DOI : 10.2478/aucft-2024-0011

FOOD UPCYCLING STRATEGIES APPLIED BY THE LISTED COMPANIES INVOLVED IN THE FOOD VALUE CHAIN

– Review –

Aleksander BUCZACKI, Bartlomiej GLADYSZ*, Michal WISNIEWSKI

Warsaw University of Technology, Poland

Abstract: This paper is aimed at the discovery of the main directions of a scientific discourse on food upcycling and cross-checking it with the perspective of leading food chain companies. Scientific discourse was analysed by systematic literature review using defined query and network analysis. The perspective of leading food chain companies was approached through the content analysis of annual reports of listed companies. A replicable analysis approach was developed and demonstrated on two samples of companies listed on two European stock exchanges. Bibliometric studies show that research on the upcycling topic is characterized by a high level of atomization, which may indicate that the research in this field is at an early stage. Qualitative research on non-financial annual reports published by selected companies has shown that companies do not widely use upcycling in business practice. The authors attribute this situation to, among others, the lack of a uniform reporting standard covering upcycling. Another conclusion from the study is that those companies operating in the food value chain that are closer to the consumer are more likely to initiate activities with the potential for upcycling.

Keywords: food waste; food chain; food upcycling; content analysis; annual report

INTRODUCTION

One of the most common types of waste associated with human activity is food waste. In addition to activities related to reducing the creation of food waste, it is essential to reduce food waste through recycling. One of the many directions may be the broader use of upcycling, which is more popular in industrial products. The concept of upcycling is quite new. The first publications on it appeared at the end of the 20th century. Since 2018, we can observe a more considerable interest in this topic (according to the SCOPUS database, in 2018, more than 100, and in 2022 – 557 publications).

Upcycling is a subtype of recycling in which waste is transformed into a full-value product instead of downcycling, which produces a product of lower value. There are several approaches available to define food upcycling and upcycled food, i.e. the output of the food upcycling process. Upcycled food uses “ingredients that otherwise would not have gone to human consumption, are procured and produced using verifiable supply chains, and have a positive impact on the environment” (Upcycled Food Association 2020). Aschemann-Witzel et al. (2023) defined upcycled food as “a product consisting of or containing materials that otherwise would be waste, this material is turned into a food product for human consumption, and this is done via a process that involves an increase in value”. Upcycling could be defined as “reuse of discarded materials which results in an increase in ‘value’” (Bridgens et al., 2018). In our opinion, ‘value’ is the most critical factor that decides if the food waste is upcycled or not. In this paper we used upcycling in the meaning of a reuse of the product or its components to produce another product/service, with the intention of increasing its value. Upcycling not only allows us to reduce food waste but also forces the introduction of innovations, particularly product innovations.

There are many publications focusing on technology aspects and food engineering to treat food waste and get new value from it (Narisetty et al., 2021; Poojary et al., 2017; Putnik et al., 2017). There are several examples of food upcycling in the literature. Most often, they are concerned with using selected ingredients as a component in manufactured food, e.g., orange peel as a topping for donuts or almond skins in biscuits (Pasqualone et al., 2020). Alternatively, parts of food waste are

Received: 30.07.2024
Accepted in revised form: 25.10.2024

* Corresponding author.
E-Mail address: bartlomiej.gladysz@pw.edu.pl

used to produce multi-ingredient dishes (juices, purees, soups, mousses, etc.) (Radzymińska & Platta, 2022; Upcycled Food Association, 2023b). The possibility of using food waste in dishes largely depends on the repeatability of available ingredients and/or flexibility and/or adaptability of the food production process.

There are a number of publications focused on the technical and technological aspects of upcycled food production processes, the majority as single or grouped case studies (Igual et al., 2023; Pagett et al., 2023; Pinela et al., 2022; Rasool et al. 2023; Schaerer et al., 2023; Yu et al., 2023; Yu & Wong 2023). They focus on plastic and glass reuse as well as on extraction and reusability of compounds or substances. Food upcycling is also becoming a topic of debate and concern on the market, and not only a topic for academics and scientists. Upcycled Certified® is an example of an Upcycled Food Association initiative where applying food upcycling could be discounted and used by companies for marketing purposes. There are 92 companies, 317 products, and 164 ingredients Upcycled Certified® as of September 2023 (Upcycled Food Association, 2023a). UFA noted 21% year-over-year growth for products with the upcycled certification (Beaton, 2023). Another example of food upcycling market-driven actions is an Upcycling Community knowledge platform from Dutch Foodvalley NL, bringing together 38 organizations commercially involved in food upcycling (Foodvalley, 2023). The Upcycling Community has demonstrated strong growth lately. However, it emphasizes that industry players still need to make more effort to make upcycle food more attractive to consumers (Cervera, 2023; van Hal, 2023). The upcycled food industry is projected to surpass $80 billion within a decade. Moreover, some analysts point out that upcycling resembles a story of the natural organic and clean-label products that at one point became huge mainstream markets (Beaton, 2023).

Food production processes have a significant impact on the environment. Animal products have a more negative effect on the environment than growing plants. However, commodity crops can also harm the environment. In general, dietary change can deliver environmental benefits on a scale not achievable by producers (Poore & Nemecek, 2018). Consumers perceive upcycled food as less valuable, but for environmentally conscious customers, upcycled food provides additional value. Moreover, this value is not static from a time perspective and could differ depending on geographical and social factors. Upcycling has a vast potential for natural resources and food waste reduction. Utilization of the system approach and especially of the whole food value chain actors makes it possible to achieve better results for popularizing this concept (Aschemann-Witzel et al., 2023). More efficient upcycling utilization needs new business model implementation. Sustainable business models should consider all stakeholders directly or indirectly influencing the food value chain (Evans et al., 2017; Zucchella & Previtali, 2019). The most important element in the food value chain is the consumer, who can decide about the value of the upcycled food. Much research focused on the consumer perception of upcycled food (Goodman-Smith et al., 2021; Grasso et al., 2023; Hellali & Korai, 2023).

Based on the literature review, we defined the research gap and the scope of our research. Our objective is to find and demonstrate a methodological approach to measure the level of food upcycling awareness in the listed companies involved in food value chains. We approach this goal by systematic literature review, applying network analysis and content analysis of annual reports. We demonstrated our approach to content analysis of annual reports considering two European stock markets. The assumption is that each company and each group of companies, even if they implement any best practice or strategy related to Food Waste management, focus on their perspective (which is natural). We aim to identify which initiatives could be integrated with other initiatives (implemented by other companies' groups) and place some interfaces. The scope of our research is the analysis of strategies, and best practices focused on food waste management implemented by companies operating in the food value chain. The food value chain definition should include the whole food life cycle, which focuses on the food itself (as a product), while the food value chain focuses on the actors (consumers, companies, and other organizations) and their impact and activities from the food management perspective.

The paper consists of the following sections. The methodology part includes a description of the literature review procedure and qualitative analysis of the non-financial reports. The result section presents the outputs of the two stages of research. In the next section, we discuss the obtained results and provide final conclusions in the last section.

MATERIALS AND METHODS

Due to the novelty of the topic presented in the Introduction, it was decided to use mixed methods and base the work on different sources of data. The study is based on secondary data analysis. The dynamic progress and interdisciplinarity of scientific research have led to a significant increase in knowledge. However, simultaneously it made it harder for researchers to manage state-of-art. It is cognitively impossible to conduct full literature reviews in most cases. Selection based on search engines risks the exclusion of important publications. As a result, it is hard to achieve comprehensive results from a literature review on a defined topic. Data mining and machine learning methods can be employed in such situations, especially in natural language processing and analysis, knowledge extraction, and document classification. Clustering and visualization techniques (van Eck & Waltman, 2010), topic modeling analysis methods (Li & Lei, 2021), or trend detection (Kontostathis et al., 2004) are prevalent among researchers. The maturity and availability of those techniques made them popular as supporting tools for literature reviews. The first part of the study is a literature review and content analysis of metadata of peer-reviewed texts gathered from scientific databases. A systematic literature review (SLR) was aimed at identifying leading topics in scientific discourse on food upcycling. SLR was chosen as it is based on search and inclusion/exclusion procedures that allow for replicability (Snyder, 2019). A set of basic keywords was defined to identify existing literature on food upcycling. The selection of keywords was based on a scoping study framework (Arksey & O'Malley, 2005). The scoping study aims to map literature related to the topical area in order to support the identification of key issues, terminology, research gaps, and evidence to inform about practice, policies, and available studies (Daudt et al., 2013). The framework of scoping study is consistent with other methodologies for systematic review, e.g., PRISMA (Moher et al., 2009). The query executed on September 13th, 2023 is presented in Figure 1.

