Review article

Exploring driving factors in employing waste reduction tools to alleviate the global food security and sustainability

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A B S T R A C T

To align with the SDG 12.3 target and ensure global food security and sustainability, it is crucial to prioritize the reduction of food loss and waste. This paper aims to synthesize previous research on waste reduction tools like lean manufacturing in the agro-food processing industry and identify areas that require further investigation to assurance worldwide food security and promote sustainability. The study uses a systematic literature review that was proposed by Denyer and Tranfield. This research work provides a descriptive analysis of the evolution of lean manufacturing in agro-food processing and identifies research gaps. The review highlights the importance of demand forecasting, managing variable raw materials and products, increasing management involvement, promoting partnership among supply chain members, and addressing supply and demand seasonality and uncertainty to apply the approach to food waste reduction. Based on the findings, the paper suggests further research areas for future investigation that will help create a more sustainable and equitable food system. Reducing food loss and waste can ensure that everyone has access to safe, nutritious, and affordable food while protecting the planet's resources and reducing greenhouse gas emissions. This study may contribute to the theory of waste minimization, specifically in post-harvest food loss and waste minimization. The findings will help researchers conduct research work interested in minimizing food loss and waste to ensure global food security.

1. Introduction

The increasing global population has led to a surge in demand for food, which necessitates a significant increase in food production. However, approximately 40% of the global food produced is wasted throughout the supply chain, wasting resources and increasing greenhouse gas emissions [1]. Reducing food loss and waste is crucial for achieving food security and global sustainable development. The United Nations has established SDG 12.3, which sets a target for reducing food waste, as well as minimizing food losses throughout the production and distribution process, by the year 2030. This global initiative aims to address the pressing issue of food waste and promote sustainable practices across the entire food system. By emphasizing the need to reduce waste and losses, SDG 12.3 underlines the importance of taking proactive measures to achieve a more efficient and sustainable use of our food resources. Various strategies, such as improving storage and transportation infrastructure and investing in food processing and packaging technologies can be employed to address this issue. Food processing can play an important role in meeting the rising demand by improving the efficiency and sustainability of food production. Processing can help to preserve food, extend its shelf life, and reduce food waste. Food

processing also helps make food more convenient to store, transport, and consume, increasing access to food in areas where fresh produce is not readily available. In addition to reducing food waste, food processing can also improve food safety and nutrition. Processing can remove harmful bacteria and toxins, fortify foods with essential nutrients, and create new products that meet changing consumer preferences and dietary needs. Overall, food processing can help ensure food security for the growing global population while promoting sustainable agriculture and reducing food waste. Aside, the rise in economic growth and urbanization has changed people's diets, with a significant portion of their food intake now consisting of processed foods. This trend has led to a rise in demand for processed packaged food, leading to increased competition in the industry. To remain competitive, businesses must increase productivity and maintain high-quality standards.

The food processing industry is faced with additional challenges due to the perishable nature of its raw materials and products, which can lead to complications in the distribution system and require improved infrastructure and reduced lead times. By implementing lean manufacturing techniques, businesses in the food processing industry can improve efficiency and reduce waste.

The food processing industry is classified as a process industry because many of its final products are a combination of various food components that cannot be separated and reassembled. The success of this industry sector depends on its ability to effectively manage these complex behaviours and meet the demands of the market. The food processing business may benefit from the improvement initiatives the manufacturing management like lean manufacturing. An effective way to boost the performance of any business is through lean manufacturing. Lean manufacturing, which is employed in the service and public sectors in addition to manufacturing, is one of the most well-known performance-improvement techniques.

As is evident, many earlier literature studies focused on acquiring information about lean manufacturing related to the food industry. Some review papers focused on relevant topics of lean manufacturing, the effects of lean six sigma, lean sustainability, and lean supply chain management system. Recognizing the significant advancements in food waste reduction literature, particularly in the utilization of lean tools for minimizing food waste, there remains a lack of comprehensive information to facilitate a comparative analysis of results. This deficit hampers the guidance available to policymakers and practitioners when it comes to effectively designing and implementing suitable lean tools within the food processing sector. Addressing this research gap is crucial to bridge the knowledge divide and provide valuable insights. In order to advance the development of this field of research, it is necessary to study the common and distinctive characteristics, the execution process of lean manufacturing, the method of overcoming the barriers, and to draw appropriate conclusions about lean manufacturing in the agro-food processing industry. It is well known that reducing waste and increasing the efficiency of any process is the prime goal of lean manufacturing.

In this context, there required a literature review that covers the aforementioned issues and permits researchers and practitioners to define the present status of the research. This study is appropriate for understanding the research studies focused on lean manufacturing in food industry providing a picture of the state, and information for future studies.

Taking into account the above scopes, this paper seeks to provide a response to the following research question: *what are the major research findings in the previous works of literature and the heading of research about food waste reduction using lean manufacturing in the food processing industry*? Some specific objectives are set to find out the answer of the main research question. First, to assess the state-of-the-art of research for food waste reduction on lean manufacturing in the food processing industry using the systematic literature review methodology [2]. Then, to recognize the unexplored area in the previous research literature to suggest new research areas. To assure the credibility and accuracy of the study result, this study uses a systematic literature review followed by two distinct articles published elsewhere [2,3].

