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Food waste in the context of Poland's food security: identifying research path dependency through bibliometric research

Sylwia Łaba* **and Igor Olech**

Institute of Agricultural and Food Economics-National Research Institute (IAFE-NRI), Warsaw, Poland
**Corresponding author:* sylwia.laba@ierigz.waw.pl

Abstract

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Food waste is often mentioned in the context of food security. Meanwhile, the research on the subject of food waste mainly focuses on the *ex-post* management of the food waste (i.e. the waste that *is*, mainly through channelling food waste as a bioenergy source), rather than on the *ex-ante* management (i.e. limiting the amount of food waste *to-be*). Thus, food waste research trends towards energy security, rather than food security. The goal of our research was to identify whether it is a similar case for the Polish research on the topic. We have applied the method of bibliometric analysis using the software RStudio and VOSviewer to identify potential keyword overlap and to identify the common points between food waste and food security in Polish publications.

Keywords: food waste; food security; Poland; bibliometric analysis; keyword co-occurrence; path dependency

Introduction

Food waste results from poor distribution, logistics, storage, or preparation of food (Jungowska et al., 2022; Kwasek and Kowalczyk, 2023), and can be described as "inedible food" (Skawińska and Zalewski, 2022). The difference between food loss and food waste is that the former occurs in the earlier stages of the value chain (e.g. grain which rots on the field), while the latter occurs for the products that already could have been consumed (e.g. bread which is not edible anymore) (e.g. Niedek et al., 2019, Jungowska et al., 2022; Skawińska and Zalewski, 2022, Kwasek and Kowalczyk, 2023). Thus, while food loss occurs in the production and transportation stages, food as waste is being qualified from the retail sales to HoReCa and household consumption (Ankiel and Samotyja, 2020; Łaba, 2020, Żmieńka and Staniszewski, 2020, Jungowska et al., 2021; Kwasek and Kowalczyk, 2023). Żmieńka and Staniszewski (2020) claim that to limit food wastage, both technological and behavioral innovations on different levels of the supply chains have to be implemented. Yet, the data collected on food waste is not uniform around the world, making it more complex to integrate (Ankiel and Samotyja, 2020; Jungowska et al., 2022; Kwasek and Kowalczyk, 2023).

Poland is, by amount, the fifth-largest food-wasting country in Europe, with 42–62% of Poles throwing food away (e.g. Jungowska et al., 2022), and almost 5 million tonnes of food wasted annually (Łaba et al., 2020, Nicewicz and Bilska, 2022). Annually, both globally as well as in Poland, 1⁄3 of food is wasted. Most of the food waste in Poland is produced by households. The main reasons for the wasting of food in Poland are connected to spoilage and not eating the produce on time (Ankiel and Samotyja, 2020; Jungowska et al., 2021; Kwasek and Kowalczyk, 2023; Tomaszewska et al., 2022a; Żmieńka and Staniszewski, 2020). Food waste is an especially relevant problem for countries such as Poland, compared to food losses. Food losses occur mainly in developing countries, where production, storage, and transportation technologies are not as developed, while in the West, food waste occurs mainly in the set, richer nations (Kwasek, 2013; Jungowska, 2022).

As Ankiel and Samotyja (2020) point out, food waste occurs often due to improper planning or storage, resulting in produce spoilage. Thus, food waste prevention research could focus on consumer education (Jungowska, 2022), and on planning and preservation technologies. Especially since the reduction of food waste is an important goal of the Common Agricultural Policy of the EU (Kwasek, 2013). Education on properly handling the products can be especially helpful. As some research has shown (e.g., Tomaszewska et al., 2022a; Nicewicz and Bilska, 2022), proper knowledge about handling food could help consumers to save a larger share of it; as well as promotion of taking unfinished meals home in reusable containers, what is not popular among Poles so far (Tomaszewska et al., 2022b). The research shows that young consumers should be the main target of such campaigns, as they waste most of their food, and over 90% of Polish students admit to wasting food at least once a week (Nicewicz and Bilska, 2022). Nicewicz and Bilska (2022), besides the advantages of raising awareness through education, mention legal amendments, which could improve the utilization of food, thus reducing food waste. Another direction of research could be enhancing the efficiency of food bank activities to improve the food security of people in need, as suggested by Trząskowska et al. (2020), especially since some foods are edible even up to 6 months after assigned durability (ibid.).

