Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 23, Issue 3, 2023
PRINT ISSN 2284-7995, E-ISSN 2285-3952

DEVELOPING AN INTEGRATED MODEL ON FOOD WASTE CONSUMER BEHAVIOUR IN ROMANIA

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Abstract

Food waste is one of the most unusual behaviours related to economic systems located on the agrifood chain. In this matter, the study of the food waste and the mechanisms that lead to its development are complex and rooted within several components of the human behaviour and economic system dynamic. In this paper, we propose the development of a model which presents the dynamics of the phenomenon based on several cause-effect relationships between aspects of human behaviour and economic aspects. The model is built using a Systems Dynamic (SD) approach, based on the identification of connections between identified causes and effects and the determination of the ontologic and mathematical nature of the connections.

Key words**:** *food waste, food behaviour, agrifood chain, human behaviour*

INTRODUCTION

Food waste is a global problem that has a significant negative impact on the environment [1], the economy [7]and human health [9]. Studies developed by the Food and Agriculture Organization of the United Nations (FAO) claim that a third of all the food that is produced every year worldwide is lost or wasted. The quantity related to this proportion equates about 1.3 billions tons of food, which should be a sufficient quantity to feed about 2 billion people [8], [10].
An approach for the phenomenon of food loss and waste must be multidisciplinary in order for this to be solved [8]. The first step of this approach would be the understanding of the causes of food waste and their implementation in practice [5]. In this way, the impact of food loss and waste on the environment, the economy and human health [14] could be reduced. One of the solutions of the reduction of the food loss and waste can be circular economy [3, 4, 13, 15].
The main purpose of this paper is the presentation of the main causes of food loss and waste (FLW) along the agrifood chain, using tools specific to System Dynamics (SD). In this matter, a model based on the agrifood chain is presented. In order to build the model, we have run a bibliographic study in order to establish several terms and topics related to food waste and to determine principal causes for the phenomenon [16].

MATERIALS AND METHODS

The main purpose of the research is to determine the causality of various factors on the food waste phenomenon. In this matter,

for the accomplishment of this purpose, several objectives are established:
O1. The identification of the main factors that influence food waste in Romania
O2. The assessment of the extent to which the identified factors impact food waste
O3. The description of the model framework and structure (parameters and relationships between them)
The research has a methodology which is based on the development of the model framework and structure. This methodology comprises several steps:
S1. The formulation of a bibliographic study related to the food waste factors:
(a)the completion of a search of research papers and studies within a research database;
(b)the mapping of the results from the previous sub-step using a mapping software;
S2. The identification of the factors that cause the food waste and their model-based nature;
S3. The classification of the factors in several groups related to economic and social, collective and individual aspects;
S4. The determination of the quantitative and qualitative relationships between the factors;
S5. The establishment of the model structure and the generation of its results[6].
During the development of the research, several tools will be used. These tools are related to the phase of the research:
-for the bibliographical study, the Dimensions.ai database will be used, alongside VOSViewer software [19]to map the database search result;
-for the identification of the factors, a qualitative research method in form of documentation and analysis will be made;
-for the establishment of the model framework and structure, tools related to System Dynamic method will be used: causal loop diagrams, stock-flow diagrams (in the future research papers) using specific software (Vensim) [17].

RESULTS AND DISCUSSIONS

A bibliographic study

The food waste phenomenon is greatly influenced by a numerous number of factors, one of the most important being related to the economic aspects of food production [16].
The literature shows a great deal of interest in various fields related to food, starting from the biological implications of food waste and including agrifood chain [10], consumer behaviour [11], and policy-based perspectives of the food waste phenomenon[6].
In order to formulate a wider image of the issue, we have formulated a bibliographic study for which we have followed the next steps:
(1)the determination of the study parameters and objectives: for the database, we have used Dimensions.ai academic database (Digital Science, 2018) and we have aimed the attainment of the main concepts used in the research papers, as well as a geographical and institutional distribution of the research initiatives related to food waste; [2].
(2)the determination of the search terms within the database: three terms were established which were determined in relation of inclusion between them:
(a)“food waste”: includes all documents related to food waste;
(b)“food waste AND economy”: this term includes documents related to economic aspects of the food waste;
(c)“food loss”: includes documents focused on consumer behaviour [7], [11].
(3)the mapping process of the obtained search results, using VOSViewer software for the described objectives, with the results in form of concept graphic mapping, term relevance, their number of occurrences and geographic and institutional distribution. The mapping was run for two instances: minimum 10 and minimum 100 number of occurrences of terms within the papers.
The two terms (food loss and food waste) were studied separately because, although they refer to the same process, several subtle differences are established [12].
Food loss is considered to be an unexpected reduction of the quantity and quality of food, both in pre-harvest, post-harvest or production