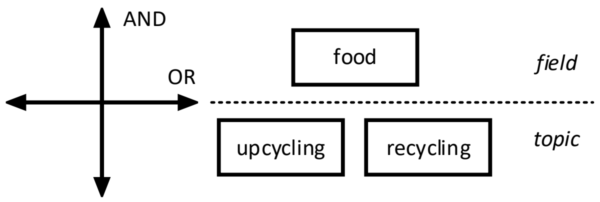

Figure 1. Query for literature review

The full research procedure for the presented review is depicted in Figure 2. To find clusters and trending topics VOSviewer was employed. No exclusion criteria were used in order to cover the widest possible scope of articles. Web of Science CC (WoS CC) and Scopus were selected as the most commonly used and leading databases for literature reviews (Joshi, 2017; Visser et al., 2021). Scopus returned 194 documents, and WoS CC returned 32. Both datasets were merged. Duplicates were eliminated through a comparison of document metadata like DOI and title. 211 were left (with no duplicates) and used for title and abstract screening. Finally, 201 documents were left after the screening procedure, exclusion of papers unrelated to food upcycling or without abstracts. We calculated the Global Citation Score (GCS) to identify prominent publications constituting the basis for other studies (Knoke & Yang, 2008). Citations are counted even if they appeared in a publication not selected for the review. We ranked articles according to the number of citations divided by the number of years since publication date to identify papers with potentially big impact and promising scientific contribution to the food upcycling topic. This way, we included papers with low GCS but with high recent interest from the scientific community. We performed keywords co-occurrence network analysis to analyze characteristics of information. Network analysis may also be applied to authors, document types, and other available metadata of documents (Lou & Qiu, 2014; Morris, 2000). We included in our network analysis keywords provided by authors and keywords indexed by bibliometric databases. Indexing is grounded on the analysis of words used in abstracts. The identified network of relations divides input set of documents into thematic clusters to identify leading topics and research gaps in the analyzed literature. We performed co-citation network analysis additionally to better define the thematic scope of clusters (Knoke & Yang, 2008). Two stock exchange markets were chosen. We analyzed published annual reports of companies listed on the Nordic Nasdaq (NordN) and WSE (Buczacki et al., 2024). NordN companies were selected since Nordic countries are leaders in sustainability initiatives. Moreover, NordN companies have been reporting on sustainability even longer than it has been mandatory to report this issue within annual reports. developments.

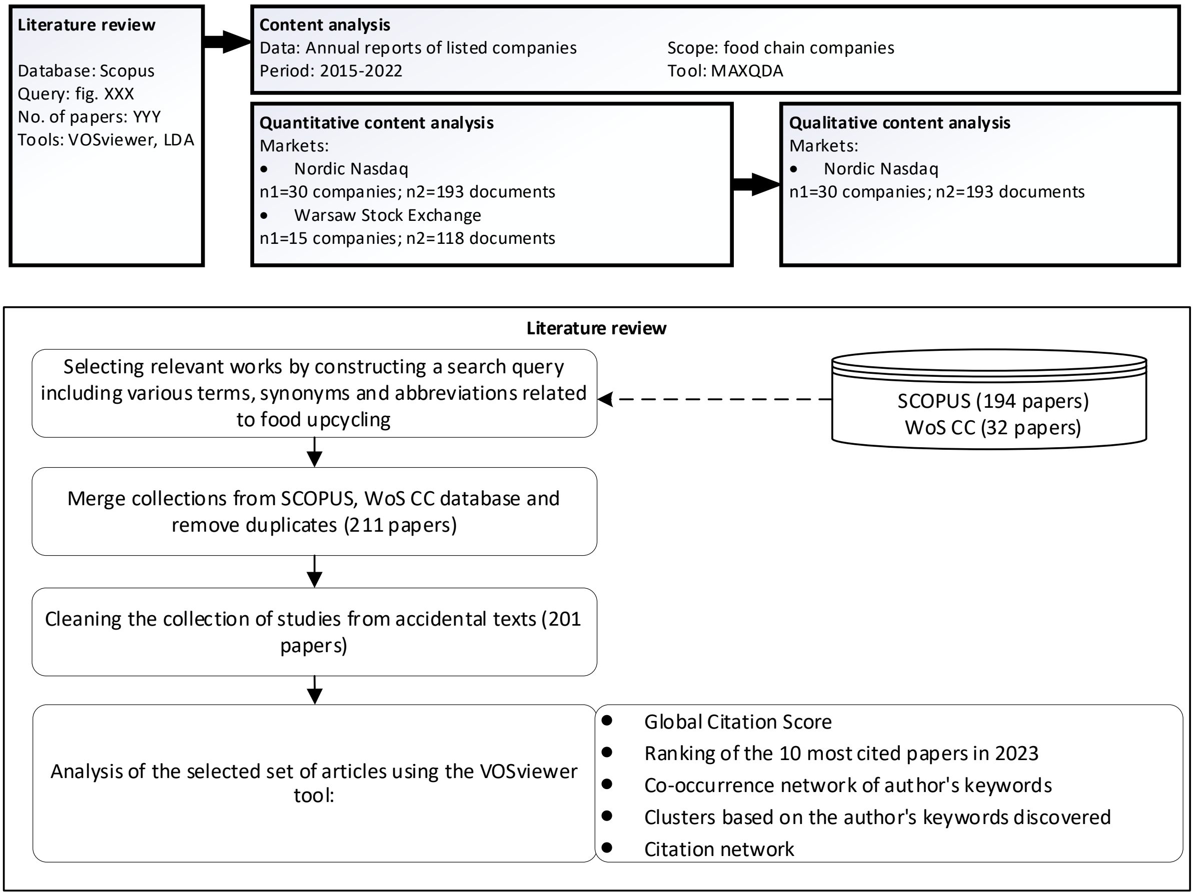

Figure 2: The review procedure

Therefore, it was assumed that results for these objects could possibly constitute a set of best practices or show emerging trends and the perspective for the future. WSE was chosen to compare a leading market with another dynamic European market as well as for the comparison of markets different with respect to the economic development level of their countries. The study covers 30 companies of Nordic Nasdaq and 15 companies of the Warsaw Stock Exchange. We selected companies whose operations relate to the food value chain, including food producers, retailers, and HoReCa companies. The selection was based on search engines available on the NordN and WSE (GPW, 2023; Nasdaq Nordic, 2023) websites, where we filtered companies using industry/sector criteria. In reports, we tried to identify strategies and/or best practices currently implemented by the companies. We analyzed reports from the period of 2015-2022. For each company and each year, the non-financial and sustainable development reports were merged into one file. Such merged files were the objects of content analysis. For those companies, 175 documents for the Nordic Nasdaq index and 118 documents for the Warsaw Exchange Stock were obtained. Content analysis was performed in MAXQDA software using the dictionary presented in the Methodology section. It was decided to use a mixed-method approach using text mining and statistics of keywords occurrences in the set of secondary sources. Quantitative content analysis was adopted as the first step (Coe & Scacco, 2017). The second step was qualitative content analysis for NordN, as the results of the first step for WSE were scarce and did not allow for deeper qualitative considerations.

