, 2024; Nattassha *et al.*, 2020).

Contemporary businesses are continuously seeking ways to enhance their business performance aligned with CE and sustainability (Yin *et al.*, 2023) by delivering cost-effective, high-quality products promptly, to stay competitive (Hassan *et al.*, 2022; Ng and Hung, 2001). This led to the implementation of well-established approaches (e.g. TQM, Business Process Re-engineering, Lean and Six Sigma), which streamline the operation processes and improve the quality standards and quality management systems, which ensure product reliability, consistency and compliance (Nanda, 2005).

Among these approaches, Lean and Six Sigma stand out as globally recognised philosophies for quality improvement by reducing waste, minimising product deviation, improving process efficiency and customer satisfaction (Bakar *et al.*, 2015). The Lean approach is a philosophy that aims to increase production quality and efficiency by eliminating waste (Hu *et al.*, 2015; Stone, 2012). On the other hand, Six Sigma is a set of statistical tools used to develop a framework for process improvement within the quality management perspective (Goh and Xie, 2004). Lean and Six Sigma were initially used separately (Dahlgaard and Dahlgaard-Park, 2006), but were subsequently integrated as Lean Six Sigma (LSS), which provides a more comprehensive approach towards obtaining business improvement by reducing waste and process variability simultaneously (Laureani and Antony, 2012). Voehl *et al.* (2013) suggested that LSS plays a significant role in enhancing overall organisational performance, efficiencies and customer satisfaction.

LSS has been implemented across many different industries, such as chemical manufacturing (Alarcón *et al.*, 2023), food manufacturing (Widiwati *et al.*, 2024), automobile (Rathi *et al.*, 2021), hospitality and tourism (Fiala and Thirumaran, 2021), airlines (Psychogios and Tsironis, 2012) and education (Lu *et al.*, 2018), improving the production processes (Voehl *et al.*, 2013), productivity (Rane *et al.*, 2023), quality (Anh *et al.*, 2023) and customer satisfaction (Laureani and Antony, 2012), regardless of organisational size (Kumar *et al.*, 2023), nature (Singh and Rathi, 2019) and national boundaries (Charles and Price, 2016; Citybabu and Yamini, 2023) which leads to sustainability.

Nowadays, sustainability has emerged as a key topic in academic research across multiple disciplines. The importance of integrating Lean, Six Sigma and LSS with sustainability across various industries has been acknowledged and helps accelerate the organisational performance in achieving the three sustainability pillars; namely (1) economy that emphasises the creation of sustainable and inclusive economic growth that provides opportunities for all without sacrificing environmental or social well-being, (2) environment that focuses on responsible resource management, pollution reduction and the protection of ecosystems and (3) society which aims to create more resilient and inclusive societies that benefit individuals and communities (Khanzode *et al.*, 2021; Park and Linich, 2008). Many studies (*Belhadi et al.*, 2020; *Riyanto et al.*, 2023) have revealed that the application of LSS has contributed positively to these sustainability pillars. Studies have shown that LSS contributes to the achievement of CE principles (Skalli *et al.*, 2022). CE is regarded as an economic system that considers the "End of life" with the applications of reduction, reuse, recycling and recovery of the materials in the entire business system (Kirchherr *et al.*, 2017), which presented a new business framework to reach sustainability goals (McDowall *et al.*, 2017). While CE is concerned particularly about environmental protection (Haupt and Hellweg, 2019), LSS focuses on providing a structured approach to environmental conservation and achieving environmental sustainability (Powell *et al.*, 2017). In recent years, there has been a growing trend among researchers (Orlov *et al.*, 2024; Skalli *et al.*, 2023) to identify the contribution of Lean and Six Sigma towards CE principles, particularly addressing environmental concerns. However, studies (Farrukh *et al.*, 2023; Zironi *et al.*, 2024) highlight the relationship between LSS and CE in agribusiness remains scarce, which this study aims to fill.

There has been increasing attention drawn to Lean and Six Sigma, especially in industries with financial barriers and operational efficiency-seeking organisations, particularly for agribusiness (Antony *et al.*, 2017; Satolo *et al.*, 2017a). According to Davis and Goldberg (1957), agribusiness is defined as the total of all operations involved in the manufacture and distribution of farm supplies; production operations on the farm; and the storage, processing and distribution of farm commodities and items and from them. It reflects the activities of supplying materials, performing operational activities, storing and distributing agricultural products to its end-users, leading towards a business-oriented approach (Khalatur *et al.*, 2023).

LSS has been recognised as an optimal approach to improve long-term competitiveness in the global market and enhance the environmental quality of agribusinesses (Rifqi *et al.*, 2021). Although LSS is increasingly adopted in agribusinesses to improve business processes (Antony, 2011), productivity (Sreekanth *et al.*, 2024), quality (Fletcher, 2018) and enhance strategic decisions (Muganyi *et al.*, 2019), but their application in agribusiness in the context of sustainability and CE remains unexplored in the extant literature (Skalli *et al.*, 2023). Cahyadi *et al.* (2024) emphasised the importance of moving towards sustainable production from linear production (take-make-dispose) in agribusiness to enhance resource efficiency, environmental benefits and economic resilience. In addition, they highlighted the importance of identifying CE principles for sustainability improvement within the challenges of efficient resource management and waste minimisation. Similarly, Sahoo *et al.* (2025) highlighted the profit, planet and people benefits of proper identification of the relationship between different ways of Lean, Six Sigma applications and CE towards sustainability.

Based on the above, two Research Questions (RQs) have been developed for this study as follows:

RQ1. How have Lean, Six Sigma and LSS been applied in agribusiness and support the circular economy principles?

RQ2. How do Lean, Six Sigma and LSS in agribusiness drive sustainability within a circular economy framework?

This study seeks to fill this gap by systematically reviewing the literature to provide further theoretical insights into the role of LSS in supporting sustainability in agribusiness through the CE framework. Specifically, this study brings novel insights to the existing knowledge by exploring the Lean, Six Sigma and LSS applications as a strategic tool to attain sustainability goals through the CE framework, particularly in the agribusiness sector (Marques *et al.*, 2025; Veloso *et al.*, 2025). The significance of this study lies in the fact that the proposed framework can be adopted by agribusinesses, which can be used as a guide for sustainable transformation.

This paper is structured into six sections. Section 1 provides the introduction and background information about this study, and the methodology adopted in this study will be outlined in Section 2. Section 3 presents the descriptive analysis of the key findings, and discussions on the two *RQs* will be provided in Section 4. Section 5 discusses the theoretical contribution and practical implications of the study, and conclusions will be drawn in Section 6. And finally, Section 7 will outline the future research and limitations of the study.

2. Research design

A systematic literature review was conducted to evaluate the existing body of work on the application of Lean, Six Sigma and LSS in agribusinesses that drive sustainability through the CE framework. Many researchers (Payne and Kwofie, 2024; Zironi *et al.*, 2024b) have used the ReSOLVE (i.e. Regenerate, Share, Optimise, Loop, Virtualise and Exchange) framework developed by the Ellen MacArthur Foundation (Ellen MacArthur Foundation, 2015), to implement the CE principles and accelerate growth. The ReSOLVE framework has been applied in many industries (Nobre and Tavares, 2020; Sell *et al.*, 2023), including assessing CE's impact on agriculture business-related industries (Halpern *et al.*, 2024; Payne and Kwofie, 2024). This study has adopted the ReSOLVE framework to evaluate the CE principles addressed across various applications of Lean, Six Sigma and LSS in the reviewed articles. Figure 1 below briefly illustrates the procedure followed.

To assess the contribution of Lean, Six Sigma and LSS to agribusiness sustainability, the three key pillars of economy, society and environment were considered. Furthermore, the reviewed articles were examined on how various applications of Lean and Six Sigma have been applied in agribusiness using LSS principles. These key principles include: (1) eliminating waste, which involves removing process activities that do not directly add value for the customer (Pristyanto and Rochmoeljati, 2024), (2) eliminating process variations, which ensures consistent output with minimal variability (Antony and Kumar, 2012), (3) customer focus that emphasises meeting customer requirements (Bazrkar *et al.*, 2017), (4) reducing lead time that helps shorten the duration from process initiation to completion (Antony *et al.*, 2017), (5) continuous improvement, which promotes ongoing enhancement of processes, systems and products (Iswanto, 2017) and (6) archiving perfection that aims to attain zero waste in processes (Dobrin *et al.*, 2017). The steps undertaken to determine the total number of reviewed articles on the different applications of Lean, Six Sigma and LSS in

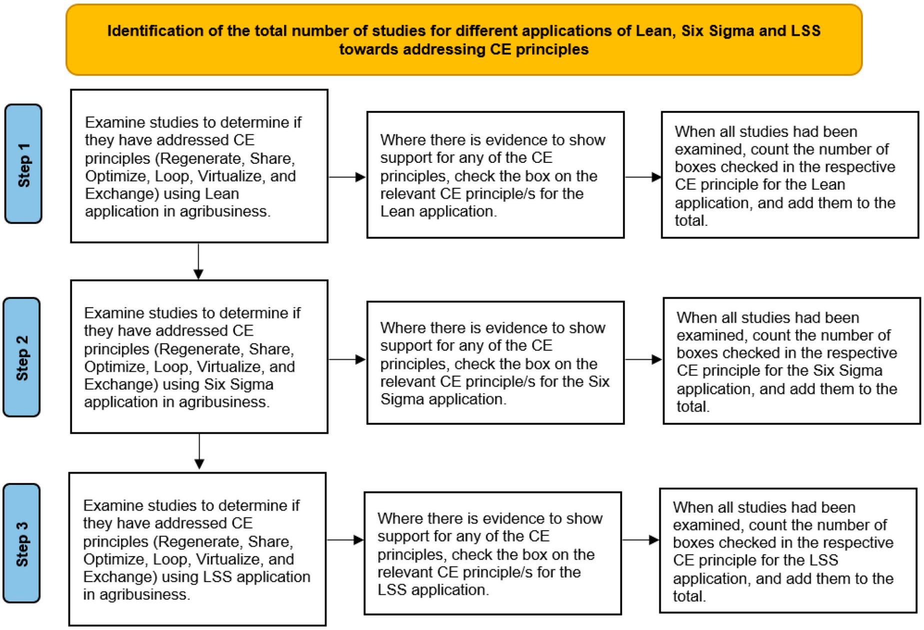

Figure 1. Procedure to identify the total number of studies for different applications of Lean, Six Sigma and LSS that addressed CE principles

Source: Authors' own work

agribusiness towards sustainability pillars, and LSS principles are as shown in Figures 2 and 3, respectively.

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement, developed by (Moher *et al.*, 2009) was adopted in this study (Figure 4), as it provides a concise and transparent literature review of different academic disciplines, scholars and practitioners (Liberati *et al.*, 2009; Tam *et al.*, 2019) The guidelines provided in the PRISMA statement include: (1) identifying existing literature in search databases and other relevant sources, (2) screening and checking the inclusion eligibility of existing literature, (3) data extraction from selected and eligible literature and (4) synthesising the findings to make available a comprehensive summary. The steps of selecting review papers will be discussed in turn next.

2.1 Step 1 – Identification of the reviewed articles

The term "agribusiness" used in this study has been defined as an integrated system that encompasses input supply, agricultural production, processing and distribution of agricultural products (Boehlje, 1999). Martínez-Burgos *et al.* (2021) also, suggested that the integrated agribusiness activities and industrial functions form an agribusiness system called agri-industry within the broader approach of the agribusiness context. The term "agri-industry" refers to an economic system with industrial components connected to agriculture that includes any organisation's involvement in the storage, processing and handling of agricultural commodities (Nazrul and Xayavong, 2010). Özaydın and Direk (2022) and FAO (2013) pointed out that the close link between agribusiness and agri-industry is the principal

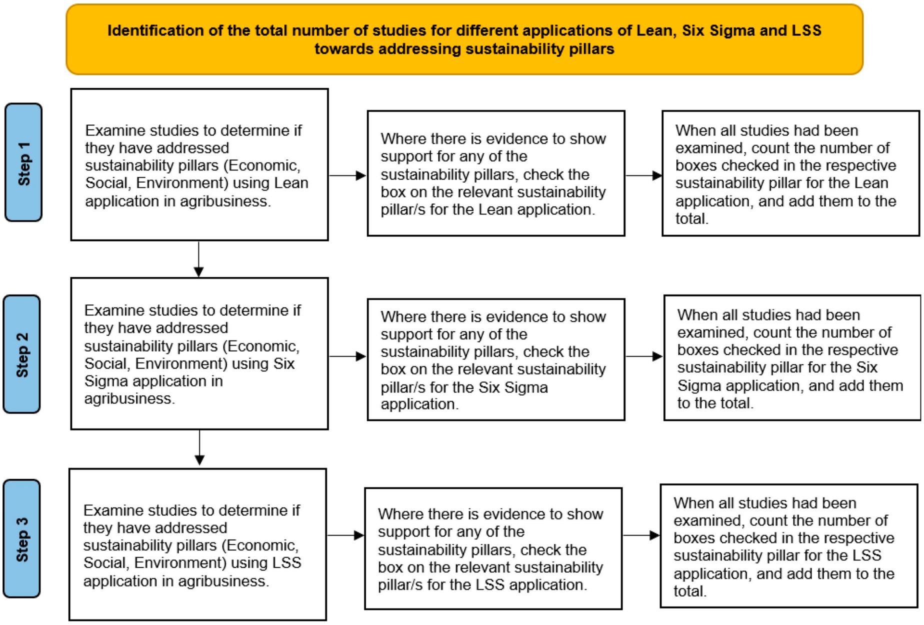

Figure 2. Steps to identify the total number of studies for different applications of Lean, Six Sigma and LSS that addressed sustainability pillars

Source: Authors' own work

source of value addition for primary agricultural products. The term "agriculture" reflects the primary production activities of agricultural products that are considered the primary node of the agribusiness system (*Ambor et al.*, 2025; *Oliveira et al.*, 2023). Agri-industry and agriculture are conceptually interconnected to agribusiness, in which agriculture provides primary activities of the agribusiness, and agri-industry represents the broader value-adding dimension of agribusiness (Zylbersztajn, 2017). Therefore, these three keywords (i.e. agribusiness, agri-industry and agriculture) have been used as part of the search terms.