This paper is organized as follows. The study's literature review is presented in the following part. Then the methodology of the research is given. After that, a descriptive analysis of the literature is presented and a classification of main findings of earlier studies is given. In the next section, certain gaps are established, and new study fields are chosen. Finally, the conclusions and limitations of the study are presented.

The focus of this literature review has been specifically centred on the food industry and lean manufacturing, creating a more accurate study of the literature on lean in the food processing sector.

2. Literature review

A literature review is a criterion for a systematic literature review. As the goal is specific, the literature review is arranged in two folds. Lean manufacturing and food processing and will be presented and reviewed as follows.

2.1. Lean manufacturing

Lean manufacturing aims to minimize waste and maximize productivity in manufacturing systems. Waste refers to anything that does not add value for customers and that they do not want to pay for. Many well-known companies have adopted lean manufacturing based on Toyota's production system. Lean manufacturing has also been applied beyond manufacturing in healthcare, software development, and the service industry. The five fundamental principles of lean manufacturing are: identifying customer value, mapping the value stream, streamlining flow, establishing a pull system, and continually improving through Kaizen. Toyota identified seven types of waste: excess transportation, surplus inventory, unnecessary motion, waiting, overproduction, excessive processing, and defects. Lean manufacturing relies on constant progress, enabled by several tools and concepts, including production levelling (*Heijunka*), to maintain a steady production level and avoid spikes. Workplace organization (5S) to organize and clean the workplace. Just-in-time delivery (Kanban) to deliver only what is needed and when it is needed. Problem detection and solving (*Jidoka*) to detect issues promptly and resolve them. Visual aids (*Andon*) to alert staff to problems using visual signals. Error prevention (*Poka-yoke*) through

mechanisms that prevent mistakes. Cycle time is the measurement of the time taken for a full production cycle or process. Lean manufacturing aims to continually improve processes to maximize flow and minimize waste while ensuring high quality and high customer value. The goal is to create an efficient and sustainable manufacturing system that meets customer needs.

2.2. Food processing

Food processing refers to the various physical and chemical processes involved in transforming raw food materials into attractive and marketable food products. The main objectives of food processing include increasing the shelf life of food products, preventing contamination, and facilitating storage and transportation. Food processing methods range from peeling, chopping, and cooking to gasification and packaging. Food preservation techniques such as drying, cooling, freezing, heating, and pickling are also employed to prevent the growth of microorganisms and improve the shelf life of food products. The benefits of food processing include reducing harmful bacteria in food, improving the shelf life of food products, and reducing health inequalities. However, there are also drawbacks to food processing, such as the inclusion of artificial ingredients in processed foods, overconsumption due to the pleasant taste of processed foods, and the high levels of added sugar in processed foods that can negatively impact health.

The processing of food involves many processes, starting from harvesting to end-use. To convert raw food materials into value-added form, different unit operations are required. Processing refers to all the actions that were taken to improve the usability, stability, and handling of raw food materials in order to produce a more valuable final product. Food processing involves not only value addition but also improvement of the shelf-life of agricultural food elements. Processing involves operations including classifying, removing the raw material's outer layer, cutting, chopping, liquefying, fermenting, emulsifying, cooking, combining, gasifying, proofing, pasteurizing, drying, and packaging. Food is transformed either on its own or in combination with other components. Different categories of agricultural commodities, such as cereals, dairy goods, edible oils, vegetables, and fruits, each have unique processing requirements in terms of input and technology.

With the growth of the global economy, the number of middle-income people is growing. The growing urban population, working people, and fast-paced lifestyle have resulted in time constraints for various households that eventually popularise numerous processed food products in different developed and developing nations [4].

3. Methodology

As previously stated, the primary goal of this study is to find out the already studied area by the existing literature and to search future research areas of lean manufacturing in the agro-food processing industry. For this, the study uses a systematic literature review method to examine, review, and draw maps from the literature on lean manufacturing and food processing. A detailed process was used to analyze and collect the most reliable and relevant papers for the study. At the beginning of the study, a review procedure is specified so that the systematic review is carried out step by step and completed in detail. The procedure holds the creation of the study question, an appropriate article searching procedure, the exclusion criteria of the article, search string selection, and an evolution basis. This methodology seeks a strong literature review that examines all information given in all articles on a given issue in a thorough and impartial manner [2]. They suggested five steps including formulation of questions, studies location, study selection and evaluation, analysis of the study and reporting. The five steps are summarised in Fig. 1.