Food waste is a consequence of inefficient management of the resources dedicated to its production resources, such as water, land, energy, or labor (Ankiel and Samotyja, 2020; Łaba et al., 2022). The lack of resources puts pressure on the food systems (Li and Song, 2022). If not for the food waste, the world would be able to feed a population of 10 bn people (Kwasel and Kowalczyk, 2023). Successful food waste reduction can bring considerable economic returns (Trząskowska et al., 2020), limit resource use, and enhance food security (Skawińska and Zalewski, 2022). Although the resources used for the production of wasted agricultural goods can be partly redeemed by utilizing them as bioenergy, compost, or even animal feed (Jungowska et al., 2021; Łaba et al., 2022; Żmieńka and Staniszewski, 2020), it is not equivalent. For instance, the use of food waste for bioenergy means the energetic redemption of resources from 10% (Lee et al., 2019) to 90% (Dias et al., 2022). Thus, the full prevention of food waste generation is the most efficient way of resource preservation. Yet, as Żmieńka and Staniszewski (2020) have shown, a greater part of the food waste management scholarship focuses on handling food waste as a bioenergy source. The research so far may also indicate that shifting this focus might be difficult due to the so-called *path dependency*.

In the scientific community functions a long-established concept of *path dependency*, which stems from the neo-institutional school of thought (Kluttz, 2019; Sánchez and Leadem, 2018). It means that the development directions taken so far shape the directions for the future, limiting the possibility of deviating from the established ideas. It can occur in civil service, public and private institutions or companies, politics, as well as in academia. Klutts (2019) suggests the dominance of certain research paradigms in the field of law, attributing it to the strengths of established law reviews. Rodriguez-Esteban (2021) identifies such dependencies in biomedical research through so-called *information silos* (similar to widely known concept of a *knowledge bubble*), i.e. isolated knowledge fields are unable to draw from other research fields which tackle similar problems, simply because they are not aware of their existence. Similarly, Smith (2020) mentions such development in the impact of the human food chain and its impact on human health. Shinagawa (2019) reports on how *path dependency* limits the possibilities within technological development since building on already established foundations is less costly and safer for the industry. Path dependency has been also identified in the fields of agriculture (see: Harmel et al., 2020; Hess et al., 2010; Min et al, 2018; Zaleczna, 2017) and food economics (Thow et al., 2020). However, the research on path dependency in agricultural economics does not analyze the research patterns among the scholarship trends themselves. It is important, as food security often mentions the reduction of food waste production as a goal (see: Ammar et al., 2022), but rarely offers tangible solutions to reach this goal, besides utilizing food waste for other purposes than human nutrition (bioenergy, animal feed, fertilization etc.). Based on the above, we formulate three hypotheses:

H1: Polish scholarship on food waste does not significantly differ from the global trends

H2: Polish scholarship on food waste focuses on the *ex-post* management of food waste, rather than *ex-ante* food waste management

H3: Polish scholarship on food waste, similar to the global one, can be classified more in the field of the energy security rather than food security

The research was conducted with the use of bibliometric analysis. Bibliometric research aims to analyze the research done in a certain field so far (Kumpulainen et al., 2022), as well as to understand trends driving it (Turmuzi et al., 2023). There have been a significant amount of bibliometric studies on both food security (e.g. Akbari et al., 2022; Ammar et al., 2022; Li and Song, 2022), as well as food waste, among these there was Polish research (see: Gorzeń-Mitka et al., 2020; Żmieńka and Staniszewski, 2020).