Keywords for food waste issues were based on the results of the literature review. All the keywords were used in English for NordN and WSE and in Polish for WSE. Lemmatization was done thanks to the built-in mechanism in the MAXQDA tool. Analyses were performed using MAXQDA software for text mining and quantitative text analysis. The frequency of keywords' occurrence within the total number of words in the document was calculated. A dictionary of keywords and categories for content analysis is presented below:

- Category "customers": consumer; enterprise; household; restaurant; shop;
- Category "environmental protection": environmental care; reducing food waste
- Category "food chain": agri-food chain; food chain; food supply;
- Category "food waste": eating loss; eating scraps; eating waste; expired food; expired

grocery; food loss; food packaging; food remains; food scrap; food waste; garbage; organic garbage; organic waste; product loss; product waste; remains of grocery;
- Category “recycling”: food recycling; food upcycling; grocery recycling; recycling; scraps recycling; waste processing.

After quantitative consideration, reports of companies from NordN were analyzed qualitatively in order to classify mentions found for the provided dictionary on a three-level scale: directly on food upcycling; indirectly on food upcycling, and/or potentially moving in the direction of food upcycling; not related to the study, i.e. no potential for food waste upcycling (actions focused on food waste reduction, majority recycling). Additionally, in our analysis, we considered the company’s place in the food chain in accordance with the following categories: agriculture, including the production of unprocessed food; food production, including the processing of agricultural products; food distribution and storage (wholesale), serving food, including meal preparation.

RESULTS

Literature review

Requests directed to the SCOPUS and WoS CC databases resulted in obtaining 201 studies combining the topics of Food upcycling. The number of papers obtained compared with the total number of papers dealing with the topic of upcycling (9 612 papers in the SCOPUS database) or the topic of sustained operations (1 754 papers in the WoS CC database) demonstrates the niche character of these issues.

Considering leading papers ranked according to their Global Citation Score in the SCOPUS and WoS CC databases, Wei et al. (2017) is the paper ranked highest (208 citations). The next-highest cited paper with only slightly fewer citations (194) was Mak et al. (2020), with Knickmeyer (2020) (178 citations) and Arancon et al. (2016) (178 citations), coming in third. The obtained results show that no single paper is dominant. However, the number of citations does not take into consideration the time since but gives the absolute number of citations. The next ranking list of papers was constructed to identify recent groundbreaking research that has the potential to make a significant impact and promising scientific contribution to the topic of Food upcycling. The ranking of the top three papers based on all citations divided by the number of years since publication is following:
- (Mak et al., 2020): 65 citations per year;
- (Knickmeyer, 2020): 59 citations per year;
- (Jeswani et al., 2021): 42 citations per year.

The map of connections between keywords appearing in the analyzed studies was developed based both on keywords indicated by the authors and words indexed by the SCOPUS and WoS CC databases. Both sets of keywords were analyzed together. The reference number of keywords was adopted in accordance with the proposals tested in previous research (Wisniewski et al., 2022). The entry criterion was set at five occurrences of the keyword. This means that the keyword had to appear in at least five different papers to be classified on the linkage map. If a higher value had been chosen, the number of identified keywords would decrease, which could lead to the omission of an important issue that has not yet been sufficiently researched and described or simply not properly highlighted in the paper. Conversely, setting a value lower than 3 would return too many words as keywords, making map analysis impossible.

The total number of keywords in the analyzed papers is 1914. Using the VOSviewer program and applying the input criterion, a network was obtained (Figure 3) consisting of 89 nodes corresponding to 4 clusters. Each cluster is highlighted in a different color. The size and clarity of a node correspond to the frequency of its occurrence in the analyzed set. In turn, the proximity of individual elements indicates more frequent co-occurrence in specific sets compared to more distant elements. In order to understand research trajectories, keywords were ranked according to their total strength of association. The 'total strength' attribute of the association indicates the total strength of the co-occurrence of a given keyword with other keywords. The higher the value, the more frequently a given keyword co-occurs with others and is more relevant to the network. Detailed information about the selected keywords can be found in Annex 2. Keywords included in the linkage map (Figure 3) were grouped into thematic clusters using the VOSviewer tool and approach. The resulting clusters were described in relation to the articles in which the searched keywords appeared.

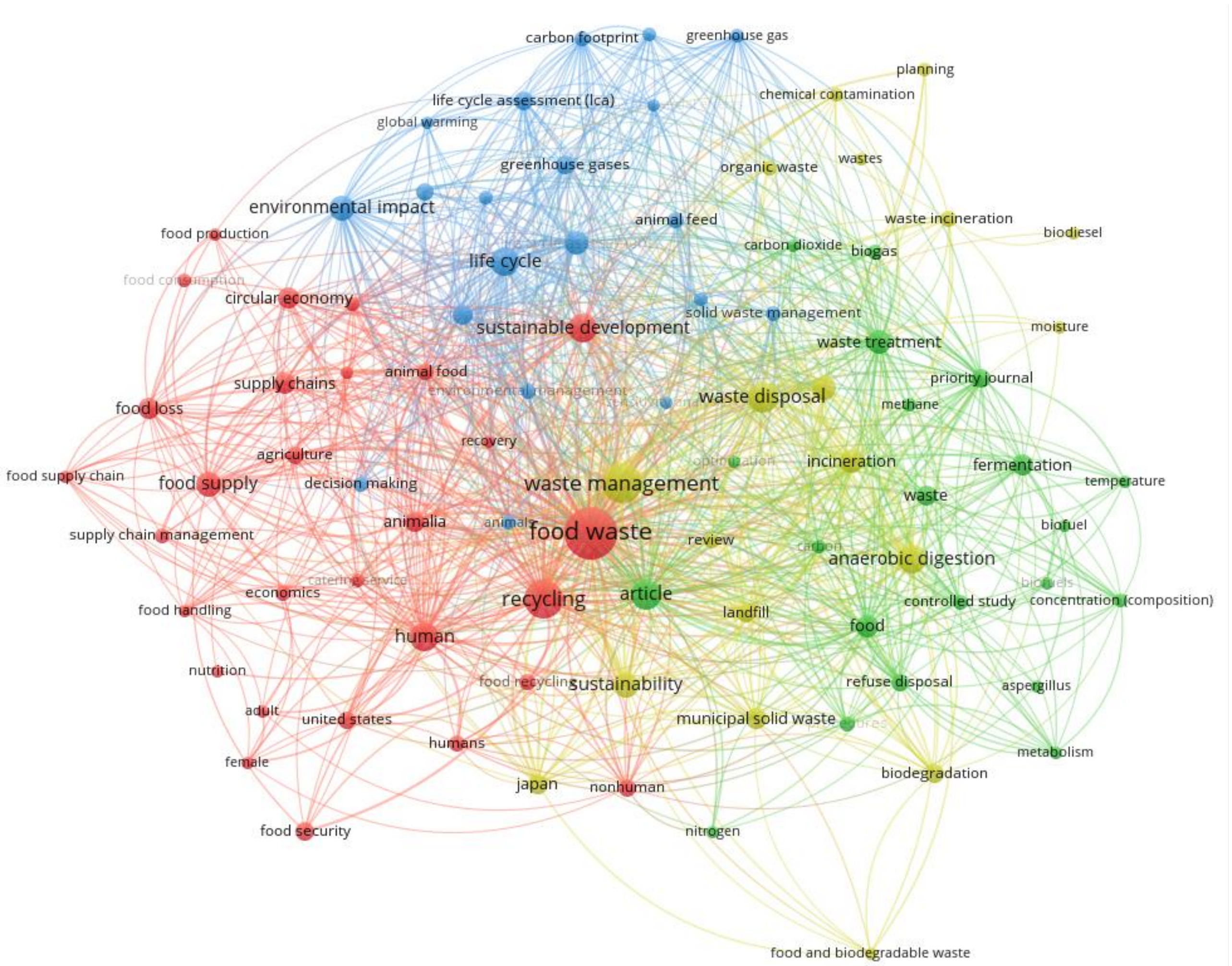

Figure 3. Co-occurrence network of author's keywords created in VOSviewer (minimum number of occurrences of a keyword: 5)

The resulting clusters designated by keywords, along with their qualitative and quantitative characteristics are presented in Table 1. The cluster name represents the author's attempt to define a common thematic area covered in the papers grouped within the cluster. Figure 4 illustrates the popularity of keywords over time. Dark blue indicates issues popular until 2014. The more the color shifts towards yellow, the more popular the issue becomes toward 2023. Keyword popularity has changed over time. At first, it was more about technical methods of waste recycling, and now more publications concern analyses of various types of impact on the environment or supply chain.