3.1. Question formulation

The first step of a systematic literature review is the creation of the research question. Then this research paper will find the answer to this question. In order to achieve the goals of this research,

the following research questions have been formulated: *what are the major research findings in the previous works of literature and the heading of research about lean manufacturing in the food processing industry*? Due to the more focused goals of this study, this broad research question has been split into two distinct questions. As a result, the following two questions are the focus of this study:

Question 1. What are the major research issues of the lean manufacturing studies in the agro-food-processing industry carried out worldwide so far?
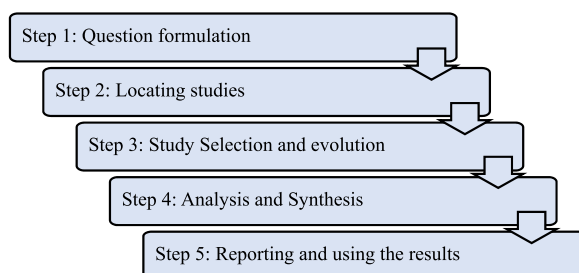
Step 1: Question formulation

Step 2: Locating studies

Step 3: Study Selection and evolution

Step 4: Analysis and Synthesis

Step 5: Reporting and using the results

Fig. 1. Stages involved in the process of conducting a systematic literature review.

Question 2. What are the gaps and possible future study topics can be found in the current literature?

3.2. Locating studies

This part of the systematic literature review consists of finding the most important articles connected to the research questions. To eliminate the chance of bias to the publication in a systematic literature review, selecting two or more databases is suggested [2]. As a result, the studies were found by searching the Science Direct and Emerald Insight databases from the earliest year that was available until 2022. Table 1 shows the field and article type of literature search in different databases. The keywords used for the search related to lean manufacturing and agro-food processing were identified and used in the search string. These keywords included terms such as "Lean manufacturing" OR "Lean" OR "Lean management" combined with "Agro-food processing" OR "food processing" OR "food industry" OR "food" OR "Agri" OR "Agri food". The search for relevant articles related to lean manufacturing and agro-food processing involved searching for the identified keywords in the title, abstract, and keywords fields of the selected databases. This was done to ensure that the resulting articles contained all the necessary search words in these specific areas of the paper. To ensure the quality of the information, the search focused on papers from journals that are peer-reviewed. The search was conducted in the articles title, abstract or given keywords. In the main body of the paper also searched the selected search phrases. The search string was formulated by selecting essential terms relating to the core topics under investigation. Initially, "lean" and "agro-food processing" were identified as fundamental keywords. Each database has a different structure thus different search terminology is defined separately for each database. Various experimental tests were conducted for each database separately to make the paper selection relevant to the research questions. Lean manufacturing in food processing industry related publications have been collected to conduct the literature review. "Lean" and "Agro-food processing" were used as search terms in the "Topic" column.

Search phrases in the database Emerald was like ("lean manufacturing" or "lean" or "lean management") and ("food processing" or "food industry" or "food") which results 7220 contents. Another search string like ("lean manufacturing" or "lean" or "lean management") * ("food processing") results 590 contents. It is observed that the search string was very wide-ranging after conducting a preliminary search using this combination of terms. Then, in order to be as specific as possible, additional keywords that were added to the initial search string are found in the literature. Like in the database "Science direct" it is found 212 results while the search string is (Title, abstract, keywords: {lean} and ({Agro food processing} or {Food processing})). After that there is another search string in Emarald database is like (content-type:article) and ({Lean} and {agro food processing}) which results 270 papers. In Science Direct database the 42 results were found after the string is like - title, abstract, keywords: (("lean") and ("agro food processing" or "food processing" or "food industry" or "agro food" or "agri food" or "agri")). The unit of analysis is lean manufacturing in agro-food processing written in English and published in journal papers is chosen.

This selection process resulted in total of 29 papers from both databases. Finally, selected research and review articles contained lean and food topics. Lean and food in title, abstract or in keywords was searched.

3.3. Study selection and evaluation

In this stage, the standards of which papers will be included and excluded have been made with some phases. The initial literature search yielded 7220 papers related to lean manufacturing and agro-food processing. Strict inclusion and exclusion criteria were applied to narrow down the papers and select only the most relevant ones for this review. First, filters were used to select only published journal articles, in English, related to the key research topics in the search terms (lean manufacturing, agro-food processing). This process turns in to 319 number of papers. Papers that were clearly irrelevant remained discarded, reducing the set to 33 papers. These 33 papers were then read to check the relevance with question of this article. Any papers that were only loosely related or addressed a distinct concept from "lean" manufacturing were excluded. Following this rigorous process of applying inclusion or exclusion criteria at multiple stages, 29 papers were selected as the most relevant for inclusion in this literature review. In short, through screening titles/abstracts, filtering for key topics/keywords, thoroughly reviewing relevance with this research topic, the initial large set of papers was narrowed down step-by-step until the most relevant 29 papers for the research question remained that is shown in Fig. 2. Strict adherence to inclusion/exclusion criteria at each stage ensured high quality and coherence across the selected papers included in this literature review.