At the initial stage, extensive literature review searches were performed on electronic databases such as Scopus, Emerald Insight, Web of Science and JSTOR. The search terms included "Agribusiness", "Agriculture", "Agri-industry", "Lean", "Six Sigma", "Lean Six Sigma", "Sustainability" and "Circular Economy" with proper usage of "AND" and "OR" commands to allow for a more optimal search in the existing literature reviews. These keywords were decided based on the study objectives.

The Boolean operation was performed to search extant literature such as ("Lean Six Sigma" OR "Six Sigma" OR Lean) AND (Agribusiness OR Agriculture OR Agri-industry). The second string was operated as [("Lean Six Sigma" OR "Six Sigma" OR Lean) AND (Agribusiness OR Agriculture OR "Agri-industry") AND (Sustainability OR "Circular Economy")] in each considered database. In the initial attempt, a total number of 2,281 articles were retrieved.

2.2 Step 2 – Filtering the retrieved articles

At this step, the selected review articles' titles were scanned thoroughly to identify duplicated reviewed papers published in different journals in different formats. Also, papers

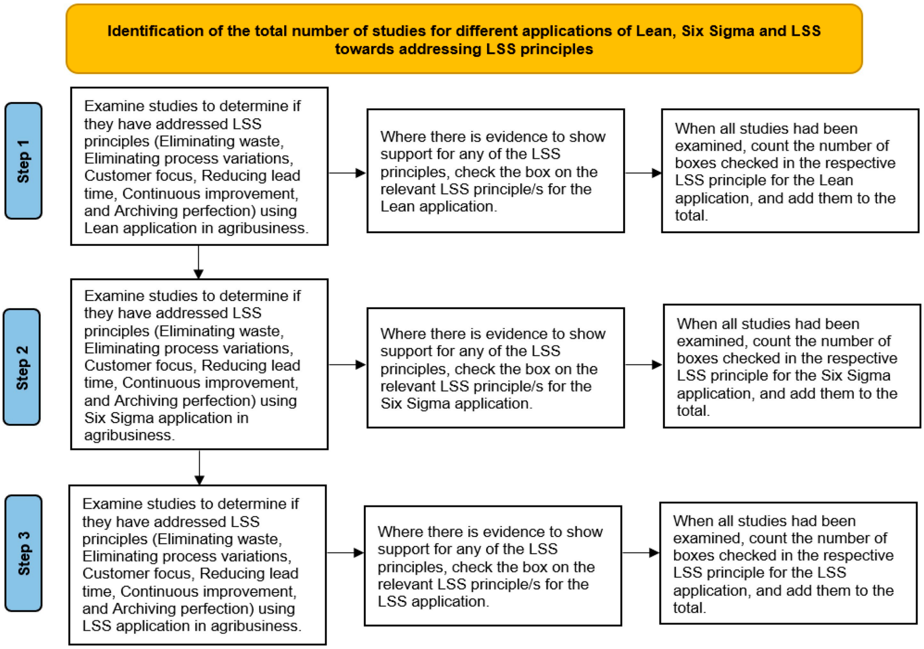

Figure 3. Steps to identify the total number of studies for different applications of Lean, Six Sigma and LSS that addressed LSS principles

Source: Authors' own work

outside the time period of 2005–2024 were excluded. In this stage, 24 papers were excluded and as a result, 2,257 review articles were filtered for further review.

2.3 Step 3 – Screening of the articles' titles

In the record screening stage, the retrieved papers were filtered based on different criteria. Peer-reviewed articles (including systematic literature review) published in journals, and the application of individual or combined applications of Lean and Six Sigma across entire activities in the agribusinesses were considered for the inclusive criteria of the review selection. Next, review articles that were published other than in English were excluded, resulting in the elimination of 2,160 articles. With inclusion and exclusion criteria, a total of 97 articles proceeded to further screenings.

2.4 Step 4 – Screening of the article's abstract and other parts of the reviewed articles

In this last step, abstracts were examined to determine whether the contents fulfilled the requirements of the inclusive criteria and applications of Lean, Six Sigma and LSS across many activities in agribusiness processes. Furthermore, the results, discussion and conclusion sections of the full paper were checked to determine their adherence to the inclusion criteria. As a result, 61 papers were omitted due to content not aligned with the inclusive criteria, and therefore, only 36 review articles remained for the systematic literature review. Figure 4 outlines the PRISMA statement process that this study has followed, and a

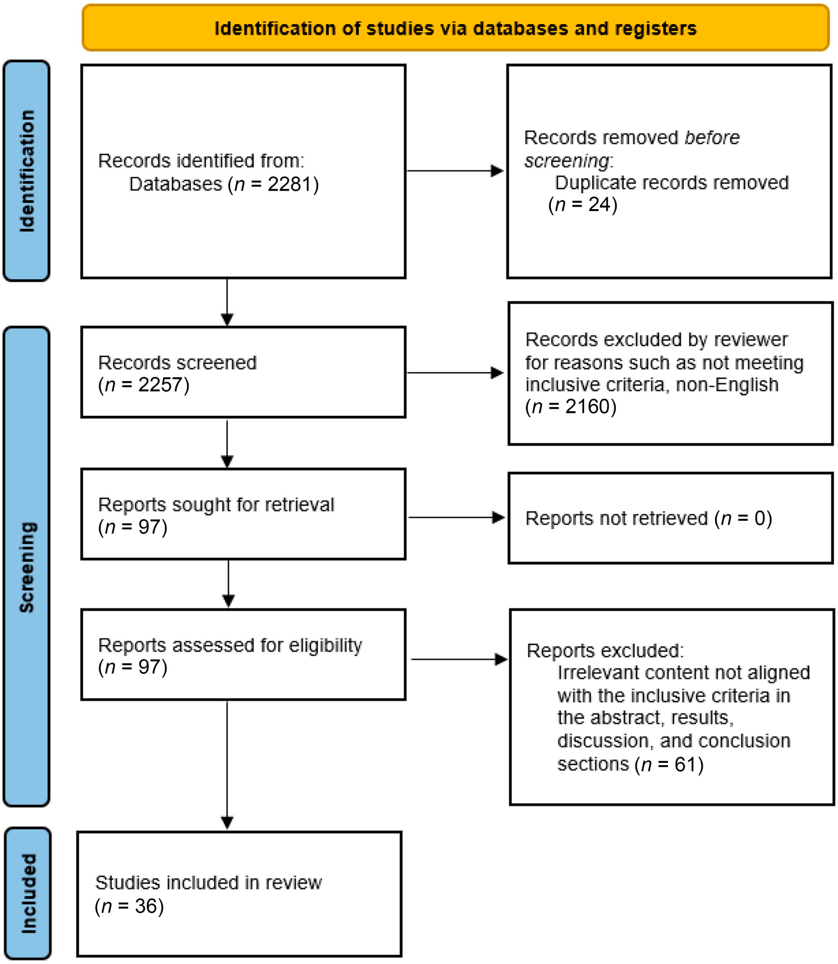

Figure 4. PRISMA statement for identification, screening and eligibility of data collection
Source: Authors' own work

summary of the study methodology for this systematic literature review is provided in Table 1, and the reviewed papers in Appendix.

3. Analysis of the application of lean, Six Sigma and lean Six Sigma in agribusiness

3.1 Descriptive analysis of the lean, Six Sigma and lean Six Sigma applications in agribusiness

3.1.1 Implementation methods of different applications of lean and Six Sigma in agribusiness. Figure 5 highlights that the reviewed articles adopted two main methods to implement Lean, Six Sigma and LSS in agribusiness. Half of the reviewed papers (18 out of 36) are related to the implementation of the DMAIC (Define, Measure, Analyse, Improve and Control) process, which highlights the structured improvement framework for

Table 1. Summary of the study methodology

Summary aspect	Illustration
Research keywords	Lean, Six sigma and lean Six sigma agribusiness, agriculture, Agri-industry sustainability circular economy
Boolean operator	("Lean Six sigma" or "Six Sigma" OR Lean) AND (Agribusiness OR Agriculture OR Agri-industry) ("lean Six sigma" or "Six Sigma" OR Lean) AND [(Agribusiness OR Agriculture OR Agri-industry) AND (Sustainability OR "Circular Economy")]
Database	Scopus, emerald insight, web of science and JSTOR
Language	English
Inclusive criteria	Peer-reviewed journal articles published in journals, application of individual or combined applications of lean, Six sigma or LSS across entire activities in agribusinesses
Exclusive	Duplicated reviewed papers published in different journals
Time period	2005–2024

Source(s): Authors' own work

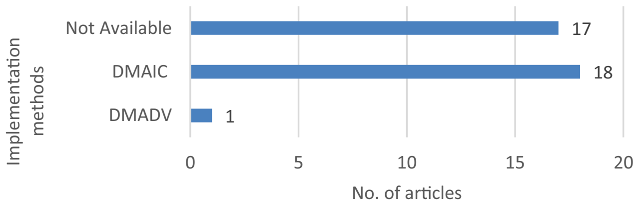

Figure 5. Implementation methods of different applications of Lean and Six Sigma
Source: Authors' own work

implementing solutions in agribusiness practices (Rifqi *et al.*, 2021). These findings align with the study by Nolasco Mezares and Trujillo Vilcapoma (2025), which reported approximately 86% of agribusinesses used the DMAIC process, which is a common Six Sigma approach for improving existing processes to minimise inefficiencies and quality defects. In contrast, only one reviewed paper has adopted the DMADV (Define, Measure, Analyse, Design and Verify) process, suggesting that this method remains underutilised in the agribusiness context in developing innovative products and processes, which is an opportunity for future research. The limited adoption of the DMADV approach may be explained by the fact that its implementation requires a high level of technical knowledge, which poses a challenge for many agribusinesses (Yang *et al.*, 2022). The remaining reviewed papers did not identify any specific method used.

3.1.2 Publication years of the reviewed articles. Figure 6 highlights the distribution of the reviewed articles by publication year, revealing an increasing trend with minor fluctuations, drawing attention to studying Lean, Six Sigma and LSS in agribusinesses over the period from 2005 to 2024. The highest number of papers published was in the year 2023, which accounted for six of the 36 reviewed papers, and no studies related to Lean, Six Sigma and LSS in agribusiness were identified between the years 2007 and 2009. Most of the reviewed papers (55.5%, $n = 20$) were published in or after the year 2020, and this may be attributed to the growing pressure for sustainable practices and resource efficiency in the agribusiness sector, which has led to a greater level of research interest in this area.