Materials and Methods

The steps of the analysis were performed as shown in Table 1. The initial results which included keywords "food waste", "food security" and "Poland" provided too small results (13 in WoS and 5 in Scopus, with 100% overlap) to conduct bibliometric analysis, but most of them were used in the literature review. Thus, we performed two separate searches: (1) "food waste" and "Poland", and (2) "food security" and "Poland", without specifying other search criteria, to encompass the whole publication landscape in those areas. Thus, we were able to analyze whether there are overlaps between the research on food waste and food security in Poland. Both search criteria and periods were not specified, as we intended to analyze all the research in these fields so far. Databases Web of Science (WoS) and Scopus were the sources of the data fetching.

Table 1. Five steps of the bibliometric analysis

Step	Action required
1	selection of search criteria (a), keywords (b), time period (c)
2	selection of databases
3	adjustment of the search criteria, outcome filtering
4	result export
5	outcome analysis and discussion of results

Source: own elaboration, based on Ruiz Real et al., 2018 and Turmuzi et al., 2023

Scopus and WoS databases were merged in the software RStudio, with the use of bibliometrix library (Aria and Cuccurullo, 2017). The duplicates were removed by the mentioned software.

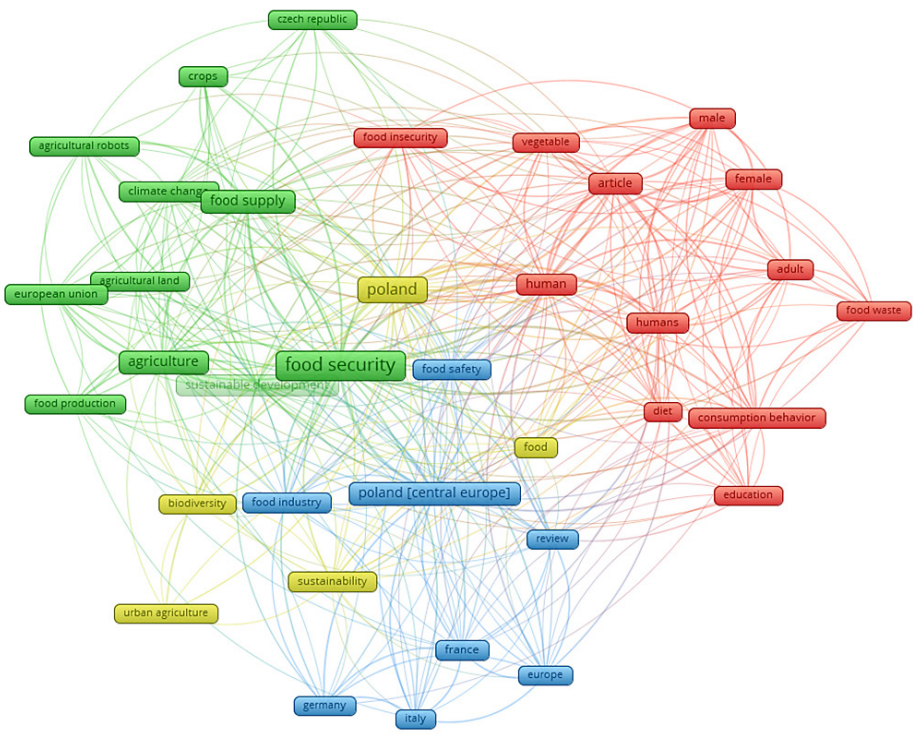
Results and Discussion

(I) "Food security" and "Poland"

For the search of terms "food security" and "Poland", WoS provided 92 papers, while Scopus 93 papers. The Bibliometrix library in RStudio removed 45 duplicates, thus the merged database consisted of 140 documents. First, we performed an *all-keyword* co-occurrence analysis, setting the minimum number of co-occurrences to 5. The software identified 36 keywords that met this threshold, out of 1333 total keywords. The neural network created by the software can be seen on the graphic 1.