3.4. Analysis and synthesis

In this stage, the selected papers from the earlier step were carefully analyzed and synthesized to identify relevant areas of discussion related to the research question. An Excel database was created to facilitate this process, with separate columns for information such as the paper's title, objective, methodology, findings, author name, year of publication, country, and conclusion. The papers were then divided into several parts based on their topics, which were classified according to their common features. This allowed for a more

Table 1
Field and article type of literature search in databases.

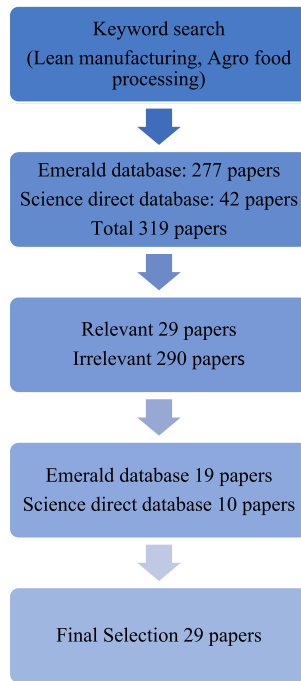| Database	Field	Article Type
Emerald	All fields, Title, Abstract	Research paper, Review paper
Science Direct	Title, Abstract, Keywords	Research paper, Review paper

Fig. 2. Outlines of the steps involved in the material collection process.

comprehensive analysis of the main contributions of the papers on lean manufacturing in the food processing industry. The resulting classification provides a clear and organized overview of the literature and highlights the significance of each area of research by emphasizing the similarities among the content of the articles.

3.5. Reporting and using the results

Coming to this part of the review, the result of the analysis of the previous stage is shown. Papers were examined from different angles to review the results in depth. First, a descriptive analysis has been done. The evolution and profile of lean and food processing topics are discussed. Then the main topics discussed in the reviewed papers are identified. By identifying
themes with similar objectives and coordinating them together, the content of the subjects is grouped so that important aspects of previous research are identified separately. Thus, in this review a total of eight aspects have been highlighted which are discussed in the descriptive analysis part of this stage.

4. Descriptive analysis of the studied literature and research aspects classification

4.1. Evolution and profile of the reviewed articles

The number of published articles is calculated according to the year of publication to show whether the number of studies is increasing or decreasing day by day. A sequential view is presented to observe the studies published annually in Fig. 3. As seen, interest
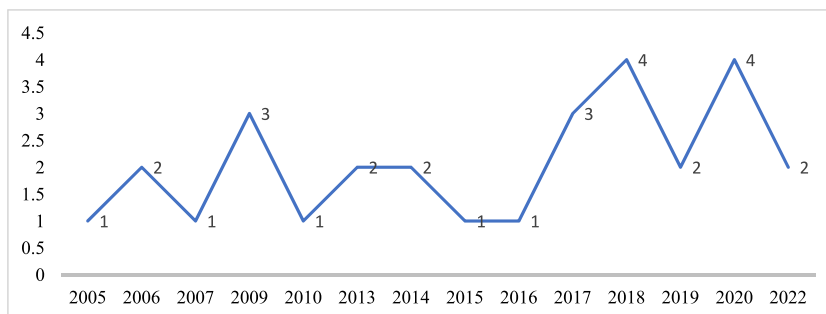

Fig. 3. Visual description of the distribution of research papers across different years.

of the study subject starts to grow since 2005. Throughout the time period under consideration, there has been a gradual increase in the number of publications on the issue under study as shown in Table 2. With a total of four papers per year, 2018 and 2020 have the most publications to date in terms of numbers. Based on the methodology employed the study literatures have been categorized as shown in Fig. 4. Most studies, seventeen out of the twenty-nine, have used case study methods. Table 3 provides a comparison of the methodologies used in the studies. Furthermore, the majority of papers were published in the "British Food Journal" and "International Journal of Lean Six Sigma,". Table 4 displays the distribution of the most frequently published studies across various journals. Fig. 5 clearly shows the distribution of papers published in the journals. Table 5 displays the distribution of papers according to country. The evolution of studies by country, with the highest number of studies carried out in the UK, followed by Brazil, as shown in Fig. 6.

4.2. Constructive outcomes from adopting lean tools in the food industry

Research suggests that adopting lean supply chain practices can positively impact the performance of the food industry [5]. Additionally, some authors propose a positive correlation between the size of the grower operation, workforce training, and the ability to achieve superior performance outcomes through lean practices [6].

Efficiency can also be improved through lean and six sigma initiatives, leading to increased productivity and reduced production fluctuations [7]. The implementation of lean and six sigma practices in the food industry has been found to reduce costs and increase productivity [8]. Many authors have highlighted the strategic benefits of adopting lean practices, which can serve as the basis for operational change [9]. Adopting a lean production system can enhance organizational performance [10]. Lean Distributed Manufacturing have the potential to enhance the resilience capabilities of food manufacturing companies across various stages [11]. In the pork sector, lean management techniques have been actively adopted, and the structure of the specific chain in the Catalan pork sector is suitable for implementing lean supply chain strategies [12]. Furthermore, value chain analysis methods combined with lean principles can provide a powerful framework for analyzing and improving supply chain activity, as demonstrated in numerous papers that build on existing theoretical work.