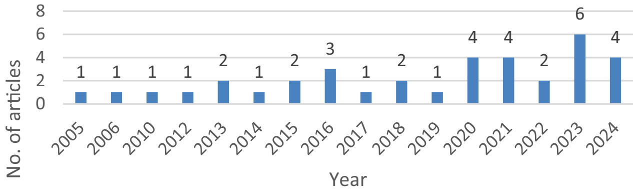

Figure 6. Distribution of the reviewed articles by publication year
Source: Authors' own work

3.1.3 Geographical distribution of the review articles. As shown in Figure 7, findings show that the application of Lean, Six Sigma and LSS in agribusiness was reported across 21 different countries. Accordingly, Brazil ($n = 5$, including 2 combined with other countries), India ($n = 4$), Turkey ($n = 4$) and Sweden ($n = 3$) are the most common countries from which the data is collected. This is consistent with the findings of Satolo *et al.* (2017), who noted that Brazil has become one of the largest exporters of agricultural products and has increasingly adopted strategic tools to improve agribusiness performance and maintain global competitiveness (Basso *et al.*, 2024). Furthermore, agribusinesses in Brazil exhibit a strong continuous improvement culture, with strategic tools such as Lean and LSS being widely implemented (Sakumoto *et al.*, 2019). Similarly, India is an agriculture-dependent

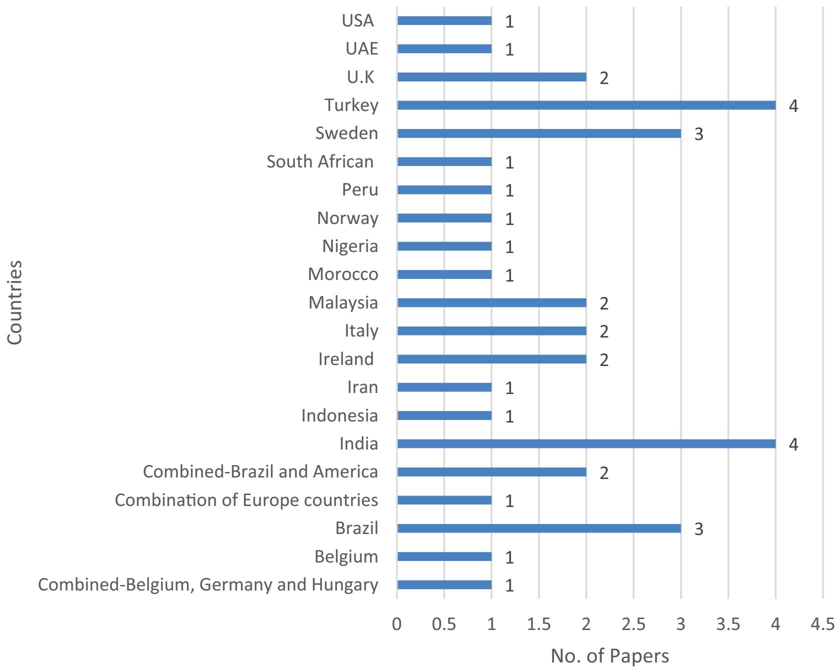

Figure 7. Distribution of review articles by country
Source: Authors' own work

economy, and government support for LSS implementation has encouraged its adoption across many industries, including agribusiness (OECD, 2023). These initiatives aim to enhance customer satisfaction and reduce the likelihood of product failures within agribusiness operations (Antony *et al.*, 2016; Prashar, 2014). It is worth noting that key agricultural-producing countries such as China, Russia, France and Mexico have not appeared in this research. This absence may be explained by potential cultural misalignments between Lean principles and organisational practices, negative perceptions of Six Sigma's efficiency, and a general lack of knowledge and resources necessary for its implementation in these countries, which can hinder the adoption of these applications (Al-Abdallah and Lic, 2020; Cronemyr *et al.*, 2014).

3.1.4 Types of research methodology in reviewed articles. According to Figure 8, there are four types of research methodology adopted by these reviewed articles. Most articles ($n = 27$) have used the single case study methodology, and this is followed by empirical research ($n = 4$), multiple case studies ($n = 3$) and applied research ($n = 2$).

3.1.5 Journal publications in reviewed articles. Figure 9 presents the journal publications in which the review articles related to the different applications of Lean and Six Sigma in agribusiness were published from 2005 to 2024. A total of 26 different journals has been identified, and the International Journal of Lean Six Sigma has the most articles ($n = 8$). Next is the Total Quality Management Journal with three articles, then the Production Planning and Control Journal with two articles. All remaining articles are evenly spread across other journals, with one publication each. This suggests that the International Journal of Lean Six Sigma has been the key publication outlet disseminating academic research work related to the adoption of different applications of Lean and Six Sigma in agribusiness.

4. Discussion

4.1 RQ1: Different applications of lean, Six Sigma and lean Six Sigma in agribusiness

As shown in Figure 10, most of the reviewed articles are related to the application of LSS, and this is followed by the Lean approach, Six Sigma, Green Lean, Design for LSS and Green Lean Six Sigma. There are 15 (out of 36) reviewed articles related to the application of LSS in agribusiness, 10 of which are in the context of food and beverages manufacturing, two are in dairy products manufacturing, and the remaining three reviewed papers are not mentioned in any specific setting. The increasing adoption of LSS application has been supported by findings of Costa *et al.* (2018) and Thammasang *et al.* (2021), which showed

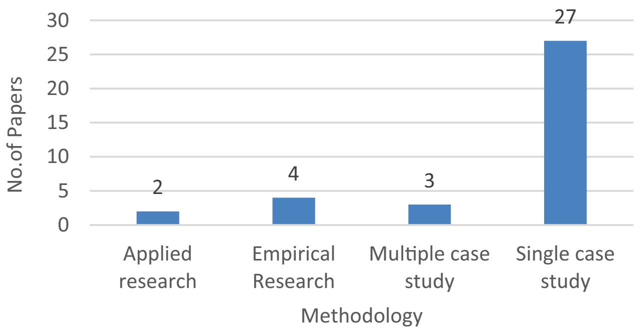

Figure 8. Different research methodologies were used in the reviewed article
Source: Authors' own work

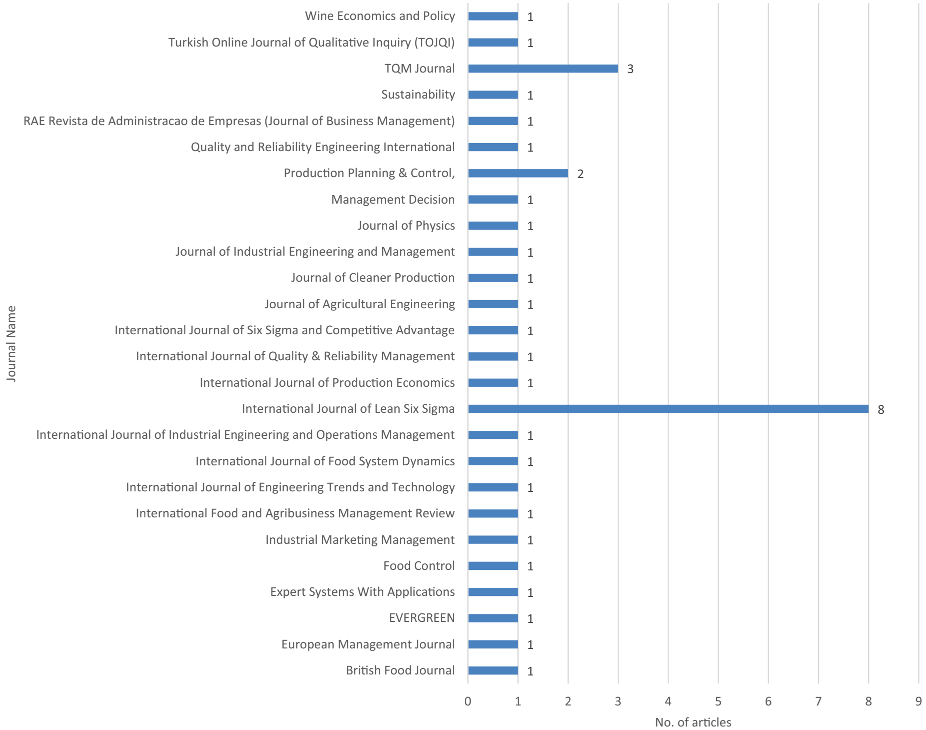

Figure 9. Distribution of different journal publications
Source: Authors' own work

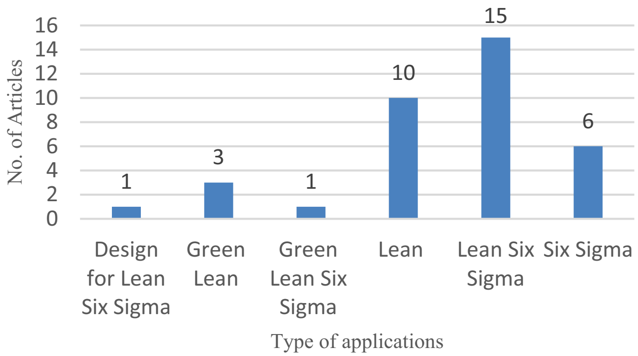

Figure 10. Different applications of Lean and Six Sigma in agribusiness
Source: Authors' own work

that agribusinesses have begun to recognise numerous benefits (e.g. cost reduction, improved productivity and quality) when compared with implementing either Lean or Six Sigma alone. Previous studies (Costa *et al.*, 2018; Marques *et al.*, 2025) also suggested that the combined application of Lean and Six Sigma can optimise quality-related outcomes across different industries, including agribusiness.

As for the application of the Lean approach in agribusiness, 10 (out of 36) reviewed papers are identified. These are mainly related to food and meat processing, with three reviewed papers identified each, and the remaining papers are not specified. There are six reviewed papers related to the Six Sigma application, and they are associated with food processing, farming and equipment production. Furthermore, the results indicate that four reviewed papers are related to the application of Lean and Six Sigma approaches that incorporate the green concept (Green Lean, Green Lean Six Sigma) in agribusiness. It is interesting to note that some authors (*Rothenberg et al.*, 2001; Venkat and Wakeland, 2006) argued against this finding that the positive environmental impacts are already included in the Lean approach. It is considered an inducement factor for greener concepts in agribusiness, leading to the idea that Lean is a green concept, and it provides a foundation for green initiatives (Dieste *et al.*, 2019; King and Lenox, 2001). In addition, Chugani *et al.* (2017) pointed out that both Lean and Six Sigma can be used as effective strategic tools for resource conservation, reducing global warming and energy saving in agribusiness. However, Chen *et al.* (2020) challenged this idea that Lean does not explicitly aim at environmental aspects, as it aims at operational performances by targeting waste instead. Notably, the integration of the green concept in agribusiness with the Six Sigma application has not been observed among the reviewed articles, which serves as an opportunity for further investigation because LSS lacks a holistic environmental metric (Ghasemibojd *et al.*, 2025). Finally, only one reviewed article is associated with the application of Design for LSS in agribusiness, which is specific to value chain lifecycle data management in agribusiness. This finding contrasts with the increasing uptake of Design for LSS in other industries such as engineering (Ó Longaigh *et al.*, 2023), and medical manufacturing (Trubetskaya *et al.*, 2023). A possible reason for the limited application of Design for LSS in agribusiness may be that the industry has traditionally prioritised operational activities over design-driven approaches (Costa *et al.*, 2018).

4.1.1 Applications of lean and Six Sigma across agribusiness activities. More than half (20 out of 36) of the reviewed articles have addressed the implementation of the different applications of Lean and Six Sigma for activities related to food processing in agribusiness. The primary focus has been on performance improvements in the production process, reducing waste generation in production. This finding is consistent with previous studies (Algassem *et al.*, 2014; Costa *et al.*, 2018) reported LSS initiatives are evident in different contexts within the food industry to enhance production quality. Jamil *et al.* (2025) further supported this observation, highlighting that the application of LSS contributes to achieving sustainability in the food and beverage sector.

Reviewed articles related to Lean, Six Sigma and different applications in the supply chain process accounted for five papers, whereas three reviewed articles have highlighted the improvement of food quality and safety, particularly on implementing quality management systems such as ISO 9001 in agribusiness. Marques *et al.* (2016) highlighted the similarities between LSS and ISO 9001 clauses in areas such as process mapping, performance measurement and continuous improvement, suggesting that LSS can be effectively integrated with ISO 9001 applications.

The remaining reviewed articles are evenly spread across activities related to agricultural equipment processing, farm management, food management, system management and value chain data management. These findings are supported by previous studies (Rifqi *et al.*, 2021; Utama and Abirfatin, 2023) that suggested LSS can be adopted across a broad range of business processes, regardless of their industry function. It is observed that no evidence has been recorded in developing innovative products using the DMADV method, using Six Sigma application, highlighting a need to further investigate the use of DMADV in agribusiness. A possible explanation is that the DMADV method requires substantial resources, extensive data and rigorous testing, which may limit its adoption in the agribusiness industry (Yang *et al.*, 2022). Figure 11 shows different applications of Lean and Six Sigma across agribusiness activities.

4.1.2 The overall contribution of different applications of lean, Six Sigma towards lean Six Sigma principles in agribusiness. Overall results reveal that approximately 72.2% of all reviewed articles have contributed to achieving the eliminating waste principle. This is followed by the principles of continuous improvement (58.3%), achieving perfection (33.3%), reducing lead time (30.6%), customer focus (25%) and eliminating process variation (19.4%). Figure 12 provides a summary of the overall contribution of Lean, Six Sigma and LSS applications towards LSS principles in agribusiness.