The last element that was examined at the stage of the literature review was a mutual citation of research papers within the studied set. The analysis indicated that the analyzed works are cited in works from outside the set.

Table 1. Clusters based on the keywords discovered in VOSviewer

Cluster	Keywords	Color	Cluster name/ Main Topic	Occurrences & Total link strength
Cluster 1	29: adult, agriculture, animal food, animalia, catering service, circular economy, economic aspect, economics, food consumption, food handling, food industry, food loss, food production, food recycling, food security, food supply, food supply chain, food waste, human, humans, nonhuman, nutrition, recovery, recycling, supply chain management, supply chains, sustainable development, united states, female	red	food waste recycling	375 3123

Cluster 2	19: article, aspergillus, biofuel, biofuels, biogas, carbon, concentration (composition), controlled study, food, metabolism, methane, nitrogen, optimization, priority journal, procedures, refuse disposal, temperature, waste, waste treatment	green	waste treatment	157 1797
Cluster 3	20: animal feed, animals, carbon footprint, climate change, decision making, economic and social effects, environmental impact, environmental management, environmental policy, environmental protection, environmental sustainability, global warming, greenhouse gas, greenhouse gases, life cycle, life cycle analysis, life cycle assessment, life cycle assessment (lca), sensitivity analysis, solid waste management	blue	environmental impacts (more general level)	181 2112
Cluster 4	19: anaerobic digestion, biodegradation, biodiesel, chemical contamination, composting, food and biodegradable waste, incineration, japan, landfill, moisture, municipal solid waste, organic waste, planning, review, sustainability, waste disposal, waste incineration, waste management, wastes	yellow	waste management / waste disposal	254 2398

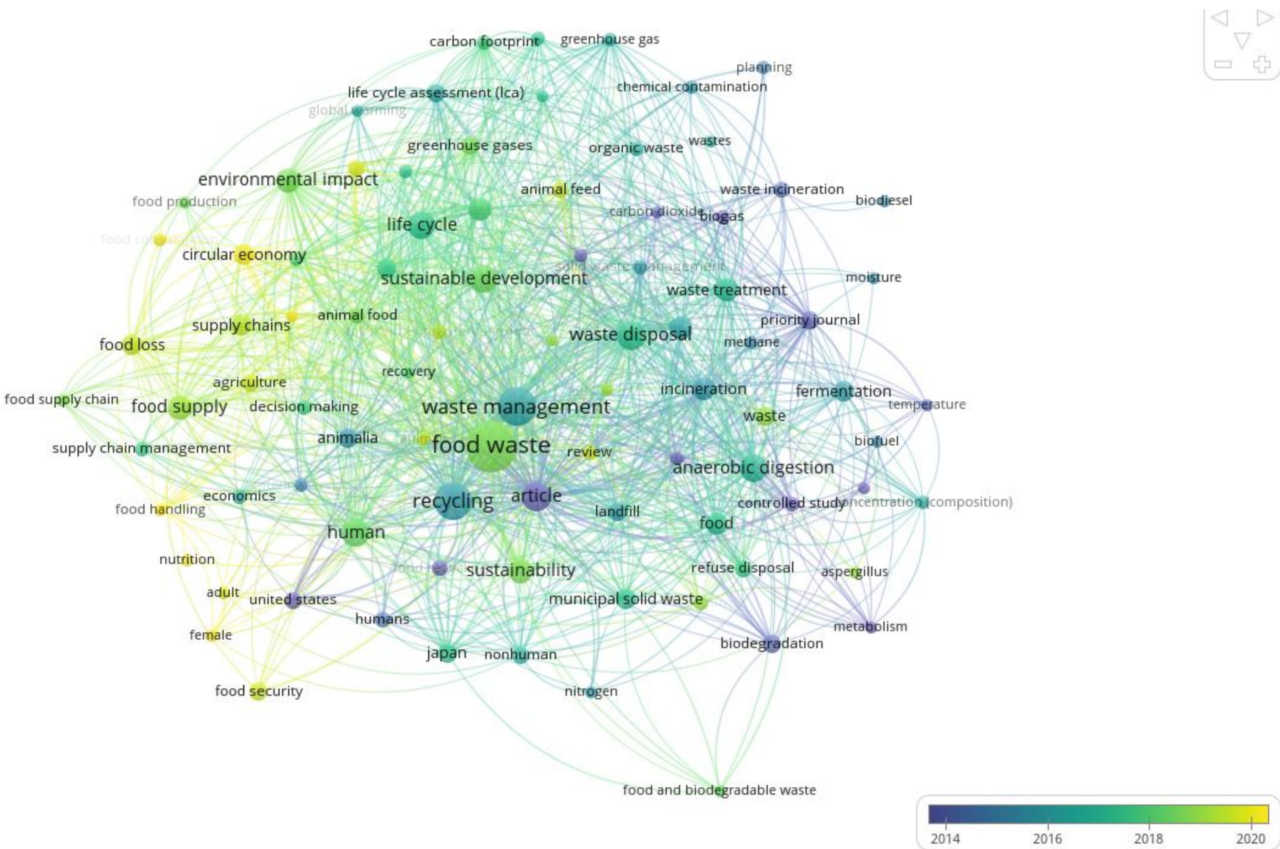

Figure 4. Timeline keyword popularity

Content analysis of annual reports

The next stage of the research was the content analysis of annual reports. Non-financial annual reports published by listed companies were analyzed, including Sustainability reports, if such reports were published. Quantitative content analysis using MAXQDA and the dictionary presented in section Methodology has unfortunately not indicated any significant correlations between considered categories either for WSE or for NordN listed companies. Therefore, we moved directly to qualitative content analysis. For WSE there was shortage of coded fragments in the documents. Due to this fact, we started directly with a qualitative content analysis for NordN companies only. These facts allow us to state that the Scandinavian companies are more advanced in implementing food waste management strategies. However, they focus only on one and, in some cases, at least two (own and consumer) perspectives. They do not consider the whole food value chain. As mentioned in the Methodology section, we selected companies involved in the food chain activities. Table 2 presents the companies involved, particularly the food chain and the numbers of analyzed companies by headquarters country. Based on the company's description, we assigned all companies to the following groups in the food value chain:

- Agriculture – agriculture companies as well as producers of non-processed food;
- Food production – producers of processed food and beverages;
- Distribution – wholesales, grocery stores, supermarket chains, and shop chains.
- Food serving – restaurants, hotels, and catering companies.

We considered the main related types of activities undertaken by the company. If the primary activity type was unclear, we assigned the company to more than one type. No one company in its reports mentioned directly or indirectly about undertaken upcycling activities. Moreover, companies from WSE do not even mention food waste reduction activities in the reports. Some of them generally mentioned about recycling not directly related to food waste in the sustainability part or in a separate sustainability report. Due to this, for further analysis, we considered only companies from NordN.

Using the MAXQDA software, we identified reports that indicated the following categories: environment protection, food chain, food waste, and recycling. We identified all crosschecks of indicated categories: (1) environmental protection - food chain; (2) environmental protection - food waste; (3) environmental protection – recycling; (4) food chain – food waste; (5) food chain – recycling; (6) food waste – recycling. After this, we reviewed all identified places, also considering contexts mentioned in companies' reports. In Table 3 below, we presented numbers of the enterprises implementing sustainability activities indirectly or/and potentially going to implement food upcycling and with no potential for the food upcycling.

