proceedings

MDPI

Proceeding Paper

On Transforming FoodEx2 to a Standardized and Interoperable Thesaurus †

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† Presented at the 11th International Conference on Information and Communication Technologies in Agriculture, Food & Environment, Samos, Greece, 17–20 October 2024.

Abstract: Food resource management plays a pivotal role in addressing global challenges related to food security, sustainability, public health, and economic development. To facilitate the collection and identification of food resources, various collections and systems have emerged from the scientific community. One such system is FoodEx2, which has been developed by the European Food Safety Authority and is used for classifying and describing food-related information. In this paper, we describe how FoodEx2 can be transformed into a standardized thesaurus using well-established technologies and standards that enhance its interoperability and exchange of data resources. The new thesaurus also promotes its usage through the adoption of unique and global identifiers for its contents and through a variety of tools that can be used for accessing and visualizing it. In addition, we describe how the thesaurus can be reconstructed from the original sources as they evolve.

Keywords: thesaurus; FoodEx2; SKOS; taxonomy; semantic web

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Published: 18 April 2025

Citation: Marketakis, Y.; Kritsotaki, A.; Axaridou, A.; Fafalios, P.; Mountantonakis, M.; Tzitzikas, Y. On Transforming FoodEx2 to a Standardized and Interoperable Thesaurus. *Proceedings* **2025**, *117*, 6. https://doi.org/10.3390/proceedings2025117006

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1. Introduction

Food resource management involves the strategic planning, utilization, and conservation of food-related assets to ensure the sustainable production, distribution, and consumption of food. It encompasses various aspects such as agricultural practices, food processing, storage, transportation, and distribution systems, as well as policies and regulations governing food production and consumption. To support all these functions, the relevant authorities are collecting massive amounts of information that has to be analyzed, such as food intake information that is collected using dietary surveys. This is a rather cumbersome activity, since there are many different ways of collecting and referring to food resources (e.g., survey participants report their food intake in a very different way to the way in which researchers classify it).

To overcome such variations, the European Food Safety Authority (EFSA) (https://www.efsa.europa.eu/en, accessed on 17 April 2024) has developed a sophisticated classification and food description system, called FoodEx2 [1]. It is designed to facilitate the harmonization and categorization of food-related data, making it easier to collect, manage, and analyze information related to food and dietary needs. Furthermore, there are tools to facilitate accessing and searching the FoodEx2 data, such as

EFSA's Catalogue Browser (https://github.com/openefsa/catalogue-browser, accessed on 17 April 2024).

Although it is a valuable and exhaustive source of information, it was implemented using its own custom schema, without relying on knowledge organization systems that provide improved interoperability and support for resource exchange and integration. In this work, we rely on SKOS [2] as the conceptual backbone for describing FoodEx2. The result of this process has numerous benefits, including sharing and integration with other knowledge organization systems, improved machine interpretability, the use of public global unique identifiers, homogeneous and effective exploration of resources, increased reusability, maintenance flexibility, etc. Furthermore, to support the evolution of FoodEx2 over time, we describe the details of a workflow that automatically constructs the SKOS-based version of FoodEx2.

The rest of this paper is organized as follows: Section 2 provides some background information, Section 3 elaborates with the details of constructing SKOS-FoodEx2, and Section 4 concludes and identifies future activities.

2. Background

In this section, we provide some information about FoodEx2 (Section 2.1) and SKOS (Section 2.2).

2.1. FoodEx2

FoodEx2 [1] is a standardized system that is used for the classification and description of food products, designed to facilitate the collection, analysis, and sharing of food consumption data across European countries. It provides a hierarchical structure for categorizing food items based on various attributes such as the food group, sub-group, and specific food product. This classification system enables the harmonization and interoperability of food data, allowing for consistent comparison and analysis of dietary habits and exposure to different nutrients, contaminants, and other food-related factors. Central to the system is a core list of food items or generic food descriptions that represent the minimum level of detail that is needed for intake or exposure assessments. More detailed terms can be found on the "extended list". A parent–child relationship exists between a core food item and its related extended list of food items. The terms of the core and extended list may be aggregated in different ways according to the needs of the different food safety domains.

The latest version of FoodEx2 (by the time of writing this paper (April 2024), the version was 15.0) has seven hierarchies: five domain-specific ones, one general-purpose, and one that is used for management purposes. Figure 1 shows the detailed hierarchy and the details of the term *Lager beer*, as it is shown through EFSA's Catalogue Browser.