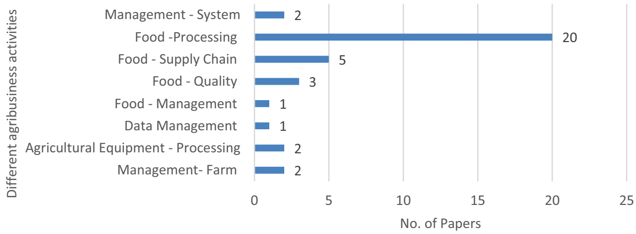

Figure 11. Lean, Six Sigma and LSS applications in different activities in agribusiness
Source: Authors' own work

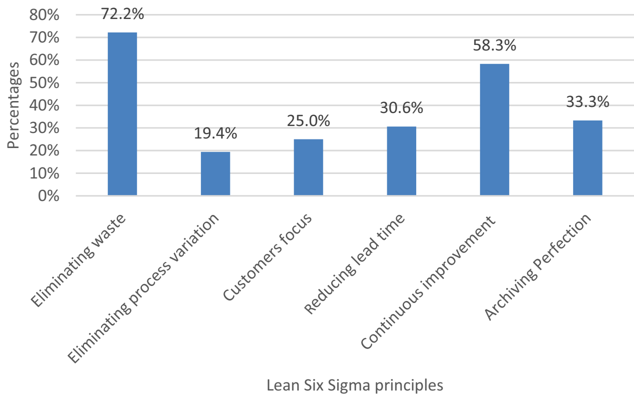

Figure 12. Overall contribution of Lean, Six Sigma and LSS applications towards LSS principles in agribusiness
Source: Authors' own work

Of the 36 reviewed articles, 15 contributed to the incorporation of the LSS application in agribusiness, and this is followed by Lean application ($n = 10$), Six Sigma application ($n = 6$) and modified Lean and Six Sigma application (i.e. a combination of Green Lean, Design for LSS and Green Lean Six Sigma) ($n = 5$). The apparent lack of research using different applications towards the LSS principles in agribusiness is evident, particularly where no one application has accounted for more than half of the total number of reviewed articles. This may be explained by the fact that Lean application alone does not address process variation, while the standalone application of Six Sigma does not address process flow speed (Schroeder *et al.*, 2003; Shah and Ward, 2007). Consequently, integrating these applications becomes essential for achieving different improvement goals. Thus, this warrants a greater level of attention for research to provide further insights and understanding in this field. Table 2 illustrates the different applications of the LSS principles in agribusiness.

Several aspects of the different applications of Lean and Six Sigma towards LSS principles in agribusiness have been observed in the reviewed articles. Firstly, the number of reviewed articles related to the customer focus principle is relatively well spread across the different applications of Lean, Six Sigma and LSS. The key findings highlight the adoption of customer changes, such as seasonal consumption, quality and health surveillance (Satolo *et al.*, 2017), customer association (Dora *et al.*, 2013), the importance of addressing customers' requirements (*Hakimi et al.*, 2018), achieving customer satisfaction (Prashar, 2014) and a need to improve customer value (Barth and Melin, 2018) in agribusiness. Our findings are consistent with previous studies (Trubetskaya *et al.*, 2023) that emphasised the core of these applications towards the delivery of customer values and ensured improvements can be achieved through efficiencies that align with customer expectations.

Secondly, there are notably more reviewed articles that used LSS applications to examine the principles of continuous improvement, eliminating waste and reducing lead time, than other applications. One possible explanation is that LSS applications are likely to generate greater benefits than using Lean or Six Sigma in isolation (Schroeder *et al.*, 2003). For the principle of continuous improvement, findings reveal that the studies are mainly related to the development of new frameworks and designs (Ariffien *et al.*, 2021) that strengthen traceability, supplier relationships (Yeni *et al.*, 2024), as well as supply chain performance systems (Sharma *et al.*, 2023). On the other hand, key themes in the eliminating waste principle have focused on the reduction of production and resource waste (Zironi *et al.*, 2024; Powell *et al.*, 2017), scrap rate (Rifqi *et al.*, 2021) and energy cost (Trubetskaya *et al.*, 2023). In terms of the reducing lead time principle, key themes identified are associated with reducing setup time (Costa *et al.*, 2020), lead time (Zironi *et al.*, 2024) and cycle time (Dora and Gellynck, 2015). It is observed that these three principles lack applications from the use of Lean and Six Sigma in agribusiness. This finding differs from the study by Widiwati *et al.*

Table 2. Different applications of the LSS principles in agribusinesses

	LSS principles					
Application	Eliminating waste	Eliminating process variations	Customer focus	Reducing lead time	Continuous improvement	Achieving perfection
Lean	6	1	2	3	6	5
Six sigma	5	3	3	1	2	2
LSS	10	3	3	6	11	3
Modified LSS	5	0	1	1	2	2

Note(s): The total number of counts is for each application in the different LSS principles
Source(s): Authors' own work

(2024) that revealed these principles are more likely to reduce waste and improve processes in the food industry using the LSS application, as it can achieve better performance compared with using Lean or Six Sigma alone (Mojumder, 2025). Therefore, an opportunity for future research existed in this area so that further insights and a better understanding can be attained about different applications of these principles.

Thirdly, findings suggest Lean application towards the principle of achieving perfection has been identified in a higher number of reviewed articles than other applications. Key themes in this principle have focused on increasing productivity and efficiency (Fernandes Junior and Pinto, 2020), increasing sales (Zokaei and Simons, 2006), optimising production systems (Satolo *et al.*, 2017) and reaching more profit margins (Cox and Chicksand, 2005) in agribusiness. This may be because the primary goals of Six Sigma and LSS are aimed at improving efficiency and quality, defect reduction and process control, rather than continual refinement towards achieving perfection (Mittal *et al.*, 2023; Sutherland, 2001). This observation is further supported by Jadhav *et al.* (2014), who highlighted the strategic value of Lean in the "pursue perfection" principle, as it represents a core and final objective of Lean manufacturing. This presents an opportunity for future research to provide the much-needed evidence.

Finally, application of the modified Lean and Six Sigma application towards five principles (i.e. eliminating waste, continuous improvement, achieving perfection, customer focus and reducing lead time) has been observed in the reviewed articles. Common themes highlighted in these principles include: waste reduction in agribusiness (Andreazza de Freitas *et al.*, 2024; Barth and Melin, 2018), determining a long-term perspective (Barth and Melin, 2018), reducing carbon footprint (Ortiz Porras *et al.*, 2023) and cycle time (Andreazza de Freitas *et al.*, 2024), and improve customer value (Barth and Melin, 2018). However, it is worth noting that no reviewed article has been identified to address the principle of eliminating process variations. A possible explanation may be that agribusiness processes are inherently variable because they are highly dependent on the biological growth cycles and environmental conditions, making variation extremely difficult to eliminate (Coetzee and Mangaroo-Pillay, 2023). Therefore, this research gap poses an opportunity for future investigation.

4.1.3 Lean, Six Sigma and lean Six Sigma application to support circular economy principles in agribusiness. According to Table 3, the majority (28 out of 36) of the reviewed papers found that the optimisation principle has often been considered in Lean, Six Sigma, LSS and modified Lean and Six Sigma applications. The common themes identified are related to increasing production performance (Hakimi *et al.*, 2018; Rifqi *et al.*, 2021), improving productivity (Fernandes Junior and Pinto, 2020; Ortiz Porras *et al.*, 2023), reducing waste (Ortiz Porras *et al.*, 2023) and saving cost (Zokaei and Simons, 2006). The CE principle of exchange is

Table 3. Different applications of lean and Six Sigma towards addressing circular economy principles in agribusiness

Application	CE principles					
	Regenerate	Virtualisation	Share	Loop	Exchange	Optimise
Lean	0	0	0	0	7	8
Six sigma	0	0	0	0	1	5
LSS	1	1	2	1	13	12
Modified LSS	0	1	0	1	3	3

Note(s): The total number of counts is for each application in the different CE principles
Source(s): Authors' own work

observed in 24 reviewed articles, and the key areas of focus are mainly on implementing new technologies (Hakimi *et al.*, 2018; Manzouri *et al.*, 2013) and designing new products (Trubetskaya *et al.*, 2023). As for the virtualisation, share and loop principles, only two reviewed articles in each have been identified. The main themes in these papers have focused on visual management (Rifqi *et al.*, 2021), reducing and reusing resources (Zironi *et al.*, 2024; Powell *et al.*, 2017) and redesigning and remanufacturing (Barth and Melin, 2018). Finally, the regenerate principle has only been highlighted in one reviewed paper, and the focus is on recovering resources (Zironi *et al.*, 2024). It is noted that most studies have predominantly focused on the optimisation and exchange principles, whereas other principles (i.e. loop, share, virtualisation and regeneration) are notably neglected. A possible explanation is that the optimisation and exchange principles emphasise resource efficiency and system effectiveness (Cunningham *et al.*, 2002), which closely align with the fundamental principles of LSS. This disparity provides an opportunity for future research to gain a better understanding of how different applications can be used to better support the principles of loop, share, virtualisation and regeneration in the agribusiness industry.

Several observations in the different applications of Lean, Six Sigma and LSS to support CE principles in agribusiness have been noted in the reviewed articles. Firstly, LSS is the only application identified in the reviewed articles that has addressed all the CE principles (i.e. regenerate, virtualisation, share, loop, exchange and optimise) under the ReSOLVE framework. This finding reaffirms LSS being highly adaptable to support CE principles through process improvements that can effectively facilitate the implementation of circular strategies. These results are supported by Skalli *et al.* (2022), who highlighted the positive interrelationship between LSS and CE. Likewise, Salibi *et al.* (2022) demonstrated the alignment between Lean and CE by introducing the concept of "Circular Lean" because both approaches share common goals related to waste management (*Oliveira et al.*, 2022).

Next, there is limited recognition across all different applications about supporting the regeneration and virtualisation principles in agribusiness. A possible explanation is that advancements in digital technologies have increasingly facilitated virtualisation by improving accessibility and enabling digital solutions (Chen *et al.*, 2023). This indicates that there are significant gaps in the literature to be filled and provides an opportunity for future research to gain further insights about these two principles within the agribusiness context. Thirdly, it is observed that Lean and Six Sigma applications have only focused on both share and optimisation principles. A possible reason may be that the key focus of these approaches lies in process optimisation, which drives cost reduction through enhanced operational efficiencies (Gadialdean *et al.*, 2025). This prompts an opportunity to further expand the investigation into other CE principles, so that further understanding can be attained from the Lean and Six Sigma perspectives.

4.2 RQ2: Lean, Six Sigma and lean Six Sigma in agribusiness, sustainability and circular economy

According to Figure 13, approximately 94% of the reviewed papers have addressed the economic pillar of sustainability, whereas the environmental and societal pillars have accounted for 33.3% and 19.4%, respectively, in agribusiness. These findings align with the study by Barcia *et al.* (2022) that revealed LSS practices positively addressed 83% of the economic indicators, 78% of the environmental indicators and 70% of the social indicators across different industries, including agribusiness. Furthermore, Pierli *et al.* (2025) highlighted that the Lean approach is strongly associated with economic performance, and often considered environmental outcomes as secondary effects due to the difficulties in

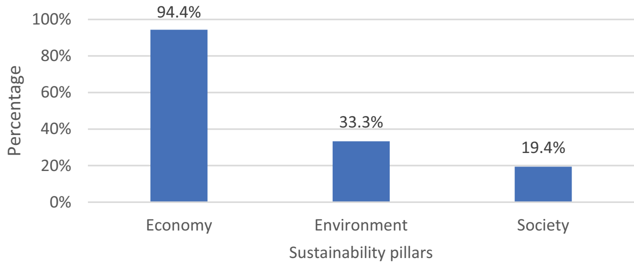

Figure 13. Different applications of Lean and Six Sigma in agribusiness towards sustainability pillars
Source: Authors' own work

measuring environmental variables. Table 4 outlines the key sustainability factors identified in the reviewed articles.

There are two notable observations on the different applications of Lean and Six Sigma towards sustainability pillars in the reviewed articles. Firstly, different applications of Lean and Six Sigma towards economic and societal pillars are evident, suggesting that these two pillars are receiving adequate attention in the agribusiness sector. The key findings in the economic pillar have focused on increasing profits (Cox and Chicksand, 2005; Zokaei and Simons, 2006), productivity (Dora *et al.*, 2013; Fernandes Junior and Pinto, 2020), process capabilities (Amani *et al.*, 2015), performance and competitiveness (Singh *et al.*, 2019; Aytekin *et al.*, 2023). On the other hand, much of the attention on the societal pillar is related to improvements in work environment (Dora *et al.*, 2015), hygiene facilities (Rifqi *et al.*, 2021), other social and safety benefits (Satolo *et al.*, 2017) and adhering to government standards (Elaradi *et al.*, 2023). These findings align with other studies (e.g. Rane *et al.*, 2023) conducted in different industries that supported the contributions of the application of Lean, Six Sigma and LSS towards achieving sustainability through economic and social development. However, a potential research opportunity existed to examine the use of Six Sigma application towards the societal pillar as it remains very limited in the existing literature.