4.3. Dependent issues of lean adoption in the food industry

From the perspective of the adoption of lean manufacturing practices in the food processing industry is critically affected by the level of expertise of any company [5]. The author added in the same article that the experience level controls two performance indicators. These are financial improvements and the quality of products which are taken most seriously in the food processing industry. Regarding cooperation, it has been emphasized many times that smaller farms of primary label producers can overcome their own resource limitations if they collaborate among themselves [6]. Scherrer-Rathje et al., recognized the important measures and conditions that determine whether the lean application will be fail or successful [13]. This author described that the implementation of lean for the first time is a failure, where success comes after the second implementation. This implies that lean implementation requires some training and expertise. Other research exposes that to achieve the optimistic results of implementing lean tools and techniques to prevent food and nutrient waste, the involvement of all stakeholders in the food industry along with the supply chain is essential [14, 15]. Numerous authors propose that a business must balance the benefits of adopting the lean philosophy against the associated operational and financial risks [9]. However, it is essential to move toward formalizing the actions, which must support the evolution of new leaders who spread the organization's values of lean manufacturing. When comparing the degrees of adherence, it was discovered that there is no straight correlation between the level of devotion to lean production and the usage of tools and techniques, stating that every organization should only choose the tools and techniques that will enhance the performance of their own organization [10].

4.4. Barriers of lean adoptions in the food industry

There are authors who express that the food industry is highly affected by its own characteristics. It is identified that the implementation of LSS strategies like reducing setup time is constrained by mandatory cleaning practices in the food processing industry [5]. Some articles identified that lean adoption barriers occur because of external organizational challenges, such as demand forecasting, lack of training in installing change programs, supplier unpredictability, etc [9,16]. Costa et al. in other articles also express that the main barriers in implementing lean practices in food industry are human factors and the characteristics of the food industry [8]. There

Table 2
Distribution of papers by year.

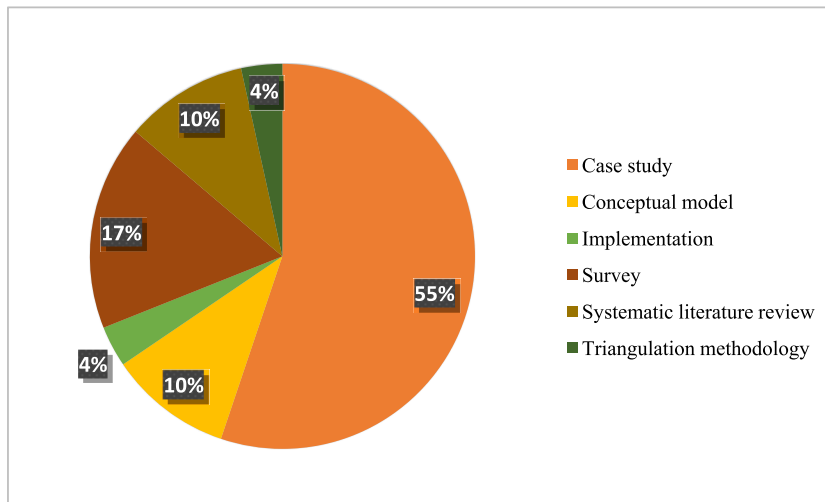| Year	Articles/Year	Year	Articles/Year
2005	1	2015	1
2006	2	2016	1
2007	1	2017	3
2009	3	2018	4
2010	1	2019	2
2013	2	2020	4
2014	2	2022	2
Total			29

Fig. 4. Classification of research articles based on the methodology used in food processing and lean manufacturing-related articles.

Table 3
Distribution of papers according to the journal.

Name of Journal	Article
Benchmarking: An International Journal	1
British Food Journal	5
Business Horizons	1
Food Control	2
International Journal of Lean Six Sigma	5
International Journal of Operations & Production Management	1
International Journal of Production Economics.	1
International Journal of Quality & Reliability Management	1
International Journal of Quality and Service Sciences	1
Journal of Cleaner Production	2
Management Research Review	1
Materials Today: Proceedings	1
Procedia Engineering	1
Supply Chain Management	2
The International Journal of Logistics Management	1
The TQM Journal	1
Trends in Food Science & Technology	1
Waste Management	1
Total	29

Table 4
Article classification by methodology type.