All companies use different reporting standards. Therefore, it cannot be assumed that the companies for which we did not identify any activities by MAXQDA do not undertake any upcycling activities. Such obligation (expected in 2025-2026 for Sustainability activities in the EU) helps further such qualitative and quantitative research. Currently, it is only possible to undertake qualitative analysis based on cases or groups of cases. Listed below are actions or/and practices undertaken by the analyzed companies (for II and III categories):

- (II) - Indirectly or/and potentially going to implement food upcycling:
  - Promotion of circular economy practices, sustainable food chain;
  - Collaborating with various actors (Unions, Communities, etc.) for meaningful food waste handling;
  - Reducing food waste in cooperation with the food supply chain, from primary production to the store;
  - Using new food packaging technologies;
- (III) - No potential for food upcycling:
  - Following national and local regulations focused on food waste reduction;
  - Converting food waste into manure and composting food waste.

Table 2. Number of companies involved in the food chain (some are engaged in several types of activities)

Stock exchange	Agriculture (A)	Food production (B)	Distribution (C)	Food serving (D)	Countries
Warsaw Stock Exchange	1	9	6	2	Poland: 15
Nordic Nasdaq	6	13	17	4	Sweden: 11; Finland: 9; Iceland: 5; Denmark: 4; Malta:1

Table 3. Categories of sustainability activities reported by the Nordic NASDAQ-listed companies

Type of activities		Year							
		2022	2021	2020	2019	2018	2017	2016	2015
I	Directly on food upcycling	-	-	-	-	-	-	-	-
II	Indirectly or/and potentially going to implement food upcycling	4	2	2	5	-	-	1	2
III	No potential for food upcycling	5	3	3	2	3	2	2	2

DISCUSSION

Properties of identified clusters and topical areas

The lack of an identified citation network based on the CNA analysis with VOSviewer may mean that the authors deal with the topics identified in Table 1 independently of each other. It is probable that even though certain studies may have a similar broad context, their detailed scope is significantly different, and therefore, there are no co-citations. In the case of the atomization of research and the lack of co-citation clusters, it can be assumed that the topic of Food upcycling is at an early stage of research.

The results obtained indicate four papers with a high number of citations despite having been published recently, i.e., Mak et al. (2020) received 65 citations; Knickmeyer (2020), 59; Jeswani et al. (2021), 42; and Mulya et al. (2022), 33. There are visible similarities between these works. Their general topical focus addresses the phenomenon of circular economy and life-cycle assessment difficulties by applications of sustainable food waste management from the perspective of different policies (macroeconomic and mesoeconomic scale, but not on the scale of industrial organization).

Mak et al. (2020) identify gaps in the identifies gaps in research on how a circular bioeconomy can be achieved through sustainable food waste management, comparing similarities and differences in the concepts of bioeconomy and circular economy, reviewing the benefits and limitations of existing policies, and assessing the global situation of food waste and its household and commercial development to promote a circular bioeconomy.

Knickmeyer (2020) points out that improving recycling efficiency to recover quality materials, save resources, and keep waste out of landfills is among the urgent challenges of our time. The transition to a circular economy requires active public participation in waste management and pre-sorting waste at home. In the process of establishing and improving well-functioning municipal solid waste management systems, understanding the underlying social factors that influence household behavior is widely underestimated but is of paramount importance. The study brings together theory and good practice from cities around the world to support practitioners and policymakers from various backgrounds in designing future strategies and interventions. It provides an overview of the main social factors influencing household recycling behavior and identifies key drivers for behavioral change. International good practices and recommendations for urban areas are then presented, with particular emphasis on areas with high population density. Taken together, the results are intended to serve as a resource for practitioners and as a basis for developing further research focusing on improving recycling behavior in specific urban areas and adapting it to local conditions.

Mulya et al. (2022) examine the waste disposal process using the life cycle assessment (LCA) technique, which helps identify different sources and enables decision-makers to exhaust the impacts by implementing disposal practices. The paper highlights the lack of review studies that lead to a meta-analysis of effects from critical methodological LCAs in the field of solid waste management. To fill this gap, the paper examines 15 elements comprising the preference of journals, 13 LCA method-related characteristics economic assessment, applicable practices, and along with dismissal trends. A study of 240 studies on LCA SWM from 2009 to 2020 was conducted and divided into two main periods (i.e., 2009-2014 and 2015-2020) to investigate the changes in trends. Among the elements found is the application of increasing energy in solid waste energy LCA studies. The number of anaerobic digestion installations almost doubled in the second-year group (2015-2020). Various characterization methods, such as ReCiPe and CML are also available. Functional units are more universal but are generally defined by mass. Often identified in many solid waste LCAs is ambiguity in data sources, such as outdated literature or inconsistent geographic references.

Jeswani et al. (2021) is of the most different topical scope than discussed above: Mak et al. (2020), Knickmeyer (2020), and Mulya et al. (2022). The common point with Mulya et al. (2022) is addressing LCA issues, but the work is of diagnostic and statistics nature mostly.

Jeswani et al. (2021) focuse on food waste in the UK with the aim of estimating its volume across supply chains and assessing the resulting environmental impacts throughout the life cycle. Furthermore, the contribution of different food groups to food waste and their impact at different stages of the life cycle is quantified. The results suggest that 13.1 million tonnes of food waste is generated annually in the UK across the supply chain, leading to greenhouse gas emissions of 27 million tonnes of CO2 equivalent per year. The largest amount of waste is generated in the cereal (31%) and vegetable and root

(28%) subsector. However, meat and fish have the greatest environmental impact throughout their life cycle, even though they only account for 10% of all food waste. Although post-consumer waste is the largest contributor, both in terms of waste volume and environmental impact, the contribution of other stages (primary production, food processing, and distribution) is also significant. These findings highlight the need to consider the environmental impact of food waste and involve all supply chain actors in formulating food waste reduction strategies.
The methodology of cluster creation is presented by Waltman et al. (2010). Each keyword could be assigned only to one cluster. Two keywords could not be assigned to any cluster: „fermentation" and „carbon dioxide". We can assume that clusters 1 and 3 are "soft" clusters and studies in these clusters are in the field of social sciences. Clusters 2 and 4 are somewhat "harder," and research in these clusters is related to a greater extent to engineering or environmental sciences.
Each cluster includes keywords indirectly related to the topic of our research. However, due to methodological reasons, we decided to keep them in the clusters' scopes. Upcycling is not listed in Table 1 because this keyword appears only in 4 publications. In our opinion, this may indicate that this concept is not yet commonly used by scientists, and studies of company reports also indicate that is also not commonly used by enterprises. Additionally, even if some entities conduct upcycling or similar activities, it may happen that they do not use this term to refer to their activities.
Cluster 1. concentrates on the food waste and recycling topics. The scope of the cluster also includes the whole food supply chain and its stages, primarily in the context of the management of food losses. This is the biggest topic in our research scope and, in our opinion, the one most impactful on the research agenda.
Cluster 2. focuses on the engineering aspects of food waste, including waste treatment. The scope of the cluster also includes the food waste ingredients and substances. Considering occurrences and total link strengths, currently this cluster is the least impactful. Considering the timeline of the keywords (Figure 4), in our opinion, the research topics undertaken in this track are mature but still important, and there is room for improvement, especially in the engineering domains.
Cluster 3. focuses on lifecycle assessment and environmental protection. The scope of the cluster also includes climate change, impact analysis, and policies and decision-making (on a global and macro scale). In our opinion, the topics undertaken in this cluster are deployed and elaborated on at the high level of the whole food supply chain (cluster 1).
Cluster 4. focuses on waste management and technologies utilized in the waste management process. In our opinion, this cluster correlates with the topics from Cluster 2 but focuses more on the utilization and impact aspects of the technologies used in waste management processes.
The map (Figure 1) clearly shows that the newest cluster is made up of papers concerning the topics of food loss, food handling, food supply, circular economy, and climate change. These concepts are mainly included in the red thematic cluster (cluster 1). This cluster includes research on the social and business impact related to the implementation of recycling practices. This study falls within the scope of cluster 1 as it concerns the analysis of good practices used by enterprises.
Based on the qualitative analysis of the companies' annual reports, we can assume that if the company implemented practices from Group II, it usually implemented practices from Group III (Table 3). Companies that operate closer to the final customer – consumers are more interested in the upcycling activities than other types of companies in the food chain. We assume that probably these companies are pressed by their customers. This could also be why Polish companies do not include such types of activities in the annual and sustainability reports. Another insight is that soft-social programs often focus on young people and children.