Secondly, the environmental pillar was only addressed by Lean and LSS applications, where the key findings are mainly associated with reducing carbon dioxide footprint and other emissions (Ortiz Porras *et al.*, 2023; Sharma *et al.*, 2023), enhancing reuse, recovery and making compost from waste (Powell *et al.*, 2017; Rifqi *et al.*, 2021; Elaradi *et al.*, 2023). While researcher (e.g. Herrmann *et al.*, 2008) have highlighted the positive impact of Lean and Six Sigma on environmental performance, which contributes to sustainability, however, other studies (e.g. Utama and Abirfatin, 2023) found environmental concerns in agribusiness to be less evident as compared to other sectors. This observation suggests an opportunity for future research to gain further insights about the impact of the environmental pillar on sustainability in agribusiness.

5. Theoretical contribution and practical implications of the study

5.1 Theoretical contribution

This study makes several theoretical contributions. Firstly, it fills the gaps in the existing literature by expanding knowledge on the different applications of Lean, Six Sigma and LSS in the agribusiness context. Insights have been provided on how different applications are used across agribusiness activities, as well as their roles contributing to achieving CE

Table 4. List of reviewed articles relevant to the three sustainability pillars

Sustainability pillar	Key sustainability factors identified in the reviewed papers	Relevant reviewed articles
Economic	Standardise production and quality management in an organisation	Hakimi *et al.*, (2018), Dora *et al.* (2015), Zironi *et al.* (2024), Barth and Melin (2018), Sharma *et al.* (2023), Azalanzazllay *et al.* (2022), Besseris (2014)
	Improve efficiency and productivity	Dora *et al.* (2013), Fernandes Junior and Pinto (2020), Ortiz Porras *et al.* (2023), Dora *et al.* (2015), Andreazza de Freitas *et al.* (2024), Singh *et al.* (2019), Barth and Melin (2018), Besseris (2014) Manzouri *et al.* (2013), Gilligan *et al.* (2023)
	Market competition	Costa *et al.* (2021), Aytekin *et al.* (2023), Zironi *et al.* (2024)
	Increase sales and profits	Cox and Chicksand (2005), Zokaei and Simons (2006)
	Improve process capabilities	Amani *et al.* (2015)
	Increase cost savings	Dora *et al.* (2013), Zokaei and Simons (2006), Prashar (2014), Costa *et al.* (2020), Trubetskaya *et al.* (2023)
	Reduce cycle time, lead time and delivery time	Dora *et al.* (2015), Zironi *et al.* (2024)
	Improving data management	Trubetskaya *et al.* (2024)
	Increase customer satisfaction	Prashar (2014)
Society	Increase the working environment	Dora *et al.* (2015)
	In accordance with government standards	Elaradi *et al.* (2023), Kazancoglu *et al.* (2021)
	Increase hygiene facilities	Rifqi *et al.* (2021)
	Increase the education knowledge about lean in agribusiness	Satolo *et al.* (2017)
Environment	Reduce carbon footprint	Ortiz Porras *et al.* (2023), Sharma *et al.* (2023), Trubetskaya *et al.* (2023)
	Reduce climate change	Andreazza de Freitas *et al.* (2024)
	Support environment	Powell *et al.* (2017), Barth and Melin (2018), Amani *et al.* (2015), Kazancoglu *et al.* (2021), Yeni *et al.* (2024), Zironi *et al.* (2024)
	Waste reduction	Ortiz Porras *et al.* (2023), Trubetskaya *et al.* (2024), Powell *et al.* (2017), Rifqi *et al.* (2021), Elaradi *et al.* (2023), Singh *et al.* (2019), Kolawole *et al.* (2021), Amani *et al.* (2015), Ariffien *et al.* (2021), Kazancoglu *et al.* (2021), Kiran *et al.* (2023), Azalanzazllay *et al.* (2022), Dora and Gellynck (2015), Barth and Melin (2018), Yeni *et al.* (2024)

Source(s): Authors' own work

principles towards sustainability goals in agribusiness (Zironi *et al.*, 2024). The emerging importance of integrating Green Lean, Green Lean Six Sigma and Design for LSS applications in agribusiness has also extended the existing knowledge in these areas, which remain limited. Secondly, it contributes to further understanding of the utilisation of the ReSOLVE framework in measuring CE principles in the agribusiness industry. Findings revealed how relationships are established between Lean, Six Sigma and LSS using the ReSOLVE framework within CE principles and the sustainability practices in agribusiness (Payne and Kwofie, 2024). This study provides a structured pathway for agribusinesses to measure how operational practices contribute to CE outcomes through the ReSOLVE framework. Thirdly, this study extends the work of Yadav *et al.* (2023) on the drivers of LSS towards sustainability in different industries by investigating the key sustainability factors on the applications of Lean, Six Sigma and LSS in agribusiness. Findings provided insights about the different applications used and their impact towards the economic, societal and environmental pillars of sustainability in the agribusiness context. Furthermore, theoretical knowledge has been broadened through an understanding of the relationship between different applications, sustainability and the CE in agribusiness.

5.2 Practical implications

From a practical standpoint, this study contributes to a better understanding of how agribusinesses implement Lean and Six Sigma as a strategic tool to address critical sustainability issues, such as financial constraints, improve productivity, streamline the agribusiness process and waste management (Talapatra and Gaine, 2019). This can assist decision makers to determine whether to apply these approaches individually or combine them strategically to achieve the desired objectives from a sustainability perspective (Taylor *et al.*, 2013). Furthermore, it helps agribusinesses appreciate the important role that Lean, Six Sigma and LSS play in the implementation of the CE principles, which can help facilitate their goal towards achieving sustainability (Utama and Abirfatin, 2023). This provides a guide to developing an implementation plan that could have a significant economic and commercial impact on the business (Farrukh *et al.*, 2023).

6. Conclusions

In conclusion, this systematic literature review examined the impact of Lean, Six Sigma and LSS on sustainability in agribusiness through the lens of the CE framework. The reviewed articles suggest diverse applications of Lean and Six Sigma, implemented either independently, integrated with green concepts or as part of Design for LSS. There is a predominant use of the DMAIC methodology over DMADV, indicating a stronger focus on process improvement rather than new product development within agribusiness. Among the LSS principles, waste elimination is most frequently addressed, while eliminating process variations is least mentioned. Although a clear alignment between LSS and CE principles in agribusiness has been observed, agri-waste regeneration appears to be lacking. It is also revealed that LSS is an appropriate strategic tool to be used in agribusiness for strengthening CE principles (optimise and exchange) in enhancing resource efficiency and circulation. Furthermore, the adoption of CE and LSS principles towards ecosystem restoration can potentially lead to a better outcome for agribusinesses. Further exploration of the CE principle of regeneration and LSS could present insights that are beneficial for agribusinesses. This study also confirms that LSS principles contribute to the economic, environmental and social pillars of sustainability and indicates Lean, Six Sigma and LSS as strategic tools for advancing sustainability goals in agribusiness, reinforcing their relevance within the CE framework.

7. Future research and limitations of the study

There are several future research opportunities identified in this study. Firstly, the use of the DMADV method in agribusiness to develop innovative agri-products and processes is underutilised and needs further examination. Secondly, future research is encouraged to investigate the different applications of Lean and Six Sigma within the agribusiness context in other geographical regions (e.g. Asian, Oceania) and countries (e.g. China, Russia, France, Mexico). Next, there are also research gaps to be filled in the agribusiness context, where the application of Lean, Six Sigma and LSS towards the principles of continuous improvement, eliminating waste and reducing lead time, achieving perfection and eliminating process variation remains limited. A lack of understanding about the alignment of CE principles in agribusiness warrants future research, particularly in the application of Lean, Six Sigma and LSS towards the principles of regeneration, virtualisation, share, loop and exchange. Further research studies are also proposed to explore the impact of the application of Lean and Six Sigma in agribusiness associated with the social and environmental pillars of sustainability.

There are several limitations in this study. Firstly, the systematic literature review has been conducted specifically in relation to the application of Lean, Six Sigma and LSS in the agribusiness context. Next, the reviewed articles have been obtained from certain databases (e.g. Scopus, Web of Science) for the period between 2005 and 2024. Thirdly, the applications of DMAIC and DMADV in agribusiness have regional differences that may lead to biases. Furthermore, the ReSOLVE (i.e. Regenerate, Share, Optimise, Loop, Virtualise and Exchange) framework has been used to determine the CE principles, and the three key pillars of sustainability (i.e. economic, societal and environmental) have been used in the study.

References

Al-Abdallah, G.M. and Lic, C.V. (2020), "Barriers to six sigma implementation in Chinese small and medium steel enterprises", *International Journal of Business Excellence*, Vol. 21 No. 4.

Alarcón, F.J., Calero, M., Pérez-Huertas, S. and Martín-Lara, M.Á. (2023), "State of the art of lean six sigma and its implementation in chemical manufacturing industry using a bibliometric perspective", *Applied Sciences*, Vol. 13 No. 12.

Algassem, F., Yang, Q. and Au, J. (2014), "Application of lean six sigma principles to food distribution SMEs", *American Academic and Scholarly Research Journal*, Vol. 6, p. 251.

Amani, P., Lindbom, I., Sundström, B. and Östergren, K. (2015), "Green-lean synergy – root-cause analysis in food waste prevention", *International Journal on Food System Dynamics*, Vol. 6 No. 2, pp. 99-109.

Ambor, S.R.B., Bandera, A.D. and Abdul-Rashid, R.O. (2025), "Agribusiness sector dynamics: evolution, significance, and comprehensive", *Analysis International Journal of Business Marketing and Management (IJBMM)*, Vol. 10 No. 6, pp. 11-23, available at: www.ijbmm.com/paper/Nov2025/8340436743.pdf

Andreazza de Freitas, G., Hernandes de Paula e Silva, M. and Aparecido Lopes Silva, D. (2024), "Overall lean and green effectiveness based on the environmentally sustainable value stream mapping adapted to agribusiness", *International Journal of Lean Six Sigma*, Vol. 16 No. 1, pp. 25-53, doi: 10.1108/ijlss-10-2023-0173.

Anh, V.N.M., Anh, H.N., Huy, V.N., Huy, H.G. and Ly, M. (2023), "Improve productivity and quality using lean six sigma: a case study", *International Research Journal on Advanced Science Hub*, Vol. 5 No. 3, pp. 71-83.

Antony, J. (2011), "Six sigma vs lean", *International Journal of Productivity and Performance Management*, Vol. 60 No. 2, pp. 185-190, doi: 10.1108/17410401111101494.

Antony, J. and Kumar, M. (2012), "Lean and six sigma methodologies in nhs Scotland: an empirical study and directions for future research", *Quality, Innovation, Prosperity*, Vol. 16, pp. 19-34.

Antony, J., Snee, R.D. and Hoerl, R.W. (2017), "Lean six sigma: yesterday, today and tomorrow", *International Journal of Quality and Reliability Management*, Vol. 34 No. 7, pp. 1073-1093.

Antony, J., Gijo, E.V., Kumar, V. and Ghadge, A. (2016), "A multiple case study analysis of six sigma practices in indian manufacturing companies", *International Journal of Quality and Reliability Management*, Vol. 33 No. 8, pp. 1138-1149.

Ariffien, A., Adriant, I. and Nasution, J. (2021), "Lean six sigma analyst in packing house Lembang agriculture incubation center (LAIC)", *Journal of Physics: Conference Series*, Vol. 1764 No. 1.

Aytekin, A., Okoth, B.O., Korucuk, S., Mishra, A.R., Memiş, S., Karamaşa, Ç. and Tirkolaee, E.B. (2023), "Critical success factors of lean six sigma to select the most ideal critical business process using q-ROF CRITIC-ARAS technique: case study of food business", *Expert Systems with Applications*, Vol. 224, doi: 10.1016/j.eswa.2023.120057.

Azalanzazllay, N.N., Lim, S.A.H., Abidin, U.F.U.Z. and Anass, C. (2022), "Uncovering readiness factors influencing the lean six sigma pre-implementation phase in the food industry", *Sustainability*, Vol. 14 No. 14, doi: 10.3390/su14148941.

Bakar, F.A.A., Subari, K. and Daril, M.A.M. (2015), "Critical success factors of lean six sigma deployment: a current review", *International Journal of Lean Six Sigma*, Vol. 6, pp. 339-348.

Barcia, K.F., Garcia-Castro, L. and Abad-Morán, J. (2022), "Lean six sigma impact analysis on sustainability using partial least squares structural equation modeling (PLS-SEM): a literature review", *Sustainability*, Vol. 14 No. 5.

Barth, H. and Melin, M. (2018), "A green lean approach to global competition and climate change in the agricultural sector – a Swedish case study", *Journal of Cleaner Production*, Vol. 204, pp. 183-192, doi: 10.1016/j.jclepro.2018.09.021.

Basile, V., Petacca, N. and Vona, R. (2024), "Measuring circularity in life cycle management: a literature review", *Global Journal of Flexible Systems Management*, Vol. 25 No. 3, pp. 419-443.

Basso, M.F., Neves, M.F. and Grossi-de-Sá, M.F. (2024), "Agriculture evolution, sustainability and trends, focusing on Brazilian agribusiness: a review", *Frontiers in Sustainable Food Systems*, Vol. 7.