Article type	Article/Type
Case study	16
Conceptual model	3
Implementation	1
Survey	5
Systematic literature review	3
Triangulation methodology	1
Total	29

are authors who identified that the lack of commitment from the top management was one of the biggest obstacles for the baked food industry while implementing lean principles. In order to increase the organization's performance, measures of employee engagement and ongoing training is needed [17]. Unpredictable demand extreme variability of raw materials are the core barriers in implementing lean tools in the food processing sector. Focusing on the main barriers faced by small and medium size food enterprises in implementing lean manufacturing tools practices results from the special food sector characteristics. These are highly perishable food products, unpredictable demand, complicated manufacturing process and highly varying raw materials and recipes. Additionally, it is challenging for the small and medium food enterprises in the food processing industry to start the lean journey due to a lack of
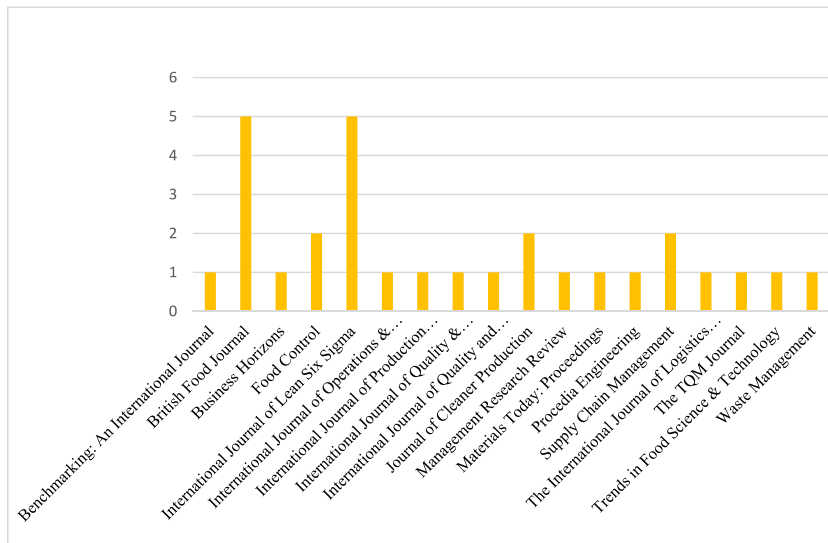
Fig. 5. Representation of the distribution of research papers across different academic journals in food processing and lean manufacturing.

Table 5
Geographic research areas.

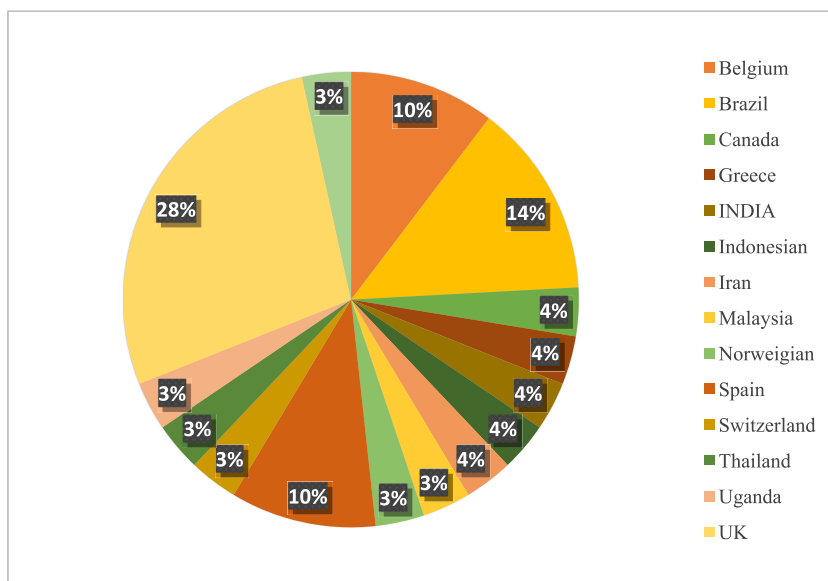| Country	Article	Country	Article
Belgium	3	Norway	1
Brazil	4	Spain	3
Canada	1	Switzerland	1
Greece	1	Thailand	1
India	1	Uganda	1
Indonesian	1	UK	8
Iran	1	USA	1
Malaysia	1		
Total			29

Fig. 6. Graphical representation of the classification of articles based on their country of origin.

resources and knowledge [18]. Sales competition and lack of certainty were emphasized as important barriers to implementing a lean supply chain among lean firms. In contrast, absence of customer awareness of lean supply chain management practices was recognized as a main barrier in non-lean firms [19].

4.5. Areas need to be explored by lean tools in the food industry

Numerous studies have revealed that demand management is an area that, in reality, is impacted by challenges and inefficiencies, that have an impact on the supply chains' operational performance. According to an analysis of the demand characteristics in the supply chains, there is a propensity for the misalignment of demand and activity as a result of problems such as demand amplification and ineffective production practices [20]. According to the author, several operational inconsistencies and inefficiencies have been discovered, most of which are related to the information systems and data handling processes used within these chains. According to several writers, the investigated agribusiness systems are significantly influenced by the distinctive characteristics of the seasonality of consumption, food quality, health monitoring, and sociological issues. The tools and techniques used in the lean production system might lessen its effects [10].