Policy Implications

The results obtained indicate a lack of a holistic view of the problem of food waste among researchers. Researchers undertake research in narrow topic areas. This fact is particularly visible in the results of the cross-citation analysis of existing papers on upcycling. There was not a single case of mutual citations in the analyzed studies. This may indicate that this research is at an early stage. This conclusion is supported by the results of a study aimed at identifying good practices in reducing food losses. The survey was conducted among companies listed on the Warsaw Stock Exchange and the NASDAQ Nordic index. The results also show isolated mentions of activities aimed at reducing food waste. Additionally, the lack of a uniform way of describing the undertaken activities was noticed. Comparing this fact with the results of the literature review, one can notice the lack of a uniform framework allowing for a substantive discussion on the upcycling phenomenon. This obviously makes it difficult to conduct research on effective and efficient methods of reducing food waste. The EU Commission is responding to this phenomenon and has introduced a directive containing the requirement to report upcycling activities. However, the analysis of the provisions of the directive did not reveal any proposals for the structure of such reports. The lack of such a standard makes it very hard to proceed with any comparisons and analysis of food upcycling-related actions. It is also visible that regulations in terms of sustainability reporting in general (as for Nordic Nasdaq listed companies) constitute a natural platform for food chain companies to report food upcycling actions and strategies.

We can observe several dimensions of the upcycling influence:

- Technological, especially food technologies, are both related to products (food and food-related services) and processes (food and services "production");
- Business, related to business models of the companies and food value chains;
- Society, related to food waste reduction and environment protection.

Looking at the food market we observe:

- More Processed food on the market;
- Processed food is more challenging to recycle and upcycle;
- Food processing using natural processes (traditional) is easier to recycle and probably recycle, so biofood is easier to upcycle.

Based on this, recycling or upcycling should be considered at the design stage of processed food products. Therefore, food producers could be encouraged (or supported) to introduce food to the market in which the food waste generated (based on this food) can be easily upcycled. Upcycling has the same challenges as recycling. Raw materials are unstable (in the case of parameters), so big companies are not interested in basing their processes on upcycled ingredients (Singh et al., 2019). Upcycling relates to product innovation, even if, at the starting point, current business models are not suitable (Donner et al., 2020; Donner & De Vries, 2023). Big companies can create spin-offs and perceive such initiatives as disruptive innovation (Christensen, 1997).

Another important factor of upcycling, which is currently a standard in the case of recycling but is not so enhanced in publications on upcycling, are the costs associated with upcycling, particularly costs of additional energy, e.g., less energy being used for food upcycling than in the case of recycling, i.e. not taking up upcycling solely because it is fashionable. The literature review discovered that apart from technology- and food engineering-oriented studies about food upcycling, there is another prospective perspective. It is the perspective of circular economy and sustainable food waste management at the level of authorities and decision-makers on the macro and meso-economy scale.

CONCLUSIONS

The presented study discovered a research gap, which is food upcycling addressed from the level of industrial organizations considering managerial and organizational issues. As the topic itself is quite novel, it is expected to be the object of strategic management and innovation management interest. We addressed this gap by demonstrating a possible approach to analysis of strategies of listed companies. We considered annual reports of listed companies are the secondary source of data about their strategies. The proposed approach is limited to analysis of annual reports. Those are biased because they are authored and published by the companies themselves. As such, reports might be declarative and might differ from reality or consumer perceptions. Therefore, we postulate further studies to eliminate this limitation by inclusion of more democratic sources in the proposed approach, i.e., communication about companies in professional media (e.g., news from professional portals) and social media (what would show the real perceptions of final consumers).

Our approach was demonstrated using samples from two stock exchanges, but a further search might include more markets. Therefore, it enables easy replicability and comparative studies. That could constitute a basis for finding benchmarks and good practices. The study itself is developed from secondary sources, which is a limitation. Therefore, we also postulate to include primary data from questionnaire surveys, in-depth interviews, and focus group interviews to triangulate results and get more qualitative data.

Assuming that the primary goal of upcycling is to fight hunger, it is also worth knowing how much food will contribute to achieving this goal: e.g., making soup or jam is worthy of being supported, but the production of candy or alcohol is debatable. It is important to realize that food waste results from ineffective action or lack of action. At the same time, it is more important to identify and eliminate food waste's causes. In this situation, building awareness among all actors involved in the food value chain (e.g., from agriculture to consumers) is extremely important, also in the context of the impact of the activities of individual actors on other participants of the food value chain, e.g., produce food in such way that food waste is suitable for upcycling. For this reason, the digitalization of the entire chain, aimed at a more effective exchange of information between actors and to better understand the whole chain's behaviors, may be promising.

The overall picture that emerges from the analysis of the current state of scientific knowledge and practical and legislative activities indicates a lack of the methodological framework for upcycling. At the same time, we can see actions of all three groups of entities (science, business, and legislation) aimed at systematizing the discussion on upcycling. The subsequent opinion on the application of the methodology presented relevant quantitative and qualitative research on the issues of upcycling and good practices in the field of reducing food losses.

REFERENCES

1. Arancon, R. A. D., Lin, K. S. K., Chan, K. M., Kwan, T. H., & Luque, R. (2016). Advances on Waste Valorization: New Horizons for a More Sustainable Society. In Waste Management and Valorization. Apple Academic Press.
2. Arksey, H., & O'Malley, L. (2005). Scoping studies: Towards a methodological framework. Int. J. of Soc. Res. Methodol., 8(1), 19–32. https://doi.org/10.1080/1364557032000119616
3. Aschemann-Witzel, J., Asioli, D., Banovic, M., Perito, M. A., Peschel, A. O., & Stancu, V. (2023). Defining upcycled food: The dual role of upcycling in reducing food loss and waste. Trends in Food Science & Technology, 132, 132–137. https://doi.org/10.1016/j.tifs.2023.01.001
4. Beaton, K. (2023, May 2). Food Waste: Investment in Upcycled Food Gaining Steam. The Food Institute. https://foodinstitute.com/focus/food-waste-investment-in-upcycled-food-gaining-steam/
5. Bridgens, B., Powell, M., Farmer, G., Walsh, C., Reed, E., Royapoor, M., Gosling, P., Hall, J., & Heidrich, O. (2018). Creative upcycling: Reconnecting people, materials and place through making. Journal of Cleaner Production, 189, 145–154. https://doi.org/10.1016/j.jclepro.2018.03.317
6. Buczacki, A., Gladysz, B., & Wisniewski, M. (2024). Food upcycling strategies applied by the listed companies involved in the food value chain [Dataset]. Zenodo. https://doi.org/10.5281/zenodo.11164382
7. Cervera, M. (2023, February 23). From sidestream to mainstream: Taste and better messaging will bring new life to upcycling. From Sidestream to Mainstream. https://fif.cnsmedia.com/a/asjeFcWmtWM=
8. Christensen, C. M. (1997). The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail (1st edition). Harvard Business Review Press.
9. Coe, K., & Scacco, J. M. (2017). Content Analysis, Quantitative. In The International Encyclopedia of Communication Research Methods (pp. 1–11). John Wiley & Sons, Ltd. https://doi.org/10.1002/9781118901731.iecrm0045
10. Daudt, H. M., van Mossel, C., & Scott, S. J. (2013). Enhancing the scoping study methodology: A large, inter-professional team's experience with Arksey and O'Malley's framework. BMC Med. Res. Methodol., 13(1), 48. https://doi.org/10.1186/1471-2288-13-48
11. Donner, M., & De Vries, H. (2023). Novel sustainable and circular business models valorizing fruit and vegetable waste and by-products. In Fruit and Vegetable Waste Utilization and Sustainability (pp. 165–180). Elsevier. https://doi.org/10.1016/B978-0-323-91743-8.00014-9
12. Donner, M., Gohier, R., & De Vries, H. (2020). A new circular business model typology for creating value from agro-waste. Science of The Total Environment, 716, 137065. https://doi.org/10.1016/j.scitotenv.2020.137065
13. Evans, S., Vladimirova, D., Holgado, M., Van Fossen, K., Yang, M., Silva, E. A., & Barlow, C. Y. (2017). Business Model Innovation for Sustainability: Towards a Unified Perspective for Creation of Sustainable Business Models. Business Strategy and the Environment, 26(5), 597–608. https://doi.org/10.1002/bse.1939
14. Foodvalley. (2023). Upcycling Community. Upcycling Community. https://foodvalley.nl/en/partner-overview/?type%5B%5D=upcycling-community-partner&search=
15. Goodman-Smith, F., Bhatt, S., Moore, R., Mirosa, M., Ye, H., Deutsch, J., & Suri, R. (2021). Retail Potential for Upcycled Foods: Evidence from New Zealand. Sustainability, 13(5), 2624. https://doi.org/10.3390/su13052624
16. GPW. (2023). GPW Main Market—Main Market. https://www.gpw.pl/en-home