Bazrkar, A., Iranzadeh, S. and Feghhi Farahmand, N. (2017), "Total quality model for aligning organization strategy, improving performance, and improving customer satisfaction by using an approach based on combination of balanced scorecard and lean six sigma", *Cogent Business and Management*, Vol. 4 No. 1.

Belhadi, A., Kamble, S.S., Zkik, K., Cherrafi, A. and Touriki, F.E. (2020), "The integrated effect of big data analytics, lean six sigma and green manufacturing on the environmental performance of manufacturing companies: the case of North Africa", *Journal of Cleaner Production*, Vol. 252, p. 119903.

Besseris, G. (2014), "Multi-factorial lean six sigma product optimization for quality, leanness and safety", *International Journal of Lean Six Sigma*, Vol. 5 No. 3, pp. 253-278, doi: 10.1108/ijlss-06-2013-0033.

Boehlje, M. (1999), "Structural changes in the agricultural industries: how do we measure, analyze and understand them?", *American Journal of Agricultural Economics*, Vol. 81 No. 5, pp. 1028-1041.

Cahyadi, E.R., Hidayati, N., Zahra, N. and Arif, C. (2024), "Integrating circular economy principles into agri-food supply chain management: a systematic literature review", *Sustainability*, Vol. 16 No. 16.

Charles, U.I.O. and Price, B. (2016), "Perceptions of the implementation of lean six sigma:a case of the U. K. and Nigerian manufacturing industries", *IEOM Detroit Conference*, *IEOM 2016*, United States.

Chen, P.K., Lujan-Blanco, I., Fortuny-Santos, J. and Ruiz-de-Arbulo-López, P. (2020), "Lean manufacturing and environmental sustainability: the effects of employee involvement, stakeholder pressure and ISO 14001", *Sustainability*, Vol. 12 No. 18, p. 7258.

Chen, X., Kurdve, M., Johansson, B.J.E. and Déspeisse, M. (2023), "Enabling the twin transitions: digital technologies support environmental sustainability through lean principles", *Sustainable Production and Consumption*, Vol. 38, pp. 13-27.

Chugani, N., Kumar, P.V., Garza-Reyes, J.A., Rocha-Lona, L. and Upadhyay, A. (2017), "Investigating the green impact of lean, six sigma and lean six sigma: a systematic literature review", *International Journal of Lean Six Sigma*, Vol. 8 No. 1, pp. 7-32.

Citybabu, G. and Yamini, S. (2023), "A state of the art of lean six sigma in the indian context – 21st century: a bibliometric analysis", *The TQM Journal*, Vol. 36 No. 7.

Coetzee, R. and Mangaroo-Pillay, M. (2023), "Lean-agriculture: unearthing the puzzle pieces across different industries", *International Conference on Industrial Engineering, Systems Engineering and Engineering Management (ISEM 2023)*.

Costa, L.B.M., Godinho Filho, M., Fredendall, L.D. and Devós Ganga, G.M. (2021), "Lean six sigma in the food industry: construct development and measurement validation", *International Journal of Production Economics*, Vol. 231, doi: 10.1016/j.ijpe.2020.107843.

Costa, L.B.M., Godinho Filho, M., Fredendall, L.D. and Ganga, G.M.D. (2020), "The effect of lean six sigma practices on food industry performance: implications of the sector's experience and typical characteristics", *Food Control*, Vol. 112, doi: 10.1016/j.foodcont.2020.107110.

Costa, L.B.M., Godinho Filho, M., Fredendall, L.D. and Gómez Paredes, F.J. (2018), "Lean, six sigma and lean six sigma in the food industry: a systematic literature review", *Trends in Food Science and Technology*, Vol. 82.

Cox, A. and Chicksand, D. (2005), "The limits of lean management thinking", *European Management Journal*, Vol. 23 No. 6, pp. 648-662, doi: 10.1016/j.emj.2005.10.010.

Cronemyr, P., Eriksson, M. and Jakolini, S. (2014), "Six sigma diplomacy – the impact of six sigma on national patterns of corporate culture", *Total Quality Management and Business Excellence*, Vol. 25 Nos 7-8, pp. 827-841.

Cunningham, R., Barclay, K., Jacobs, B., Sharpe, S. and McClean, N. (2002), "Circular economy opportunities for fisheries and aquaculture in Australia".

Dahlgaard, J.J. and Dahlgaard-Park, S.M. (2006), "Lean production, six sigma quality, TQM and company culture", *The Tqm Magazine*, Vol. 18, pp. 263-281.

Davis, J.H. and Goldberg, R.A. (1957), "A concept of agribusiness", *Journal of Marketing*, Vol. 22, p. 221.

Dennison, M.S., Kumar, M.B. and Jebabalan, S.K. (2024), "Realization of circular economy principles in manufacturing: obstacles, advancements, and routes to achieve a sustainable industry transformation", *Discover Sustainability*, Vol. 5 No. 1.

Dieste, M., Panizzolo, R., Garza-Reyes, J.A. and Anosike, A.I. (2019), "The relationship between lean and environmental performance: practices and measures", *Journal of Cleaner Production*, Vol. 224, pp. 120-131.

Dobrin, C., Dinulescu, R., Moraru, R. and Molnar, E. (2017), "Pursuing perfection in the Romanian healthcare system while applying lean six sigma methodology", in *Proceedings of the international management conference*, *Faculty of Management*, *Academy of Economic Studies*, Bucharest, Romania, Vol. 11, No. 1, pp. 542-549.

Dora, M. and Gellynck, X. (2015), "Lean six sigma implementation in a food processing SME: a case study", *Quality and Reliability Engineering International*, Vol. 31 No. 7, pp. 1151-1159, doi: 10.1002/qre.1852.

Dora, M., Kumar, M. and Gellynck, X. (2015), "Determinants and barriers to lean implementation in food-processing SMEs – a multiple case analysis", *Production Planning and Control*, Vol. 27 No. 1, pp. 1-23, doi: 10.1080/09537287.2015.1050477.

Dora, M., Van Goubergen, D., Kumar, M., Molnar, A. and Gellynck, X. (2013), "Application of lean practices in small and medium-sized food enterprises", *British Food Journal*, Vol. 116 No. 1, pp. 125-141, doi: 10.1108/bfj-05-2012-0107.

Elaradi, M., Ababneh, A. and Awad, M. (2023), "The minimisation of giveaway and underweight in poultry proportioning process", *International Journal of Six Sigma and Competitive Advantage*, Vol. 14 No. 1, doi: 10.1504/ijssca.2023.10055232.

Ellen MacArthur Foundation (2015), *Growth within: A Circular Economy Vision for a Competitive Europe*, Ellen MacArthur Foundation.

FAO (2013), "Enabling environments for agribusiness and agro-industries development, regional and country perspectives", 978-92-5-107410-7.

Farrukh, A., Mathrani, S. and Sajjad, A. (2023), "Green-lean-six sigma practices and supporting factors for transitioning towards circular economy: a natural resource and intellectual capital-based view", *Resources Policy*, Vol. 84.

Fernandes Junior, C.C. and Pinto, L.T. (2020), "Productivity increase in a large size slaughterhouse: a simulation approach applying lean manufacturing", *International Journal of Lean Six Sigma*, Vol. 13 No. 4, pp. 803-823, doi: 10.1108/ijlss-02-2018-0012.

Fiala, S. and Thirumaran, K. (2021), "Hospitality and tourism management: adopting lean six sigma, achieving service excellence", *Service Excellence in Tourism and Hospitality*, Springer, Cham, Switzerland, pp. 167-176.

Fletcher, J. (2018), "Opportunities for lean six sigma in public sector municipalities", *International Journal of Lean Six Sigma*, Vol. 9 No. 2, pp. 256-267, doi: 10.1108/ijlss-07-2017-0086.

Gadialdean, P.D., Chien, N.W., Kojima, A., Guo, Y., Mohan, G., Dong, W. and Agus, H. (2025), "Lean and green: the impact of lean production systems on sustainability in the manufacturing sector. International journal of tourism; hospitality in asia pasific".

Ghasemibojd, F., Franchetti, M.J. and George, B. (2025), "Green lean six sigma for sustainable development: a systematic review of evolution, challenges, and future pathways", *Clean Technologies and Environmental Policy*, Vol. 27 No. 13, pp. 1-24.

Gilligan, R., Moran, R. and McDermott, O. (2023), "Six sigma application in an Irish meat processing plant to improve process yields", *The TQM Journal*, Vol. 35 No. 9, pp. 210-230.

Goh, T.N. and Xie, M. (2004), "Improving on the six sigma paradigm", *The Tqm Magazine*, Vol. 16, pp. 235-240.

Hakimi, S., Zahraee, S.M. and Mohd Rohani, J. (2018), "Application of six sigma DMAIC methodology in plain yogurt production process", *International Journal of Lean Six Sigma*, Vol. 9 No. 4, pp. 562-578, doi: 10.1108/ijlss-11-2016-0069.

Halpern, C., Kennedy Freeman, K., Barrett, C.B., van Dijk, M., Mason-D'Croz, D., Simons, A., van Veen, B., Herrero, M. and van Zanten, H.H.E. (2024), "Perspective paper: framework to assess the potential of circular food system technologies", *Global Food Security*, Vol. 43, p. 100814.

Hassan, N.M., Hamdan, A., Shahin, F., Abdelmaksoud, R. and Bitar, T. (2022), "An artificial intelligent manufacturing process for high-quality low-cost production", *International Journal of Quality and Reliability Management*, Vol. 40 No. 7, pp. 1777-1794.

Haupt, M. and Hellweg, S. (2019), "Measuring the environmental sustainability of a circular economy", *Environmental and Sustainability Indicators*, Vol. 1-2, p. 100005.

Herrmann, C., Thiede, S., Stehr, J. and Bergmann, L. (2008), "An environmental perspective on Lean production", in *Manufacturing Systems and Technologies for the New Forntier: The 41st CIRP Conference on Manufacturing Systems May 26–28, 2008, Tokyo, Japan*, Springer London, London, pp. 83-88.

Hu, Q., Mason, R.J., Williams, S.J. and Found, P. (2015), "Lean implementation within SMEs: a literature review", *Journal of Manufacturing Technology Management*, Vol. 26 No. 7, pp. 980-1012.

Iswanto, A.H. (2017), *Principle of Lean Six-Sigma Management in Clinical Laboratories*, ERN: other Organizations and Markets: policies and Processes (Topic), Rochester, New York, NY.

Jadhav, J.R., Mantha, S.S. and Rane, S.B. (2014), "Development of framework for sustainable lean implementation: an ISM approach", *Journal of Industrial Engineering International*, Vol. 10 No. 3, pp. 1-27.

Jamil, N., Hassan, M.Z., Yaacob, T.Z., Omain, S.Z. and Zakuan, N. (2025), "Integrating green lean six sigma for sustainable operational excellence: a review of applications in Malaysia's food and beverage industry", *International Journal of Academic Research in Business and Social Sciences*, Vol. 15 No. 6.

Jerome, A. and Ljunggren, M. (2025), "Product lifetime in life cycle assessments of circular economy strategies — a review and consolidation of methodology", *The International Journal of Life Cycle Assessment*, Vol. 30 No. 10, pp. 2162-2189.

Kazancoglu, Y., Ekinci, E., Ozen, Y.D.O. and Pala, M.O. (2021), "Reducing food waste through lean and sustainable operations: a case study from the poultry industry", *Revista de Administração de Empresas*, Vol. 61 No. 5, doi: 10.1590/s0034-759020210503.

Kennedy, S. and Linnenluecke, M.K. (2022), "Circular economy and resilience: a research agenda", *Business Strategy and the Environment*, Vol. 31 No. 6.

Khalatur, S., Kachula, S., Oleksiuk, V., Kravchenko, M. and Klymenko, S. (2023), "Anti-crisis management as a basis for the formation of a financial mechanism for the sustainable development of agricultural business", *Financial and Credit Activity Problems of Theory and Practice*, Vol. 5 No. 52.

Khanzode, A.G., Sarma, P.R.S. and Goswami, M. (2021), "Modelling interactions of select enablers of lean Six-Sigma considering sustainability implications: an integrated circular economy and industry 4.0 perspective", *Production Planning and Control*, Vol. 34 No. 10, pp. 1020-1036.

King, A.A. and Lenox, M.J. (2001), "Lean and green? An empirical examination of the relationship between lean production and environmental performance", *Production and Operations Management*, Vol. 10 No. 3, pp. 244-256.

Kiran, E., Ozkan-Ozen, Y.D. and Ozturkoglu, Y. (2023), "A solution approach proposal with a lean perspective for the poultry sector with WRM and BWM integration", *International Journal of Quality and Reliability Management*, Vol. 41 No. 5, pp. 1290-1307, doi: 10.1108/ijqrm-03-2023-0105.

Kirchherr, J., Reike, D. and Hekkert, M.P. (2017), *Conceptualizing the Circular Economy: An Analysis of 114 Definitions*, Courses, Economics Educator.