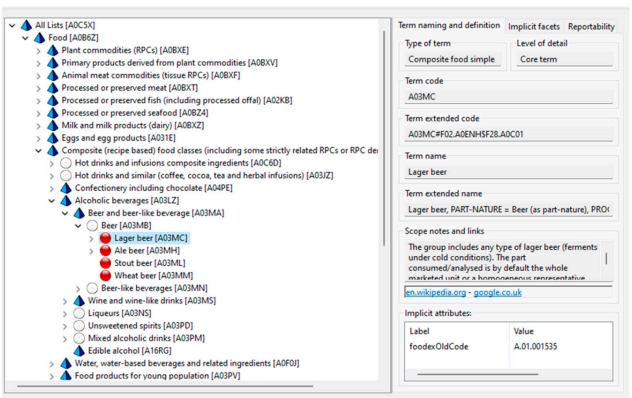

Figure 1. Details and hierarchy of the term with FoodEx2 code A03MC (Lager beer) from the EFSA Catalogue Browser.

2.2. Simple Knowledge Organization System (SKOS)

SKOS is a standardized vocabulary that is used to represent and structure knowledge organization systems, such as thesauri and taxonomies. It provides a framework for expressing hierarchical relationships between concepts, facilitating the organization and categorization of information. SKOS enables the assignment of preferred and alternative labels to concepts, making it easier to standardize terminology and enhance information retrieval. It also supports the representation of various types of relationships between concepts. It is expressed in RDF [3], ensuring compatibility with the semantic web [4] and promoting interoperability across different knowledge management systems. SKOS is widely used in libraries, archives, museums, and information retrieval systems to improve the navigation and discovery of information resources. The vocabulary of SKOS includes various elements that work together to represent knowledge organization systems; the basic ones are as follows:

- skos:Concept, any unit of thought, for example an idea, an object, or an event;
- *Labels*, which are descriptors of a concept (i.e., skos:prefLabel, skos:altLabel, skos:hiddenLabel).
- skos:Collection, for grouping SKOS concepts.
- *Relationships* are used for asserting the kinds of relationships (hierarchical/associative) between concepts, such as skos:broader and skos:narrower for hierarchical relations or skos:related, which is used for an unspecified association between two concepts.
- *Notes*, which are used for documentation purposes. SKOS provides various properties with different semantics including, skos:note, skos:definition, skos:example, and others.

3. Construction of SKOS-FoodEx2

In its original form, FoodEx2 is modeled as a relational database which is encoded in XML so that it can be easily exchanged. Furthermore, FoodEx2 is constantly evolving, with new terms being added, others being updated, etc. Given the way in which it is technically implemented, it is poor in terms of interoperability reuse. These factors necessitate the creation of a standardized representation of FoodEx2. Our aim is to provide an enhanced interoperable version of FoodEx2 and at the same time support its evolution. For this reason, we implemented a technical workflow to construct and support its maintenance as well. The workflow relies on the definition of schema mappings between the original custom schema of FoodEx2 and SKOS. Practically, those mappings describe how each resource that is found in the original FoodEx2 version will be "translated" into a resource that has been described using SKOS. Schema mappings were described using X3ML mapping specification language [5]. Figure 2 shows an indicative example of a schema mapping (X3ML schema mappings were implemented using 3M Editor (https://demos.isl.ics.forth.gr/3m/), accessed on 17 April 2024), specifying that all elements that can be found in the source XML (path/message/catalogue/catalogueTerms/term) will be mapped as instances of skos:Concept.

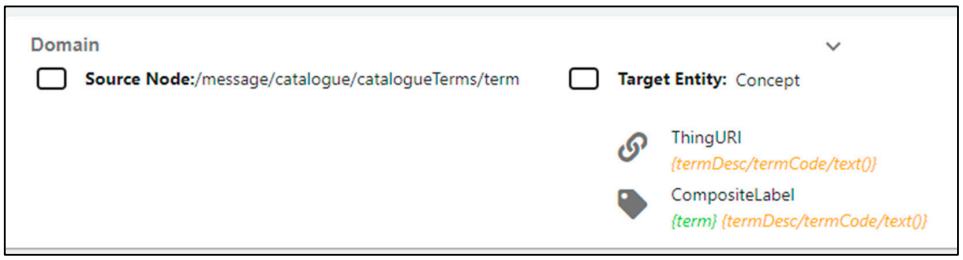

Figure 2. Indicative screenshot of X3ML mapping definition for FoodEx2 terms.