17. Grasso, S., Fu, R., Goodman-Smith, F., Lalor, F., & Crofton, E. (2023). Consumer attitudes to upcycled foods in US and China. Journal of Cleaner Production, 388, 135919. https://doi.org/10.1016/j.jclepro.2023.135919
18. Hellali, W., & Korai, B. (2023). Understanding consumer's acceptability of the technology behind upcycled foods: An application of the technology acceptance model. Food Quality and Preference, 110, 104943. https://doi.org/10.1016/j.foodqual.2023.104943
19. Igual, M., Moreau, F., García-Segovia, P., & Martínez-Monzó, J. (2023). Valorization of Beetroot By-Products for Producing Value-Added Third Generation Snacks. Foods, 12(1), 176. https://doi.org/10.3390/foods12010176
20. Jeswani, H. K., Figueroa-Torres, G., & Azapagic, A. (2021). The extent of food waste generation in the UK and its environmental impacts. Sustainable Production and Consumption, 26, 532–547. https://doi.org/10.1016/j.spc.2020.12.021
21. Joshi, A. (2017). Comparison between Scopus & ISI Web of Science. J. Glob. Values, 7, 2016.
22. Knickmeyer, D. (2020). Social factors influencing household waste separation: A literature review on good practices to improve the recycling performance of urban areas. Journal of Cleaner Production, 245, 118605. https://doi.org/10.1016/j.jclepro.2019.118605
23. Knoke, D., & Yang, S. (2008). Social Network Analysis. SAGE Publications, Inc. https://doi.org/10.4135/9781412985864
24. Kontostathis, A., Galitsky, L. M., Pottenger, W. M., Roy, S., & Phelps, D. J. (2004). A Survey of Emerging Trend Detection in Textual Data Mining. In M. W. Berry (Ed.), Survey of Text Mining: Clustering, Classification, and Retrieval (pp. 185–224). Springer. https://doi.org/10.1007/978-1-4757-4305-0_9
25. Li, X., & Lei, L. (2021). A bibliometric analysis of topic modelling studies (2000–2017). J. of Inf. Sci., 47(2), 161–175. https://doi.org/10.1177/0165551519877049
26. Lou, W., & Qiu, J. (2014). Semantic information retrieval research based on co-occurrence analysis. Online Inf. Rev., 38(1), 4–23. https://doi.org/10.1108/OIR-11-2012-0203
27. Mak, T. M. W., Xiong, X., Tsang, D. C. W., Yu, I. K. M., & Poon, C. S. (2020). Sustainable food waste management towards circular bioeconomy: Policy review, limitations and opportunities. Bioresource Technology, 297, 122497. https://doi.org/10.1016/j.biortech.2019.122497
28. Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. BMJ, 339, b2535. https://doi.org/10.1136/bmj.b2535
29. Morris, T. A. (2000). Structural relationships within medical informatics. Proc. of the AMIA Symp., 590–594.
30. Mulya, K. S., Zhou, J., Phuang, Z. X., Laner, D., & Woon, K. S. (2022). A systematic review of life cycle assessment of solid waste management: Methodological trends and prospects. Science of The Total Environment, 831, 154903. https://doi.org/10.1016/j.scitotenv.2022.154903
31. Narisetty, V., Cox, R., Willoughby, N., Aktas, E., Tiwari, B., Matharu, A. S., Salonitis, K., & Kumar, V. (2021). Recycling bread waste into chemical building blocks using a circular biorefining approach. Sustainable Energy & Fuels, 5(19), 4842–4849.
32. Nasdaq Nordic. (2023). Nasdaq Nordic—Share quotes—Indexes—Company news—Nasdaq. https://www.nasdaqomxnordic.com/?
33. Pagett, M., Teng, K. S., Sullivan, G., & Zhang, W. (2023). Reusing Waste Coffee Grounds as Electrode Materials: Recent Advances and Future Opportunities. Global Challenges, 7(1), 2200093. https://doi.org/10.1002/gch2.202200093
34. Pasqualone, A., Laddomada, B., Boukid, F., Angelis, D. D., & Summo, C. (2020). Use of Almond Skins to Improve Nutritional and Functional Properties of Biscuits: An Example of Upcycling. Foods, 9(11), 1705. https://doi.org/10.3390/foods9111705
35. Pinela, J., Fuente, B. D. L., Rodrigues, M., Pires, T. C. S. P., Mandim, F., Almeida, A., Dias, M. I., Caleja, C., & Barros, L. (2022). Upcycling Fish By-Products into Bioactive Fish Oil: The Suitability of Microwave-Assisted Extraction. Biomolecules, 13(1), 1. https://doi.org/10.3390/biom13010001
36. Poojary, M. M., Roohinejad, S., Barba, F. J., Koubaa, M., Puértolas, E., Jambrak, A. R., Greiner, R., & Oey, I. (2017). Application of pulsed electric field treatment for food waste recovery operations. Handbook of Electroporation, 1–18.
37. Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. Science, 360(6392), 987–992. https://doi.org/10.1126/science.aaq0216