Kolawole, O.A., Mishra, J.L. and Hussain, Z. (2021), "Addressing food waste and loss in the Nigerian food supply chain: use of lean six sigma and double-loop learning", *Industrial Marketing Management*, Vol. 93, pp. 235-249, doi: 10.1016/j.indmarman.2021.01.006.

Kumar, S., Swarnakar, V., Phanden, R.K., Antony, J., Jayaraman, R. and Khanduja, D. (2023), "Analyzing critical success factors of lean six sigma for implementation in indian manufacturing MSMEs using best-worst method", *Benchmarking: An International Journal*, Vol. 31 No. 9.

Laureani, A. and Antony, J. (2012), "Critical success factors for the effective implementation of lean sigma", *International Journal of Lean Six Sigma*, Vol. 3, pp. 274-283.

Liberati, A., Altman, D.G., Tetzlaff, J.M., Mulrow, C.D., Gøtzsche, P.C., Ioannidis, J.P.A., Clarke, M., Clarke, M., Devereaux, P.J., Kleijnen, J. and Moher, D. (2009), "The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration", *PLoS Medicine*, Vol. 6 No. 7.

Lu, J., Laux, C., Cudney, E.A. and Phillips, M.E. (2018), "Gaps between industry needs and lean six sigma in higher education".

Manzouri, M., Nizam Ab Rahman, M., Saibani, N. and Rosmawati Che Mohd Zain, C. (2013), "Lean supply chain practices in the halal food", *International Journal of Lean Six Sigma*, Vol. 4 No. 4, pp. 389-408, doi: 10.1108/ijlss-10-2012-0011.

Marques, P.A., Meyrelles, P.M., Saraiva, P.M. and Frazao-Guerreiro, F.J. (2016), "Integrating lean six sigma with ISO 9001:2015", 2016 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), pp. 894-898.

Marques, P., Conceição, L., Carvalho, A.M. and Reis, J. (2025), "Driving sustainable operations: aligning lean six sigma practices with sustainability goals", *Sustainability*, Vol. 17 No. 19.

Martínez-Burgos, W.J., Bittencourt Sydney, E., Bianchi Pedroni Medeiros, A., Magalhães, A.I., de Carvalho, J.C., Karp, S.G., Porto de Souza Vandenberghe, L., Junior Letti, L.A., Thomaz Soccol, V., de Melo Pereira, G.V., Rodrigues, C., Lorenci Woiciechowski, A. and Soccol, C.R. (2021), "Agro-industrial wastewater in a circular economy: characteristics, impacts and applications for bioenergy and biochemicals", *Bioresource Technology*, Vol. 341, p. 125795.

McDowall, W., Geng, Y., Huang, B., Barteková, E., Bleischwitz, R., Türkeli, S., Kemp, R. and Domenech, T. (2017), "Circular economy policies in China and Europe", *Journal of Industrial Ecology*, Vol. 21 No. 3.

Mittal, A., Gupta, P., Kumar, V., Al Owad, A., Mahalwat, S. and Singh, S. (2023), "The performance improvement analysis using six sigma DMAIC methodology: a case study on indian manufacturing company", *Heliyon*, Vol. 9 No. 3, p. e14625.

Moher, D., Liberati, A., Tetzlaff, J.M. and Altman, D.G. (2009), "Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement", *Open Medicine*, Vol. 3, pp. e123-e130.

Mojumder, M.U. (2025), "Impact of lean six sigma on manufacturing efficiency using a digital twin-based performance evaluation framework", *ASRC Procedia: Global Perspectives in Science and Scholarship*.

Muganyi, P., Madanhire, I. and Mbohwa, C. (2019), "Business survival and market performance through lean six sigma in the chemical manufacturing industry", *International Journal of Lean Six Sigma*, Vol. 10 No. 2, pp. 566-600, doi: 10.1108/ijlss-06-2017-0064.

Nanda, V. (2005), *Quality Management System Handbook for Product Development Companies*, CRC Press, Boca Raton, FL

Nattassha, R., Handayati, Y., Simatupang, T.M. and Siallagan, M.P.S. (2020), "Understanding circular economy implementation in the agri-food supply chain: the case of an Indonesian organic fertiliser producer", *Agriculture and Food Security*, Vol. 9 No. 1.

Nazrul, I.M. and Xayavong, V. (2010), "Agri-industry value chain model: a tool for industry benchmarking and scenario analysis".

Ng, K.-C. and Hung, I.W. (2001), "A model for global manufacturing excellence", *Work Study*, Vol. 50 No. 2, pp. 63-68.

Nobre, G.C. and Tavares, E. (2020), "Assessing the role of big data and the internet of things on the transition to circular economy: Part II: an extension of the ReSOLVE framework proposal through a literature review", *Johnson Matthey Technology Review*, Vol. 64 No. 1.

Nolasco Mezares, S.J. and Trujillo Vilcapoma, M.I. (2025), "Six sigma procedures and their impact on the food industries", *Proceedings of the 23rd LACCEI International Multi-Conference for Engineering, Education and Technology (LACCEI): "Engineering, Artificial Intelligence, and Sustainable Technologies in service of society*".

Ó Longaigh, B., Noonan, J., Trubetskaya, A. and McDermott, O. (2023), "Strategic facility and space planning utilising design for lean six sigma", *International Journal of Sustainable Engineering*, Vol. 16 No. 1, pp. 1-13.

OECD (2023), *Agricultural Policy Monitoring and Evaluation 2023;Adapting Agriculture to Climate Change*, OECD Publishing, Paris, France, doi: 10.1787/b14de474-en.

Oliveira, E. D S., De Oliveira, P.C.B., Craveiro, E.G., Bezerra, J.P. and Nascimento-e-Silva, D. (2023), "Analysis of conceptual definitions of agribusiness using the conceptual bibliographic method", *International Journal of Professional Business Review*, Vol. 8 No. 12.

Oliveira, J.G.D., Salibi, R., Laura, A., Souza, D., Rodrigues, M., Augusto, P., Lima, B. and Souza, F.B. D. (2022), "Lean and the circular economy: a systematic literature review".

Orlov, A.K., Riad, R., Subbarayudu, Y., Kapoor, T., Kumar, P., Kansal, L., Bhardwaj, N., Kumar, Y. and Lakshmi, P. (2024), "Circular economy in manufacturing: optimization using lean six sigma", *E3S Web of Conferences*, Vol. 581

Ortiz Porras, J.E., Bancovich Erquínigo, A.M., Candia Chávez, T.C., Huayanay Palma, L.M., Moore Torres, R.K. and Tinoco Gomez, O.R. (2023), "Green lean six sigma model for waste reduction of raw material in a nectar manufacturing company of Lima, Peru", *Journal of Industrial Engineering and Management*, Vol. 16 No. 2, doi: 10.3926/jiem.4916.

Özaydın, G. and Direk, M. (2022), "Classification of agricultural industrial enterprises in türkiye 1st international conference on sustainable ecological agriculture", Konya, Türkiye.

Park, C. and Linich, D. (2008), *Green Lean Six Sigma: using Lean to Help Drive Results in the Wholly Sustainable Enterprise*, Deloitte Consulting, New York, NY.

Payne, A. and Kwofie, E.M. (2024), "Unleashing circular economy potential in agriculture: integrating social impact assessment with the ReSOLVE framework as a tool for sustainable development", *Sustainable Development*, Vol. 32 No. 5.

Pierli, G., Murmura, F. and Bravi, L. (2025), "The impact of lean tools on sustainability dimensions: a systematic literature review", *International Journal of Quality & Reliability Management*,.

Powell, D., Lundeby, S., Chabada, L. and Dreyer, H. (2017), "Lean six sigma and environmental sustainability: the case of a norwegian dairy producer", *International Journal of Lean Six Sigma*, Vol. 8 No. 1, pp. 53-64, doi: 10.1108/ijlss-06-2015-0024.

Prashar, A. (2014), "Process improvement in farm equipment sector (FES): a case on six sigma adoption", *International Journal of Lean Six Sigma*, Vol. 5 No. 1, pp. 62-88, doi: 10.1108/ijlss-08-2013-0049.

Pristyanto, YRochmoeljati. (2024), "Eliminating production process waste with lean six sigma in the gresik ceramic industry", *Jurnal Sistem Cerdas*, Vol. 7 No. 2.

Psychogios, A.G. and Tsironis, L.K. (2012), "Towards an integrated framework for lean six sigma application: lessons from the airline industry", *Total Quality Management and Business Excellence*, Vol. 23 Nos 3-4, pp. 397-415.

Rane, S.B., Wavhal, S. and Potdar, P.R. (2023), "Integration of lean six sigma with internet of things (IoT) for productivity improvement: a case study of contactor manufacturing industry", *International Journal of System Assurance Engineering and Management*, Vol. 14 No. 5, pp. 1990-2018.

Rathi, R., Singh, M., Verma, A., Gurjar, R.S., Singh, A. and Samantha, B. (2021), "Identification of lean six sigma barriers in automobile part manufacturing industry", *Materials Today: Proceedings*, Vol. 50

Rifqi, H., Souda, S.B., Zamma, A. and Badder, O. (2021), "Lean six sigma in agribusiness: a case study in a cookie production plant", *International Journal of Engineering Trends and Technology*, Vol. 69 No. 1, pp. 56-65, doi: 10.14445/22315381/ijett-v69i1p209.

Riyanto, O., Setiawan, M.D., Hariyanto, K., Suwondo, A., Hindratmo, A., Oktavia, C., Purnamayudhia, O., Subaderi, Dewi, F., Abdullah, M.H., Endarto, B. and Widhiyanta, N. (2023), "Integration of lean six sigma and green productivity for manufacturing SMEs", *Proceedings of the 4th International Conference on Advanced Engineering and Technology.*

Rothenberg, S., Pil, F.K. and Maxwell, J. (2001), "Lean, green, and the quest for superior environmental performance", *Production and Operations Management*, Vol. 10 No. 3, pp. 228-243.

Sahoo, S., Venkatesh, V.G., Shi, Y., Sreedharan, V.R. and Schleper, M.C. (2025), "Analyzing the effect of lean six sigma practices and green culture on circular manufacturing capabilities in achieving 3P performance", *Business Strategy and the Environment*, Vol. 35 No. 1.

Sakumoto, S.M., Chiroli, D.M.D.G. and Dzulinski, A.C. (2019), "Using lean six sigma to increase efficiency of a grain receipt process of a Brazilian agroindustry cooperative", *American Journal of Engineering and Applied Sciences*, Vol. 12 No. 2.

Salibi, O., José Geraldo, D., Rangel, Rodrigues, A.L.D.S.M., Lima, P.A.B. and de Souza, F.B. (2022), "Lean and the circular economy: a systematic literature review", *Journal of Lean System*, Vol. 7 No. 4, pp. 23-46.

Satolo, E.G., Hiraga, L.E.D.S., Goes, G.A. and Lourenzani, W.L. (2017), "Lean production in agribusiness organizations: multiple case studies in a developing country", *International Journal of Lean Six Sigma*, Vol. 8 No. 3, pp. 335-358, doi: 10.1108/ijlss-03-2016-0012.

Schroeder, R.G., Linderman, K.W., Zaheer, S. and Choo, A.S. (2003), "Six sigma: a goal-theoretic perspective", *Quality Engineering*, Vol. 49, pp. 49-50.

Sell, L.G., Tedesco, M., Simioni, F.J., Sehnem, S., Soares, J.F. and Coelho Júnior, L.M. (2023), "Circular economy practices using the ReSOLVE framework: an assessment by sector and scale in the Brazilian planted tree industry", *Journal of Cleaner Production*, Vol. 433

Shah, R. and Ward, P.T. (2007), "Defining and developing measures of lean production", *Journal of Operations Management*, Vol. 25 No. 4, pp. 785-805.

Sharma, J., Tyagi, M., Bhardwaj, A. and Ravinderjit Singh, W. (2023), "Factors assessment for encumbering the implementation of sustainability based lean six sigma practices in food supply chain", *Evergreen*, Vol. 10 No. 1, pp. 379-388, doi: 10.5109/6781097.

Singh, J., Singh, H., Singh, A. and Singh, J. (2019), "Managing industrial operations by lean thinking using value stream mapping and six sigma in manufacturing unit", *Management Decision*, Vol. 58 No. 6, pp. 1118-1148, doi: 10.1108/md-04-2017-0332.

Singh, M. and Rathi, R. (2019), "A structured review of lean six sigma in various industrial sectors", *International Journal of Lean Six Sigma*, Vol. 10 No. 2, pp. 622-664.

Skalli, D., Charkaoui, A. and Cherrafi, A. (2022), "Assessing interactions between lean Six-Sigma, circular economy and industry 4.0: toward an integrated perspective", *IFAC-PapersOnLine*, Vol. 55 No. 10, pp. 3112-3117.