Apart from the schema mappings themselves, X3ML was also used to define how identifiers and values will be generated (e.g., the term code in the example of Figure 2). Compared to FoodEx2, which provides codes for terms (i.e., as shown in Figure 1, the code for *Lager beer* is **A03MC**), the SKOSified version will rely on Uniform Resource Identifiers (URIs) [6]. URIs are used to uniquely identify resources and are fundamental for addressing and accessing web resources. The chain icon in Figure 2 describes which parts of the original input will be used for constructing the URI. Eventually, SKOS-FoodEx2 will have identifiers of the form http://data.europa.eu/k36/A03MC (the form of the URIs was chosen by EFSA).

The use of URIs is already a big step towards interoperability and resource exchange, since users referring to a term will rely on a public, global, and non-ambiguous URIs, instead of a five-digit code that can only be interpreted in the context of the FoodEx2 database. In addition, URIs can also be made resolvable so that humans can see them using their web browser and obtain more details about them. Moreover, it has the potential of further connecting to other publicly available resources or knowledge organization systems. One indicative scenario is the linkage with other similar resources (for example http://purl.obolibrary.org/obo/FOODON_03543333 (accessed on 17 April 2024) from FoodOn [7] refers to the same term as A03MC from FoodEx2) using OWL sameAs [8] links.

Finally, Figure 3 illustrates the automatic workflow that supports the construction of SKOS-FoodEx2. The workflow utilizes the X3ML framework [5]. It takes as input the original version of FoodEx2 and the schema mappings in X3ML, and it produces the SKOSified version. The workflow is fully automatic, and it can be updated whenever a newer version of FoodEx2 is released. In the rare case of changes in the schema of FoodEx2, updating X3ML mappings before the execution of the workflow is required.

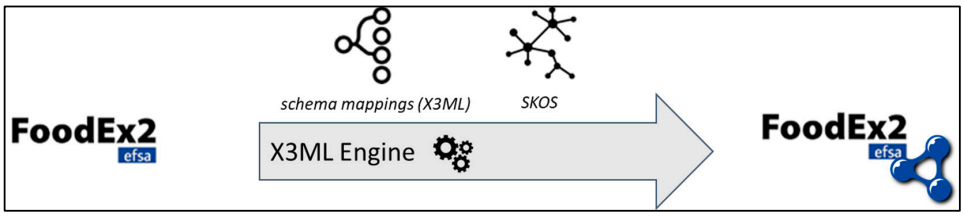

Figure 3. The automatic workflow for constructing SKOS-FoodEx2.

The latest contents of SKOS-FoodEx2 have been stored in an RDF triplestore and can be accessed by querying using SPARQL (http://demos.isl.ics.forth.gr/foodex2search/sparql, accessed on 17 April 2024). Table 1 reports some statistics for SKOS-FoodEx2 resources.

Table 1. SKOS-FoodEx2 contents.

SKOS Entity	Description	Count
skos:Concept	FoodEx2 Terms	35,267
skos:Collection	FoodEx2 Facets	52
skos:narrower/skos:broder	Hierarchical relations of terms	60,976
skos:related	General relations of terms and facets	49,615
skos:prefLabel	Preferred labels of terms and facets	30,541
skos:alsLabel	Alternative labels of terms and facets	40,015
skos:scopeNote	Detailed description of terms and facets	30,475

Apart from its benefits in terms of improved interoperability, there are also several tools available for utilizing it. This is particularly important, because it simplifies the access without the need for developing sophisticated software to use it. To demonstrate this, we used a well-known open-source web-based tool for managing and exploring SKOS taxonomies called SKOSMOS (https://skosmos.org/ accessed on 17 April 2024).

With minimal customization, it was capable of illustrating the contents of SKOS-FoodEx2. Figure 4 shows the hierarchy and details of the term *Lager beer* (the same term that was used in Figure 1). In addition, we implemented a simple search service that facilitates the discovery of FoodEx2 resources (http://demos.isl.ics.forth.gr/foodex2search accessed on 17 April 2024).