38. Putnik, P., Bursać Kovačević, D., Režek Jambrak, A., Barba, F. J., Cravotto, G., Binello, A., Lorenzo, J. M., & Shpigelman, A. (2017). Innovative “green” and novel strategies for the extraction of bioactive added value compounds from citrus wastes—A review. Molecules, 22(5), 680.
39. Radzymińska, M., & Platta, A. (2022). Food Waste from the Perspective of Assessment of Attitudes and Behaviours of Young Consumers. Scientific Journal of Gdynia Maritime University, 122, 68–81.
40. Rasool, K., Hussain, S., Shahzad, A., Miran, W., Mahmoud, K. A., Ali, N., & Almomani, F. (2023). Comprehensive insights into sustainable conversion of agricultural and food waste into microbial protein for animal feed production. Reviews in Environmental Science and Bio/Technology, 22(2), 527–562. https://doi.org/10.1007/s11157-023-09651-6
41. Schaerer, L. G., Wu, R., Putman, L. I., Pearce, J. M., Lu, T., Shonnard, D. R., Ong, R. G., & Techtmann, S. M. (2023). Killing two birds with one stone: Chemical and biological upcycling of polyethylene terephthalate plastics into food. Trends in Biotechnology, 41(2), 184–196. https://doi.org/10.1016/j.tibtech.2022.06.012
42. Singh, J., Sung, K., Cooper, T., West, K., & Mont, O. (2019). Challenges and opportunities for scaling up upcycling businesses – The case of textile and wood upcycling businesses in the UK. Resources, Conservation and Recycling, 150, 104439. https://doi.org/10.1016/j.resconrec.2019.104439
43. Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. J. of Bus. Res., 104, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039
44. Upcycled Food Association. (2020). About Upcycled Food. About Upcycled Food. https://www.upcycledfood.org/upcycled-food
45. Upcycled Food Association. (2023a). Upcycled Cerified Impact. Upcycled Food Association. https://www.upcycledfood.org/impact
46. Upcycled Food Association. (2023b). Upcycled Certified Products. Upcycled Food Association. https://www.upcycledfood.org/upcycled-certified-products
47. van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics, 84(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3
48. van Hal, J. (2023, August 17). Upcycling ingredients: Foodvalley NL highlights potential to add value to food waste. Upcycling Ingredients: Foodvalley NL Highlights Potential to Add Value to Food Waste. https://fif.cnsmedia.com/a/YNIcJzICLfU=
49. Visser, M., van Eck, N. J., & Waltman, L. (2021). Large-scale comparison of bibliographic data sources: Scopus, Web of Science, Dimensions, Crossref, and Microsoft Academic. Quant. Sci. Stud., 2, 1–37. https://doi.org/10.1162/qss_a_00112
50. Waltman, L., Van Eck, N. J., & Noyons, E. C. M. (2010). A unified approach to mapping and clustering of bibliometric networks. Journal of Informetrics, 4(4), 629–635. https://doi.org/10.1016/j.joi.2010.07.002
51. Wei, Y., Li, J., Shi, D., Liu, G., Zhao, Y., & Shimaoka, T. (2017). Environmental challenges impeding the composting of biodegradable municipal solid waste: A critical review. Resources, Conservation and Recycling, 122, 51–65. https://doi.org/10.1016/j.resconrec.2017.01.024
52. Wisniewski, M., Gladysz, B., Ejsmont, K., Wodecki, A., & Van Erp, T. (2022). Industry 4.0 Solutions Impacts on Critical Infrastructure Safety and Protection–A Systematic Literature Review. IEEE Access, 10, 82716–82735. IEEE Access. https://doi.org/10.1109/ACCESS.2022.3195337
53. Yu, I. K. M., Chan, O. Y., Zhang, Q., Wang, L., Wong, K.-H., & Tsang, D. C. W. (2023). Upcycling of Spent Tea Leaves and Spent Coffee Grounds into Sustainable 3D-Printing Materials: Natural Plasticization and Low-Energy Fabrication. ACS Sustainable Chemistry & Engineering, 11(16), 6230–6240. https://doi.org/10.1021/acssuschemeng.2c07330
54. Yu, I. K. M., & Wong, K.-H. (2023). Food waste-derived 3D printable materials: A carbon neutral solution to global foodloss. Trends in Food Science & Technology, 137, 156–166. https://doi.org/10.1016/j.tifs.2023.05.014
55. Zucchella, A., & Previtali, P. (2019). Circular business models for sustainable development: A “waste is food” restorative ecosystem. Business Strategy and the Environment, 28(2), 274–285. https://doi.org/10.1002/bse.2216

ANNEX 1. COMPANIES SELECTED FOR CONTENT ANALYSIS

Warsaw Stock Exchange:

1. Ambra, www.ambra.com.pl
2. Atlanta Poland, atlantapoland.com.pl
3. Bio Planet, bioplanet.pl
4. Dino Polska, grupadino.pl
5. Eurocash, eurocash.pl
6. Gobarto, www.gobarto.pl
7. Helio, helio.pl
8. Krynica Vitamin, krynicavitamin.com
9. Makarony Polskie, makaronypolskie.pl
10. Mex Polska, mexpolska.pl
11. Pamapol, pamapol.com.pl
12. Seko, sekosa.pl
13. Sfinks Polska, www.sfinks.pl
14. Tarczyński, tarczynski.pl
15. ZPC Otmuchów, www.grupaotmuchow.pl

Nordic NASDAQ:

1. AAK, www.aak.com
2. Anora, anora.com
3. Apetit, apetit.fi
4. Atria, www.atria.fi
5. Axfood, www.axfood.com
6. Brim, www.brim.is
7. Carlsberg, www.carlsberggroup.com
8. Cibus Nordic, www.cibusnordic.com
9. Citycon, www.citycon.com
10. Cloetta,www.cloetta.com
11. DUNI, dunigroup.com
12. First Arms, www.firstfarms.dk
13. Hagar, www.hagar.is
14. Harboe, harboe.com
15. HKScan, www.hkscan.com
16. Hufvudstaden, hufvudstaden.se
17. Iceland Seafood, www.icelandseafood.is
18. Kesko, www.kesko.fi
19. Midsona, www.midsona.com
20. NoHo Partners, www.noho.fi
21. NP3 Fastigheter, www.np3fastigheter.se
22. Olgeroin Egill Skallagrimsson, www.olgerdin.is
23. Olvi, www.olvi.fi
24. Pandox, www.pandox.se/
25. Raisio, www.raisio.com
26. Royal Unibrew, www.royalunibrew.com
27. Scandi Standard, www.scandistandard.com
28. Scandic Hotels Group, www.scandichotelsgroup.com
29. Sildarvinnslan, www.svn.is
30. UIE, uie.dk

ANNEX 2. INFORMATION ABOUT THE KEYWORDS ANALYZED IN VOSVIEWER

Keyword	Occurrences	Total link strength	Keyword	Occurrences	Total link strength
food waste	79	561	economic and social effects	5	79
waste management	45	441	waste	12	79
recycling	44	317	animals	6	78
article	26	310	food industry	6	78

Keyword	Occurrences	Total link strength	Keyword	Occurrences	Total link strength
waste disposal	26	282	catering service	6	77
life cycle	23	261	economic aspect	5	75
human	23	237	carbon	6	74
waste treatment	17	211	united states	9	74
incineration	17	207	carbon dioxide	5	73
sustainable development	24	204	organic waste	7	73
life cycle assessment	16	195	environmental protection	6	72
environmental impact	18	190	environmental management	7	70
food	15	190	climate change	9	69
composting	17	185	humans	8	69
anaerobic digestion	23	179	biogas	7	66
life cycle analysis	12	173	temperature	5	65
priority journal	11	172	concentration (composition)	6	61
sustainability	19	163	global warming	5	60
food supply	18	152	chemical contamination	6	59
landfill	11	141	decision making	7	59
animalia	12	136	environmental sustainability	6	59
life cycle assessment (lca)	11	129	metabolism	5	59
animal food	8	123	nitrogen	5	58
supply chains	13	123	food handling	5	54
japan	12	122	food supply chain	5	51
greenhouse gases	11	120	methane	6	51
refuse disposal	9	117	supply chain management	7	51
municipal solid waste	13	112	economics	7	50
circular economy	14	110	adult	5	45
food loss	14	107	sensitivity analysis	5	43
carbon footprint	7	102	female	5	42
controlled study	7	99	food production	5	42
fermentation	13	97	recovery	5	42
greenhouse gas	6	97	biofuels	5	39
nonhuman	9	95	food security	11	39
solid waste management	7	93	wastes	5	35
procedures	7	92	food recycling	8	34
waste incineration	8	87	optimization	5	34
biodegradation	10	86	aspergillus	5	32
environmental policy	6	84	biofuel	5	32
review	7	80	moisture	5	31
agriculture	9	79	food and biodegradable waste	5	29
animal feed	8	79	food consumption	6	28
biodiesel	5	16	nutrition	5	28
			planning	6	26