of food, while food waste is concentrated during the distribution and consumption phases in the agrifood chain. Thus, studying the two terms can offer a broader image of the phenomenon [13].

Firstly, we will present the structure of research types for the three terms. These are presented in Table 1.

Table 1. Research types related to food waste

	Publications	Datasets	Grants	Patents	Clinical trials	Policy documents	Total
food waste	161,684	446	1,870	91,401	26	5,607	
food waste AND economy	78,934	23	195	5,639	1	4,035	
food loss	18,797	50	181	2,607	5	1,971	
Total							

Source: Dimensions.ai [2].

The main domains that were related to the three search terms were connected to Engineering, Agriculture, Biological Sciences, Chemistry, Environmental Sciences, Human Society and Food Sector, as presented in Table 2. Depending on the search term, the amount of research entities (paper, datasets etc.) was different for the given domain and changes in the domain list also were present.

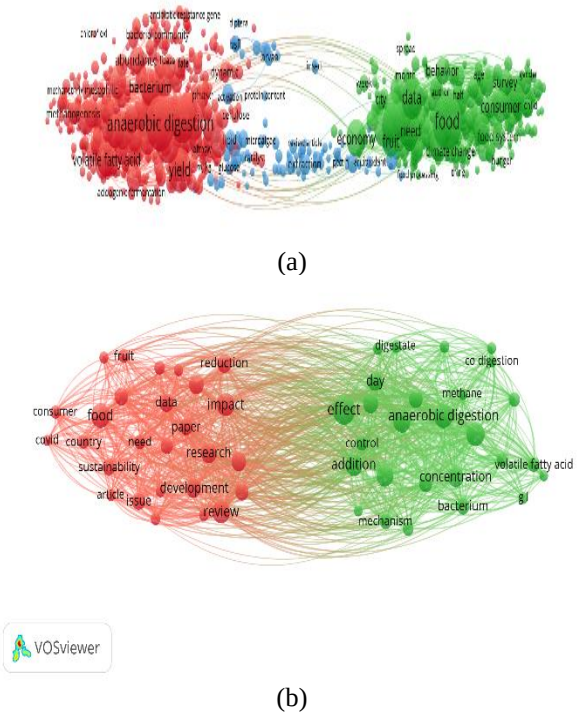
Table 2. Domains related to selected papers

	food waste		food waste AND economy		food loss	
	Domain	Research entities	Domain	Research entities	Domain	Research entities
	Engineering	44,925	Engineering	16,927	Agricultural, Veterinary and Food Sciences	5,329
	Agricultural, Veterinary and Food Sciences	26,488	Environmental Sciences	10,322	Environmental Sciences	2,600
	Biological Sciences	24,749	Agricultural, Veterinary and Food Sciences	9,491	Engineering	2,402
	Chemical Engineering	24,437	Biological Sciences	8,474	Food Sciences	2,307
	Environmental Sciences	20,778	Human Society	8,408	Human Society	2,236
Total						

Source: Dimensions.ai[2].

The more generic term „food waste" was related to domains closer to STEM-based domains, which included topics related to the production of food, the chemistry of food and biological and environmental aspects of food waste phenomenon. For the other two, the human factor and agricultural aspects of the issue gained in importance.

We will present the results based on the search term. The results obtained in form of term mapping diagram for the first term are shown in Figure 1.



(a)

(b)

Fig. 1. Graphical mapping of the search results for the term "food waste" with a threshold of minimum (a) 10 occurrences of terms; (b) 100 occurrences of terms
Source: Own determination.