The table below (tab. 2) shows clusters around keywords. The software identified four clusters. They are assigned as in the software, with the color corresponding to the graphic 1.

Secondly, we created a network of *author keywords* occurring in research, setting minimum occurrence to 5 words. Out of 554 keywords, 6 met the threshold. Due to the low number of these keywords and space limitations, we present clusters formed by the software only in Table 3.



Graphic 1. Neural network for the search "food security" and "Poland". Own work, from the software VOSviewer

Table 2. *All keywords* in clusters for "food security" and "Poland"

Cluster #	1 (red)	2 (green)	3 (blue)	4 (yellow)
Keywords	adult, article, consumption behavior, diet, education, female, food insecurity, food waste, human, humans, male, vegetable	agricultural land, agricultural robots, agriculture, climate change, crops, Czech Republic, European Union, food production, food security, food supply, sustainable development	Europe, food industry, food safety, France, Germany, Italy, Poland [Central Europe], review	biodiversity, food, Poland, sustainability, urban agriculture

Source: own work, based on the outcomes from the software VOSviewer

Table 3. *Author keywords* in clusters for "food security" and "Poland"

Cluster #	1	2	3
Keywords	food security, Poland, sustainable development	agriculture, European Union	food safety

Source: own work, based on the outcomes from the software VOSviewer

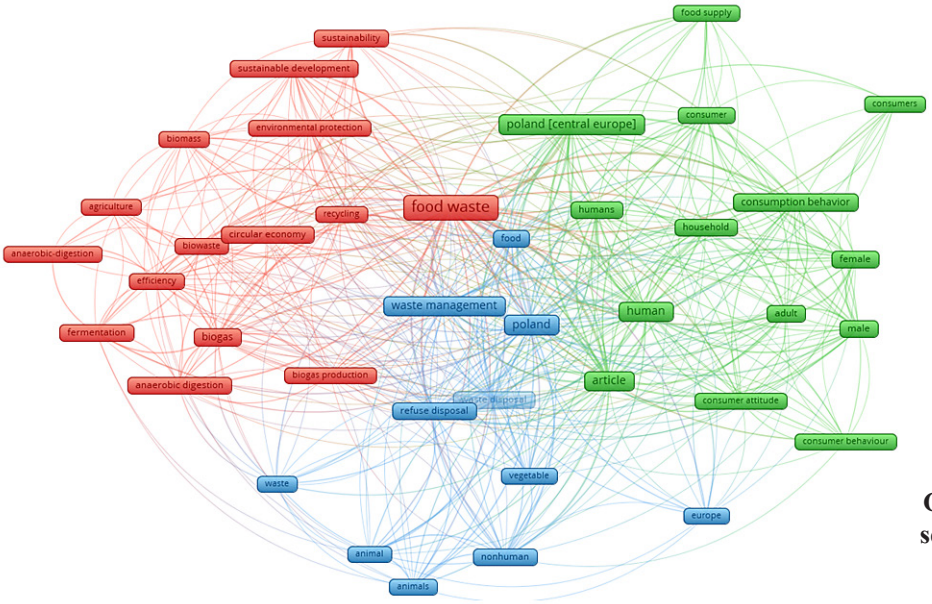
(II) "Food waste" and "Poland"

For the terms "food waste" and "Poland", there were 64 publications in WoS and 87 in Scopus. The removed duplicates amounted to 47, thus leaving the database with 107 single documents. For *all* keyword co-occurrences, the software identified 1142 of them, with 40 meeting the threshold of a minimum of 5 co-occurrences, gathering them in 3 clusters (see: graphic 2). These clusters were formed by the words presented in Table 4.

Last, we created a neural map for *author keywords* for this category. Out of 369 keywords, 9 met the threshold of a minimum of 5 co-occurrences. The software created four clusters for them. As in the first part of the analysis, we present them without the neural network, while the keyword clusters are summarized in Table 5.