4.6. Unexplored areas to the adoption of lean in the food industry

Some authors expose that Statistical Process Control and Six Sigma are among the least-used techniques in the food industry. They also reveal that lean tools practices need financial capital for training purposes, which is a challenge in the food sector. Profit margins in this sector are very low and the sector is now mainly trying to cut costs. The industry needs statistical control techniques and expertise that are typically considered too complex and very advanced level in the agro-food sector [5]. It is also suggested that managers will encourage staff to obtain practical experience with the lean tools as managerial knowledge of the applicability of lean practices to the improvement of performance in the food industry grows. There are authors who present model containing phases that benefit in reducing the level of variability in the flow of food processing system. They also present that lean would be used in categories of seven types of waste in food processing [21]. There are authors who present that future research needs to examine the degree of lean tools and six sigma practices adopted in the food processing industry. They also suggested identifying the best lean and six sigma practices to implement [8].

Regarding future research, some authors suggest asking for future scientific research about the concept of "cycles of lean implementation" [9]. Focusing on practicing lean food SMEs (Small and medium enterprises) participate in the adoption of lean tools and techniques to a high level, but there is still space for additional improvement [22]. Other author shows that the adoption of lean manufacturing tools in SMEs engaged in food processing is in a limited scale and still developing [18]. Some research mentions that the excess transportation is the waste identified by the production floor layout. Later, to complement the suggested facility layout as the guide for the production process and reduce waste, a standard operational procedure (SOP) is created [23]. Other research findings show that research has been increased on lean and green areas recently. Integration of lean and green is a gap found very important in the agro-food sector. There is a need for more theoretical, prescriptive, and quantitative research, and there is a chance to combine the two most popular lean and green tools—value stream mapping and life-cycle assessment—in future studies [24]. According to Rahimnia et al., fast-food businesses are required to adapt with changing consumer needs despite the limited personalization of mass services. To meet these requirements the case study firm can implement new tactics so that it can provide the consumer with quick delivery time, quality foods, low costs and high variety [25].

4.7. Identification of lean tools' suitability in the food industry

There are authors who test the lean tools in the food processing industry. The target was to find which tools and techniques are successfully applied in the food industry. Creating effective, consistent scale may select those lean practices for the food industry that are most appropriate. These lean practices would uncover possible areas for development in order to increase the efficiency and competitiveness of the food sector [5]. According to De Steur et al. at the food processing level discarding and nutritional loss occur mostly, which is adapted to four out of seven lean manufacturing wastes as the main categories of losses [14]. The wastes are defective food items, unnecessary raw materials, and finished inventory, overproduction of products, and incorrect processing of food. There are articles that identify the seven types of 'muda' in the food industry similar to other industries, such as; defects of food, movements, wrong process, excess inventory, overproduction of processed food, transport, and delay [26]. Identifying waste presents a chance to enhance inefficient processes; customer perception analysis reveals that these inefficiencies are felt by customers; a benchmark or auditing tool for future evaluations. However, according to some authors, more than seventy percent of businesses claimed that they have not yet implemented a lean supply chain. Fourteen percent of non-lean firms, according to data analysis, urgently need to adopt lean manufacturing [19]. Regarding demand management, some articles expressed delays and difficulties in international product delivery for insufficient efforts. Uncertain raw agricultural production, communication delay with freight forwarders, inappropriate documentation, insufficient manpower and delayed customs activities are the possible inputs. In addition to the highly central system, the restrictions of the Just in Time theory contributed to the matters, thus increasing turnover rate and mental and physical health problems. Because of these paradoxical things, the authors expanded the Just-In-Time theory to include collaborating with other supply chain participants by getting in touch with them beforehand [27]. Other authors highlighted a few crucial factors to take into account while employing a lean supply chain to help fresh food supply chains become more environmentally sustainable. The authors also provide some of the precise results and crucial success factors that the implementation team realized when the VSM (Value stream

mapping)-DMAIC (Define, measure, analyze, improve and control) approach put into use [28]. Numerous authors present by choosing lead time as the best suitable success indicator for the agri-food sector's lean manufacturing techniques. It is found that some continuous improvement approaches are like 5S and Just-in-time VSM [14].

4.8. Level of lean tools application in the food industry

Numerous studies have shown that more than half of the respondents said their employer used continuous improvement methodologies. According to Scott et al., neither firm ownership nor size significantly predicted whether a company would implement such programs [29]. Some authors supposed that adopting lean has strategic benefits and serves as a foundation for an operational change strategy [9]. Several lean manufacturing methods, such as total productive maintenance, staff involvement, and customer association, are more common [18]. Simons and Zokaei identify a typical twenty-five percent productivity gap because of the practicing lean tools and techniques, like Standardization of work and Takt-time [30]. Although a lean approach has been implemented in the supply chain for pigs, some analysis shows that it is much more problematic in the supply chains for beef and lamb. Moreover, the vast majority of those involved in the pig supply chain of UK, the first users of lean techniques, have not seen the expected growth in their businesses. However, despite having low commercial returns, the majority of supply chain participants are achieving continuous strategic lean operations efficiency [31].