As we can observe, the mapping process of the search results showed the classification of research topics into three (for 10 occurrences) and two (for 100 occurrences) clusters. For the first case, the clusters were determined based on their closeness to specific domains:

-biological domain: anaerobic, digestion, bacterium, fatty acid;

-chemistry-based domain: glucose, lipid, catalyst, pectin, antioxidant;

-agriculture-based domains (agriculture, economy, environment): food, consumer, economy, climate change, hunger, food processing.

For the second case, the clusters were determined based on their closeness to specific domains:

-nature-related domains: anaerobic, digestion, mechanism;

-agriculture-based domains: consumer, development, sustainability.

The terms with the highest number of occurrences for this search term "food waste" is presented in Table 3.

Table 3. The terms with the highest number of occurrences for the search term "food waste"

No.	Term	Occurrences	Relevance
1	effect	740	0.2195
2	food	525	1.7098
3	anaerobic digestion	522	0.8106
4	yield	494	1.1713
5	impact	478	0.3556
6	review	472	0.4951
7	addition	450	0.2390
8	performance	442	0.5071
9	condition	424	0.4106
10	concentration	360	0.9870

Source: Dimensions.ai [2].

The relevance of a term is determined as the specificity of the term. In this matter, using a relevance index separates the usual, more common and frequent terms to terms that are specific to the searched domain. The terms with the highest relevance for the term "food waste" were "covid", "consumer", "volatile fatty acid" and "country".

Next, Table 4 presents the world countries that have the most research entities on the term. The Total link strength attribute indicates the total strength of the co-authorship links of a given researcher with other researchers.

Table 4. The countries with the highest number of research entities for the search term "food waste"

No.	Country	Documents	Citations	Total link strength
1	China	898	13,669	535
2	United States	270	4,139	262
3	India	199	4,245	269
4	Italy	195	2,673	151
5	South Korea	159	3,664	205
6	Spain	138	2,085	133
7	United Kingdom	129	2,129	205
8	Australia	105	1,603	141
9	Malaysia	99	1,990	149
10	Canada	91	1,339	71

Source: Dimensions.ai [2].

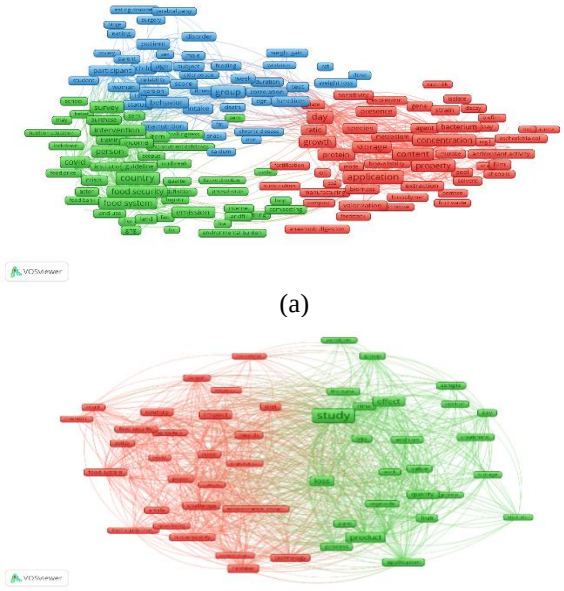
The results obtained in form of term mapping diagram for the second term are shown in Figure 2.

As we can observe, the mapping process of the search results showed the classification of research topics into three (for 10 occurrences) and two (for 100 occurrences) clusters. For the first case, the clusters were determined based on their closeness to specific domains:

-biological and chemistry-based domain: protein, species, concentration, microbe;

-human-based domain: group, correlation, behaviour, reliability, eating;

-agriculture-based domains (agriculture, economy, environment): food security, food system, food price, crisis, emission.



(a)

(b)

Fig. 2. Graphical mapping of the search results for the term "food waste AND economy" with a threshold of minimum (a) 10 occurrences of terms; (b) 100 occurrences of terms

Source: Own determination.

For the second case, the clusters were determined based on their closeness to specific domains:

-human-related domains: study, participant, quality, product;

-agriculture-based domains: food system, food supply chain, sustainability, environmental impact.