Skalli, D., Charkaoui, A., Cherrafi, A., Garza-Reyes, J.A., Antony, J. and Shokri, A. (2023), "Analyzing the integrated effect of circular economy, lean six sigma, and industry 4.0 on sustainable manufacturing performance from a practice-based view perspective", *Business Strategy and the Environment*, Vol. 33 No. 2, pp. 1208-1226.

Sreekanth, V., Kavilal, E.G., Krishna, S. and Mohan, N. (2024), "Implementation of six sigma methodology in a medical equipment manufacturing company", *The TQM Journal*, Vol. 37 No. 7, pp. 2041-2073, doi: 10.1108/tqm-12-2023-0398.

Stone, K.B. (2012), "Four decades of lean: a systematic literature review", *International Journal of Lean Six Sigma*, Vol. 3 No. 2, pp. 112-132.

Sutherland, P.E. (2001), "Assessment of industrial distribution system reliability using six sigma methodology", in *16th International Conference and Exhibition on Electricity Distribution (CIRED 2001)*, London UK, IEE, pp. v5-36.

Talapatra, S. and Gaine, A. (2019), "Putting green lean six sigma framework into practice in a jute industry of Bangladesh: a case study", *American Journal of Industrial and Business Management*, Vol. 09 No. 12, pp. 2168-2189.

Tam, W.W.S., Tang, A., Woo, B.F.Y. and Goh, S.Y.S. (2019), "Perception of the preferred reporting items for systematic reviews and meta-analyses (PRISMA) statement of authors publishing reviews in nursing journals: a cross-sectional online survey", *BMJ Open*, Vol. 9 No. 4, p. e026271.

Taylor, A., Taylor, M. and McSweeney, A.S. (2013), "Towards greater understanding of success and survival of lean systems", *International Journal of Production Research*, Vol. 51 No. 22, pp. 6607-6630.

Thammasang, S., Thermsuk, S. and Sripunchat, T. (2021), "An application of a lean six sigma methodology in an agricultural machinery industry: a case study on a production of sugar cane grapples".

Trubetskaya, A., McDermott, O. and McGovern, S. (2023), "Implementation of an ISO 50001 energy management system using lean six sigma in an Irish dairy: a case study", *The TQM Journal*, Vol. 35 No. 9, pp. 1-24, doi: 10.1108/tqm-08-2022-0252.

Trubetskaya, A., McDermott, O. and Ryan, A. (2023), "Application of design for lean six sigma to strategic space management", *The TQM Journal*, Vol. 35 No. 9, pp. 42-58.

Trubetskaya, A., McDermott, O., Durand, P. and Powell, D.J. (2024), "Improving value chain data lifecycle management utilising design for lean six sigma methods", *The TQM Journal*, Vol. 36 No. 9, pp. 136-154, doi: 10.1108/tqm-01-2024-0020.

Utama, D.M. and Abirfatin, M. (2023), "Sustainable lean six-sigma: a new framework for improve sustainable manufacturing performance", *Cleaner Engineering and Technology*, Vol. 17, p. 100700.

Velenturf, A.P.M. and Purnell, P. (2021), "Principles for a sustainable circular economy", *Sustainable Production and Consumption*, Vol. 27, pp. 1437-1457.

Veloso, V., Santos, A., Carvalho, A. and Barbosa-Póvoa, A. (2025), "A comprehensive framework for assessing circular economy strategies in agri-food supply chains", *Environment, Development and Sustainability*, pp. 1-46.

Venkat, K. and Wakeland, W.W. (2006), "Is lean necessarily green".

Voehl, F., Harrington, H.J., Mignosa, C. and Charron, R. (2013), The Lean Six Sigma Black Belt Handbook: Tools and Methods for Process Acceleration CRC Press, Boca Raton, FL.

Voulvoulis, N. (2022), "Transitioning to a sustainable circular economy: the transformation required to decouple growth from environmental degradation", *Frontiers in Sustainability*, Vol. 3, p. 859896.

Widiwati, I.T.B., Liman, S.D. and Nurprihatin, F. (2024), "The implementation of lean six sigma approach to minimize waste at a food manufacturing industry", *Journal of Engineering Research*, Vol. 13 No. 2, pp. 611-626.

Yadav, V., Kaswan, M.S., Gahlot, P., Duhan, R., Garza-Reyes, J.A., Rathi, R., Chaudhary, R. and Yadav, G. (2023), "Green lean six sigma for sustainability improvement: a systematic review and future research agenda", *International Journal of Lean Six Sigma*, Vol. 14 No. 4, pp. 759-790.

Yang, C.-C., Jou, Y.-T., Lin, M.-C., Silitonga, R.M. and Sukwadi, R. (2022), "The development of the new process of design for six sigma (DFSS) and its application", *Sustainability*, Vol. 14 No. 15, p. 9294.

Yeni, F.B., Gürsoy Yılmaz, B., Kayhan, B.M., Özçelik, G. and Yılmaz, Ö.F. (2024), "Achieving tractable and reliable agriculture supply chain operations through industry 4.0 tools to support lean six sigma application", *International Journal of Industrial Engineering and Operations Management*, Vol. 7 No. 2, pp. 117-149, doi: 10.1108/ijieom-05-2024-0029.

Yin, S., Jia, F., Chen, L. and Wang, Q. (2023), "Circular economy practices and sustainable performance: a meta-analysis", *Resources, Conservation and Recycling*, Vol. 190, p. 106838.

Zironi, A., Danese, P., Romano, P. and Zironi, R. (2024), "A lean six sigma, industry 4.0 and circular economy-driven methodology for wine supply chain process improvement", *Wine Economics and Policy*, Vol. 13 No. 2, pp. 75-88, doi: 10.36253/wep-15803.

Zokaei, K. and Simons, D.W. (2006), *Performance Improvements through Implementation of Lean Practices: A Study of the U.K. Red Meat Industry. The International Food and Agribusiness Management Review*, Vol. 9, pp. 30-53.

Zylbersztajn, D. (2017), "Agribusiness systems analysis: origin, evolution and research perspectives", *Revista de Administração*, Vol. 52 No. 1, pp. 114-117.

Further reading

Patel, A.S. and Patel, K.M. (2022), "Status of lean six sigma implementation in indian industries: a cross-sectional national survey", *International Journal of Lean Six Sigma*, Vol. 14 No. 4.

Corresponding author
Rumman Hassan can be contacted at: Rumman.Hassan@unisq.edu.au

Appendix

Table A1. List of reviewed papers

Paper No.	Name of the paper	Year	Industry	Agribusiness product	Applicable country	Study method	Subject	Application
1	Application of Six sigma DMAIC methodology in plain yogurt production process	2017	Food-Processing	Dairy	Iran	Case study	Lean Six sigma	DMAIC
2	Application of lean practices in small and medium-sized food enterprises	2012	Food-Processing	Different products	Belgium, Germany and Hungary	Case study	Lean	Not available
3	Productivity increase in a large size slaughterhouse: a simulation approach applying lean manufacturing	2020	Food-Processing	Meat	Brazil	Applied research	Lean	Not available
4	Green lean Six sigma model for waste reduction of raw material in a nectar manufacturing company of Lima, Peru	2023	Food-Processing	Nectar	Peru	Case study	Green lean Six sigma	DMAIC
5	Performance improvements through implementation of lean practices: a study of the UK red meat industry	2006	Food-Processing	Meat	UK	Case study	Lean	Not available
6	Determinants and barriers to lean implementation in food-processing SMEs – a multiple case analysis	2016	Food-Processing	Food and drink	Belgium	Multiple case analysis	Lean	Not available
7	Improving value chain data lifecycle management using design for lean Six sigma methods	2024	Value chain data Lifecycle management	Agri services	South African	Case study	Design for lean Six sigma	DMADV
8	A Lean Six Sigma, Industry 4.0 and circular economy-driven methodology for wine supply chain process improvement	2024	Food - Supply chain	Wine	Italy	Case study	Lean Six sigma	DMAIC
9	Lean Six sigma and environmental sustainability: the case of a Norwegian dairy producer	2016	Food-Processing	Dairy	Norway	Case study	Lean Six sigma	DMAIC
10	Lean Six sigma in agribusiness: a case study in a cookie production plant	2021	Food-Processing	Cookie	Morocco	Case study	Lean Six sigma	DMAIC
11	The minimisation of giveaway and underweight in poultry proportioning process	2023	Food-Processing	Poultry	UAE	Case study	Six sigma	DMAIC
12	Lean production in agribusiness organizations: multiple case studies in a developing country	2016	Management system	Different products	Brazil	Multiple case analysis	Lean	Not available
13	Process improvement in farm equipment sector (FES): a case on Six sigma adoption	2013	Agricultural equipment	Farm equipment	India	Case study	Six sigma	DMAIC
14	Overall lean and green effectiveness based on the environmentally sustainable value stream mapping adapted to agribusiness	2024	Orange farm	Orange	Brazil	Case study	Lean	Not available

(*continued*)

Table A1. Continued

Paper No.	Name of the paper	Year	Industry	Agribusiness product	Applicable country	Study method	Subject	Application
15	Managing industrial operations by lean thinking using value stream mapping and Six sigma in manufacturing unit case studies	2019	Food -Processing	Commercial and domestic food	India	Multiple case analysis	Six sigma	DMAIC
16	Findings of Six sigma "DMAIC method" for small scale manufacturer/ service provider of agricultural equipment to control the defects: a case study for Jaipur based industry	2021	Agricultural equipment	Agricultural equipment	India	Case study	Six sigma	DMAIC
17	Addressing food waste and loss in the Nigerian food supply chain: Use of lean Six sigma and double-loop learning	2021	Food - Supply chain	Different products	Nigeria	Case study	Lean Six sigma	DMAIC
18	The limits of lean management thinking: multiple retailers and food and farming supply chains	2005	Food - Supply chain	Meat	U.K	Case study	Lean	Not available
19	A green lean approach to global competition and climate change in the agricultural sector: a Swedish case study	2018	Farming	Different products	Sweden	Case study	Green lean	Not available
20	Green-lean synergy – root-cause analysis in food waste prevention	2015	Food-Processing	Dough based food	Sweden	Case study	Green lean	DMAIC
21	Six sigma application in an Irish meat processing plant to improve process yields	2023	Food-Processing	Meat	Ireland	Case study	Six sigma	DMAIC
22	Lean Six sigma analyst in packing house lembang agriculture incubation center (LAIC)	2020	Food-Processing	Vegetables	Indonesia	Applied research	Lean Six sigma	Not available
23	Reducing food waste through lean and sustainable operations: a case study from the poultry industry	2020	Food-Processing	Poultry	Turkey	Case study	Lean	Not available
24	A solution approach proposal with a lean perspective for the poultry sector with WRM and BWM integration	2023	Food-Processing	Poultry	Turkey	Case study	Lean	Not available
25	Uncovering readiness factors influencing the lean Six sigma pre-implementation phase in the food industry	2022	Food-Processing	Different products	Malaysia	Case study	Lean Six sigma	Not available
26	Lean Six sigma implementation in a food processing SME: a case study	2015	Food-Processing	Bakery	Europe	Case study	Lean Six sigma	DMAIC
27	Lean in Swedish agriculture: strategic and operational perspectives	2018	Management system	Different products	Sweden	Case study	Lean	Not available
28	Lean Six sigma in the food industry: construct development and measurement validation	2021	Food - Quality	Different products	Brazilian and American	Empirical analysis	Lean Six sigma	DMAIC
29		2023	Food - Management	Not mentioned	Turkey	Case study	Lean Six sigma	DMAIC

(*continued*)

Table A1. Continued

Paper No.	Name of the paper	Year	Industry	Agribusiness product	Applicable country	Study method	Subject	Application
	Critical success factors of lean Six sigma to select the most ideal critical business process using q-ROF CRITIC-ARAS technique: case study of food business							
30	Multi-factorial lean Six sigma product optimization for quality, leanness and safety	2014	Food - Quality	Bakery	USA	Case study	Lean Six sigma	Not available
31	Achieving tractable and reliable agriculture supply chain operations through Industry 4.0 tools to support Lean Six Sigma application	2024	Food-Processing	Agri services	Turkey	Case study	Lean Six sigma	DMAIC
32	Factors assessment for encumbering the implementation of sustainability based lean Six sigma practices in food supply chain	2023	Food - Supply chain	Not mentioned	India	Empirical analysis	Lean Six sigma	Not available
33	The effect of lean Six sigma practices on food industry performance: implications of the sector's experience and typical characteristics	2020	Food-Processing	Different products	Brazil and the United States	Empirical analysis	Lean Six sigma	Not available
34	Implementation of an ISO 50001 energy management system using Lean Six Sigma in an Irish dairy: a case study	2022	Food - Quality	Dairy	Ireland	Case study	Lean Six sigma	DMAIC
35	The lean Six sigma approach for process improvement: a case study in a high quality tuscany winery	2010	Food-Processing	Wine	Italy	Case study	Lean Six sigma	DMAIC
36	Lean supply chain practices in the halal food	2013	Food - Supply chain	Different products	Malaysia	Empirical analysis	Lean	Not available