5. Gaps and future research scope

Some gaps in the literature were found by the review study, and they are worth further study. In addition, there are some areas found in the literature which has not been sufficiently studied. In order to fill these gaps and further examine the issues that have not been covered in the prior literature, several future research subjects are consequently suggested. Table 6 displays the core area of research gaps identified and the new area of research is suggested to fill in these gaps. The first column in the table is the research gap areas that need to be analyzed, while the second contains the reason needed to cover the identified gaps. The activities for potential future research are listed in the final column. Future research work on demand forecasting in agro food processing is needed since this literature review has found it the main barrier to lean implementation. Concerning the food industry's characteristics, there are many differences with other industry sectors. The characteristics of the food processing industry are found another crucial issue that could impede the effective implementation lean manufacturing. So, more studies are required to take the food industry characteristics into consideration. In the food industry, the significance of environmental uncertainty has also grown recently. Because of the COVID-19 global epidemic, many businesses are now operating in an environment that is more uncertain and complex than before. To better understand the new problems and opportunities, empirical research should be conducted to address the role of demand and supply uncertainty. It has been shown in this review that collaboration among the supply chain members focused on mitigating wastage and resource usage, so further research study should pay attention in to this context. The previous literature has also identified a lack of studies examining the operational, financial, social, and environmental quantitative outcomes of lean manufacturing in the food processing industry. This gap should be filled in future research in this area by examining outcomes in greater detail.

6. Conclusions

This literature review focuses on the practice of waste reduction tools usage in the agro-food processing industry aiming global food security while advancing the food waste reduction. By examining and synthesizing the literature on this topic, this study aims to fill a gap in the current literature, which has limited reviews on this subject. The findings of this study can serve as a useful guide for researchers, academics, managers, and practitioners interested in exploring and identifying topics related to food waste minimization using lean manufacturing in agro-food processing to mitigate food crisis and environmental issues.

The literature review highlights the potential of lean manufacturing to enhance operational efficiency and reduce waste in the agro-food supply chain. Lean manufacturing can improve food and nutrition safety by minimizing waste and reducing the environmental impact of food production. Investing for lean tools in food processing can help reduce food loss and waste, which is crucial in a world with limited natural resources. By creating a more sustainable and equitable food system, reducing food loss and waste can ensure that everyone has access to safe, nutritious, and affordable food while protecting the planet's resources and reducing greenhouse gas emissions. Overall, this literature review emphasizes the importance of lean manufacturing in the food sector to ensure food security for the growing world population. Reducing food loss and waste should be a top priority to create cost-effective solutions for producing enough safe and nutritious food for everyone.

It is important to acknowledge the limitations of this literature review. Firstly, the search for articles was limited to only two databases, excluding other relevant databases that may have articles on this topic. Expanding the search to include additional databases may yield different results. Additionally, the review focused solely on two topics, lean manufacturing and food processing, which may have excluded relevant articles that could have informed the study.

Data availability statement

The data supporting the findings of this study are available in Elsevier and Emerald Publishing Limited at https://www.sciencedirect.com/ and https://www.emerald.com/insight/ respectively. All the relevant data are publicly available. For inquiries or assistance regarding data, please contact nayema@student.sust.edu.

Table 6

Gaps and future research areas of lean manufacturing in the food processing industry.

Research gap area	Reason for covering these gaps	Future research area
Variability	One of the challenges to implementing lean manufacturing in the food sector is very variable raw materials and products.	- Classification of variables - To specify variability - Way forward to control variability
Food sector characteristics	Key barriers to the implementation of lean practices result from the special characteristics of the food sector.	Development of the way of controlling the food sector's characteristics
Supply uncertainty	Supply uncertainty is one of the barriers to lean implementation in the food processing sector.	Development of a way forward to mitigate the supply uncertainty.
Demand uncertainty	Unpredictable demand is the main barrier to lean implementation in the food processing sector	A deeper understanding of uncertainty factors needs while demand forecast is done for food processing
Supply and demand seasonality	Since the demand and supply have both seasonality and uncertainty relevant to the environment or season, the demand forecast must be carefully done.	Exploration of demand forecasting seasonality factors considered needs to find out.
Requirement of knowledge and resources	Required continuous training to mitigate the lack of knowledge and resources for lean implementation	Specify which training is required along with financial requirements to implement lean.
Low shelf life	One of the main reasons for wastage in the food sector	Determine the factor need to find out to mitigate it.
Environmental Aspects	The global environment outlook is changing the around the world hence companies are facing the uncertainty and complexity of their environment in new circumstances. The significance of environmental uncertainty to implement lean is great.	Studies need to be carried out to address the role of environmental uncertainty to help managers and practitioners to better understand the new challenges and opportunities provided by lean.
Managerial awareness	Lack of commitment from the top management, and hence, employee engagement measures were necessary for the performance improvement of the organization by adopting lean practices.	Determine the level of managerial awareness.
Collaboration among the supply chain members	Multi-stakeholder partnership along the entire food supply chain is essential. Horizontal cooperation between primary producers may help overcome resource limitations.	Determine the level of partnership

CRediT authorship contribution statement

N.R. Ema: Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **M.A.H. Mithu:** Writing – review & editing. **Ahmed Sayem:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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