The terms with the highest number of occurrences for this search term "food waste AND economy" is presented in Table 5.

The terms with the highest relevance for the term "food wasteabd economy" were "pandemic", "covid", "shelf life", "day" and "food system".

Next, Table 6 presents the world countries that have the most research entities on the term.

Table 5. The terms with the highest number of occurrences for the search term "food waste AND economy"

No.	Term	Occurrences	Relevance
1	study	1,215	0.3332
2	product	589	0.3655
3	loss	577	0.1046
4	effect	572	0.5190
5	impact	445	0.4129
6	review	380	0.3920
7	quality	369	0.6998
8	time	354	0.3739
9	value	350	0.6766
10	health	336	0.3075

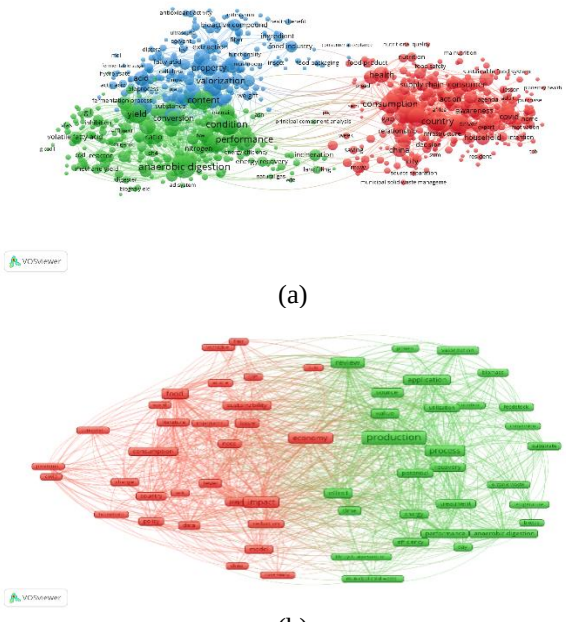
Source: Dimensions.ai [2].

Table 6. The countries with the highest number of research entities for the search term "food waste AND economy"

No.	Country	Documents	Citations	Total link strength
1	United States	569	22,903	442
2	China	307	6,564	337
3	Italy	223	7,471	267
4	United Kingdom	193	11,373	334
5	Spain	155	4,763	160
6	India	129	1,586	145
7	Australia	128	5,922	190
8	Germany	109	7,313	197
9	Brazil	99	1,675	100
10	Canada	88	2,441	101

Source: Dimensions.ai [2].

The results obtained in form of term mapping diagram for the third term are shown in Figure 3.



(a)

(b)

Fig. 3. Graphical mapping of the search results for the term "food loss" with a threshold of minimum (a) 10 occurrences of terms; (b) 100 occurrences of terms
Source: Own determination.

As we can observe, the mapping process of the search results showed the classification of research topics into three (for 10 occurrences) and two (for 100 occurrences) clusters. For the first case, the clusters were determined based on their closeness to specific domains:
-biological and chemistry-based domain: acid, bioactive compound, property, fermentable sugar, food industry;
-food industry domain: yield, conversion, condition, ratio, performance;
-economic-based domains: consumption, country, health, supply chain, sustainable food system.
For the second case, the clusters were determined based on their closeness to specific domains:
-economic-based domains: economy, impact, consumption, policy;
-food industry domains: production, process, review, performance, potential.
The terms with the highest number of occurrences for this search term "food loss" is presented in Table 7.

Table 7. The terms with the highest number of occurrences for the search term "food loss"

No.	Term	Occurrences	Relevance
1	production	1,003	0.2997
2	process	714	0.5767
3	impact	669	0.2626
4	review	632	0.1707
5	food	614	0.9258
6	economy	570	0.0292
7	effect	529	0.0789
8	value	504	0.2449
9	application	499	0.5141
10	source	460	0.3155

Source: Dimensions.ai [2].