Comparing Table 2 and 4, some parallels can be identified. Both relate to food, agriculture, sustainability, and Poland, yet these do not create specific interlinkages between topics of food security and food waste in Poland. The strongest overlapping clusters are presented in the Table 6. Table 2, cluster 1 mentions food waste in the environment of keywords connected to consumer behaviour, overlapping with cluster 2 in the Table 4.

There were also further overlaps, which were not taken into account. Both relate to some human and nonhuman aspects of food production and consumption (consumer behaviour, food waste, biogas, and biodiversity), yet these connections are a result of the commonality of the research field, i.e. food. Also, both relate to Europe and the EU, as well as specific countries like France, Germany etc.).Yet, these are not relevant for our study. Similarly, overlaps in such words as "article" do not indicate any theme overlaps. Although there are researches focusing on the matters of limiting food



Graphic 2. Neural network for the search "food waste" and "Poland". Own work, from the software VOSviewer

Table. 4. All keywords in clusters for "food waste" and "Poland"

Cluster #	1 (red)	2 (green)	3 (blue)
Keywords	agriculture, anaerobic digestion, anaerobic-digestion, biogas, biogas production, biomass, biowaste, circular economy, efficiency, environmental protection, fermentation, food waste, recycling, sustainability, sustainable development	adult, article, consumer, consumer attitude, consumer behavior, consumers, consumption behavior, female, food supply, household, human, humans, male, Poland [Central Europe]	animal, animals, Europe, food, nonhuman, Poland, refuse disposal, vegetable, waste, waste disposal, waste management

Source: own work, based on the outcomes from the software VOSviewer

Table. 5. *Author keywords* in clusters for "food waste" and "Poland"

Cluster #	1	2	3	4
Keywords	biowaste, circular economy, waste management	consumers, food waste, Poland	anaerobic digestion, biogas	consumer behavior

Source: own work, based on the outcomes from the software VOSviewer

waste occurrence, it might well be that these will stay outside of the main research focus.

Regarding *author keywords*, no keywords were overlapping in the research on food security and food waste in Poland. It means, that there were no main themes, which would occur in both research fields, i.e. there were no overlaps in themes which were relevant so much that authors would include them in the keywords of their research (with minimum occurrence in 5 papers). Surprisingly, "consumer behavior" from cluster 4 was not assigned to cluster 2 (table 5).

We conclude that majority of the Polish scholarship on food waste so far, tackles the topics of water and energy security rather than food security, i.e. research on the already produced waste rather than mitigating the occurrence of newly produced food waste. Building on the results provided by Gorzeń-Mitka et al. (2020), the results we have obtained were similar. It could imply the path dependency in the thematic engagement of the scholarship. Similarly have indicated Żmieńka and Staniszewski (2020), that most of the research points towards handling food waste as an energy-producing biomass.

Klotts (2019) suggests that the persistent grip of the path dependence on the research can be loosened with the development of the interdisciplinary research (as for what can be transplanted from the research on the legal scholarship into the field of agricultural and food economics). Similarly, Harmel et al. (2020) call for transdisciplinary collaboration, in which data could be analyzed by experts in different fields, teaching software to analyze it from different angles. Indeed, Skawińska and Zalewski (2022), present such a holistic approach in their research, integrating the concepts of food loss and food waste into FAO's Water-Energy-Food (W-E-F) Nexus. For instance, they cite other research (Bowen et al.), in which food loss and waste play an integrating role in sustaining different elements of the W-E-F Nexus: the waste (F) supports the generation of the biofuels and biogas (E), while (E) maintains transportation and fertilization of (F). While this system supports partial redemption of the sunk costs, it does not prevent losses altogether.