The terms with the highest relevance for the term "food loss" were "pandemic", "covid", "consumer", "household" and "change".
Next, Table 8 presents the world countries that have the most research entities on the term.
The dedicated term used in the literature for the food waste made during the entire agrifood chain is known as Food Loss and Waste (FLW). In this matter, we can observe that food loss is mainly referred as food that is lost during the entire process and includes biological and health-based aspects of wasting food.

Table 8. The countries with the highest number of research entities for the search term "food loss"

No.	Country	Documents	Citations	Total link strength
1	China	586	13,408	615
2	Italy	321	7,221	225
3	India	268	7,803	428
4	United States	239	6,374	319
5	United Kingdom	223	9,071	351
6	Spain	221	3,817	200
7	South Korea	141	5,442	255
8	Australia	114	3,114	173
9	Germany	101	2,672	182
10	Malaysia	100	2,986	176

Source: Dimensions.ai [2].

Food waste, according to the bibliographic study, mainly refers to agricultural production and human-centered factors, such as behaviour, buying patterns and purchasing power.

The main terms that were determined for all the search terms are related mainly on the production efficiency, the human economic behaviour, the agrifood chain, the economic food system and the impact of the health hazards or dangers on the food industry and consumption. Additionally, we can state that the largest amount of studies in respect to their number is documented in countries such as China, India, United States and Italy, examples of countries where socio-economic conditions lead to significant challenges. Thus, the concern related to food waste research is considered extremely important, due to its effects on national economies and global market.

Factors determination

In order to determine a comprehensive list of the factors that influence the food loss and waste, we will use the results of the bibliographic study and aspects related to literature. Related to the previous research, we can determine several categories of factors, as follows:

-behavioural factors, related to human individual behavioural patterns and reactions;

-demographic factors, related to societal behavioural patterns and trends;

-biological factors, related to the food composition and natural processes;

-policy-based factors, related to rules and regulations, as well as campaigns related to food behaviour;

-economic factors, related to agrifood chain, from food production to food consumption.

Related to the placement of factors within the agrifood chain, classified in the latter category, we can define the next checkpoints:

(a)food production, where several factors related to the agricultural production are considered;

(b)processing, where raw materials obtained in the first phase are transformed by a series of processes in refined food;

(c)packaging [18], where processed food is prepared for sale;

(d)logistics, where the food is handled from the producer to the processer and then to the distributor;

(e)distribution, where food is brought close to the final point, to the consumer;

(f)consuming, where food is consumed [18].

The model will be presented based on the linear structure of these checkpoints, taking into consideration the categories of factors and their major influence on the food loss and waste phenomenon. A list of the factors classified on the taxonomy presented previously is shown in Table 9.

Table 9. The list of factors taken into consideration for the model structure

No.	Category	Factor	
1	Behavioural	Buying patterns Habits Attitudes Subject norms Educational background	
2	Demographic	Age Number of members in household Region	
3	Biological	Food perishability External biological agents (e.g., COVID-19 pandemic, food toxins, bacteria, viruses)	
4	Policy	Social policies related to food waste Economic policies related to income	
5	Economic	Producer	Productivity Management type
		Processing	Number of processing phases Quality standards
		Packaging	Package parameters
		Logistics	Logistic parameters Storage
		Distribution	Promotions Sales volume Low prices
		Consuming	GDP per capita Income

Source: own determination.

For the mentioned parameters in Table 9, we have also added several variables that complete the model and connect several parameters and which will be presented in the next subsection.

Model framework and structure

The present model is created based on the parameters presented in Table 9 and the relationships between these parameters. One of the results is the obtaining of a causal loop diagram, shown in Figure 4, where the parameters were connected in order to establish a causal influence related to food waste. To further detail the model, a stock-and-flow diagram will be projected, in order to determine the quantitative aspects of the food waste phenomenon, based on the agrifood chain phases. The causal loop diagram presented in Figure 4 was created using the Vensim software and presents the most important parameters delimited in Table 9 in respect to the agrifood chain phases. The blue arrows indicate a positive influence, the red ones a negative influence and the green ones indicate a mixed influence, based on the context of the model. In future researches, the green arrows will be detailed and transformed in either positive or negative dependencies.

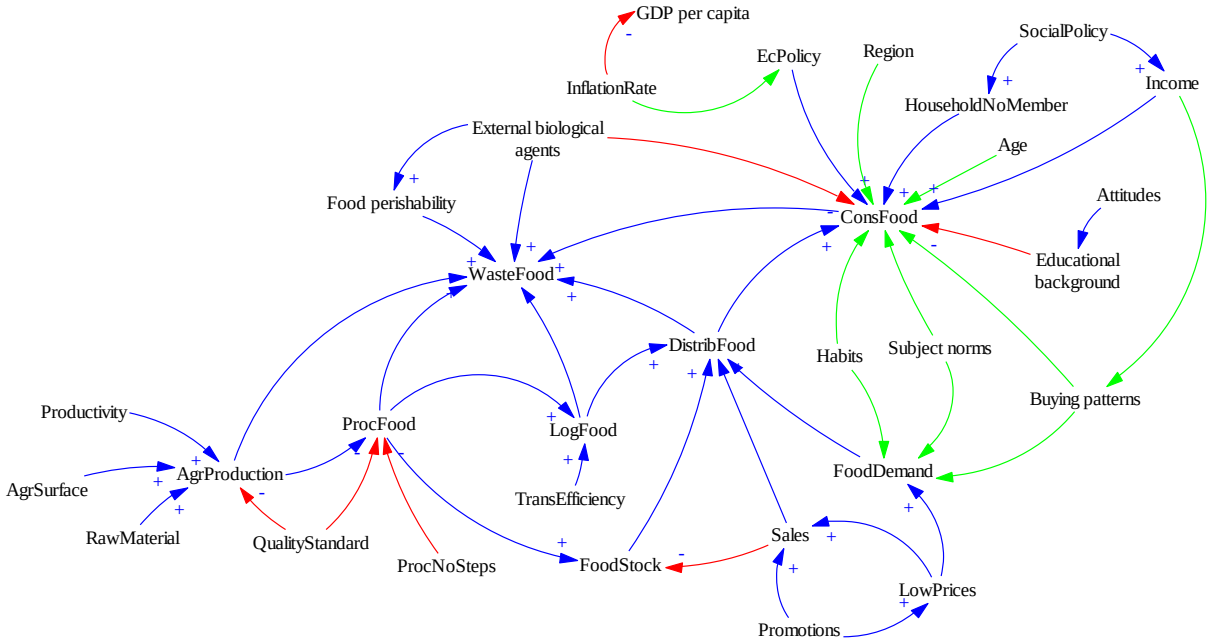


Fig. 4. The causal loop diagram for the considered food waste model
Source: Own determination.

This model illustrates the complex agri-food chain and its interactions related to food waste. The chain starts with agricultural production (AgrProduction) and raw materials and goes through food processing (ProcFood), distribution (LogFood) and retail sales (DistribFood) to consumers (ConsFood). Food waste (WasteFood) is influenced by many factors, including processing and distribution efficiency, food stocks, food demand and consumer behavior. In turn, food waste affects inventory, costs and waste awareness. Farmers, as producers of raw materials, have a significant impact on the entire agri-food chain. The analysis of the feedback and interactions leads to the highlight of the need for effective resource management, a more effective collaboration between the actors and processes on the all levels of the agri-food chain and a consumer educational background which will permit the reduction of food waste amount with socio-economic and environmental benefits.

CONCLUSIONS

Food wastage is a multifaceted issue with substantial social, economic, and

environmental consequences. It arises from a variety of interrelated factors that operate across various levels of the agricultural and food supply chain. These include inefficient agricultural production, inadequate production and distribution processes, strict aesthetic standards, consumer behaviour and poor inventory management.

Overall, combating food waste requires a holistic approach that considers the entire agri-food chain and involves the collaboration and commitment of all actors involved, from producers and processors to consumers and policy makers.

Future work is related to the development of the current model, by adding detail levels on the causal loop diagram, and by formulating a stock-and-flow diagram that would quantify the food loss and waste phenomenon in terms of volumes and their influence.

ACKNOWLEDGEMENTS

This work was supported by a grant of the University of Agronomic Sciences and Veterinary Medicine of Bucharest, project number 2023-007 acronim **ReWaFA**, within IPC 2023.

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