Table. 6. *All keywords* cluster comparison

Overlapping words	Not overlapping (Tab. 2, cl. 1)	Not overlapping (Tab. 4, cl. 2)
adult, article, consumption behaviour, female, human, humans, male	diet, education, food insecurity, food waste, vegetable	consumer, consumer attitude, consumer behavior, consumers, food supply, household, Poland [Central Europe]

Source: own analysis

Bernhard (2015) claims that change of the dominating paradigm can occur in the instance of the instability of the ruling paradigm, defining stability as the state in which the cost of sustaining the ruling paradigm outweighs the cost of disturbing it for the participants involved. For the case of limiting food waste to preserve food security, it would mean that the societal expense of *ex post* waste management (i.e. using it as the fuel for biogas) would have to be higher than the expense of *ex ante* waste management (i.e. limiting the amount of the food wasted). Moreover, the material in the category "food loss" is able to provide a significant material for the energy creation, as occurring on the earlier stages of the food chain, these losses are unable to be consumed by people and have to be handled in a different way.

Similarly as Goldstein et al. (2023) described path dependency in the energy sector regarding the dominance of fossil fuels over bioenergy, there can be a similar path dependency in the food waste research, i.e. most of the scholarship focusing on the management of the food waste already after the food became the waste. Especially, that significant amount of research has shown that in some cases energy security and food security can compete, as agricultural produce can be either channeled towards food consumption or towards the biofuel production, as well as due to the resource scarcity and land constraints (see e.g., Martínez-Jaramillo et al., 2019).

Conclusion

To our knowledge, this is the first research that identifies path dependency in the field of food waste. From the data we have gathered, following conclusion can be drawn. Although there are overlaps in the jargon used in both research on food security and food waste (all keywords), there is no overlap in the main themes (author keywords), i.e., most of the Polish research on food security does not focus on the topics of the food waste, and most of the Polish research on food waste does not focus on the questions of food waste. On one hand, it shows that both research themes are stuck in their information silos. On the other, as both research fields use similar jargons and methods (e.g., research on consumer choices), it may be easier to merge these information silos, and to effectively exchange information between both research fields. Thus, we confirm all of the hypotheses stated in our research.

Such situation can be qualified as the so-called path dependency, and the direction the scholarship (globally) takes in the fields of food waste. The solution to the questions of merging both fields could be establishment of interdisciplinary research teams. The change can also appear wit the greater need of food preservation, which would outweigh the possibility of the cost redemption through using food waste for energy generation, animal feed, fertilization etc. This possibly could balance the discrepancies between the goals of food security and energy security in the context of food waste.

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Annex 1. Search criteria and links for the searches (for the reviewers)

WoS – Search within: Topic

"Food security" and "Poland"

https://www.webofscience.com/wos/woscc/summary/2ecbe4bf-dd3a-4161-99fb-43ee7a5ce19f-ae9fae1e/relevance/1.

"Food waste" and "Poland".

https://www.webofscience.com/wos/woscc/summary/3e2e788fd159-4a9c-ab14-304cc4392d47-ae9fb68b/relevance/1.

Scopus – Search within: Article title, abstract, keywords.

"Food security" and "Poland".

https://www.scopus.com/results/results.uri?sort=plf-f&src=s&st1=%22food+security%22&st2=Poland&sid=cfc63b4d1e4dc4d8708499d6a5eb510d&sot=b&sdt=b&sl=58&s=%28TITLE-ABS-KEY%28%22food+security%22%29+AND+TITLE-ABS-KEY%28Poland%29%29&origin=searchbasic&editSaveSearch=&yearFrom=Before+1960&yearTo=Present&sessionSearchId=cfc63b4d1e4dc4d8708499d6a5eb510d&limit=10.

"Food waste" and "Poland".

https://www.scopus.com/results/results.uri?sort=plf-f&src=s&st1=%22food+waste%22&st2=Poland&sid=f196f4d9b9946abeb84abfcdefcecfd3&sot=b&sdt=b&sl=55&s=%28TITLE-ABS-KEY%28%22food+waste%22%29+AND+TITLE-ABS-KEY%28Poland%29%29&origin=searchbasic&editSaveSearch=&yearFrom=Before+1960&yearTo=Present&sessionSearchId=f196f4d9b9946abeb84abfcdefcecfd3&limit=10.

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