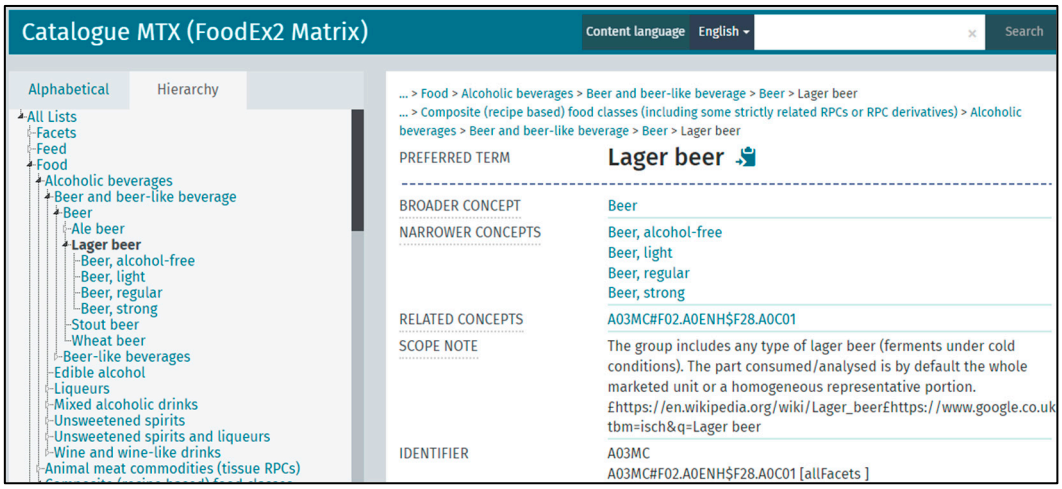

Figure 4. Visualizing and searching SKOS-FoodEx2 terms using SKOSMOS.

Another benefit that is gained from SKOS-FoodEx2 is that its semantic richness empowers advanced reasoning capabilities, enabling inferencing and deduction to derive new insights or make informed decisions. Furthermore, it facilitates sophisticated query answering, allowing users to pose complex questions that span multiple parts of the source and receive meaningful responses. Figure 5 indicates the queries and the corresponding results regarding (a) terms with "Yoghurt" as part of their ingredients, and (b) terms related to the facet source commodities that were recently updated (after 2023).

```
select ?term_uri ?term_pref_name ?term_desription
where{
      ?term_uri rdf:type skos:Concept.
      ?term_uri skos:prefLabel ?term_pref_name.
      ?term_uri skos:scopeNote ?term_desription.
      ?term_uri skos:related ?rel_combination_uri.
      ?rel_combination_uri skos:related  ?rel_facet_uri.
      ?rel_facet_uri rdf:type skos:Collection.
      ?rel_facet_uri skos:prefLabel "Ingredient".
      ?rel_combination_uri skos:related  ?rel_term_uri.
      ?rel_term_uri rdf:type skos:Concept.
      ?rel_term_uri rdfs:label "term A02NE"
}
```

term_pref_name	term_desription
"Tzatziki"@en	"The group includes any type of Tzatziki sauces, i.e. a Greek dres
"Frozen yoghurt"@en	"The group includes any type of frozen yoghurt, a frozen dessert m

```
select ?term_uri ?term_pref_name ?last_modified
where{
      ?term_uri rdf:type skos:Concept.
      ?term_uri dct:modified ?last_modified.
      ?term_uri skos:prefLabel ?term_pref_name.
      FILTER(xsd:dateTime(?last_modified)
                  > "2023-01-01"^^xsd:dateTime).
      ?term_uri skos:related ?rel_combination_uri.
      ?rel_combination_uri skos:related ?rel_facet_uri.
      ?rel_facet_uri rdf:type skos:Collection.
      ?rel_facet_uri skos:prefLabel "Source-commodities".
}
```

term_uri	term_pref_name	last_modified
http://data.europa.eu/k36/A029G	"Arctic char"@en	"2023-06-09T15:58:51"
http://data.europa.eu/k36/A02DH	"Sprat"@en	"2023-10-16T18:09:12"
http://data.europa.eu/k36/A02DS	"Bonito"@en	"2023-10-16T18:09:12"
http://data.europa.eu/k36/A0F8C	"Black carp"@en	"2023-06-09T15:58:51"
http://data.europa.eu/k36/A0F9H	"Pacu"@en	"2023-06-09T15:58:51"
http://data.europa.eu/k36/A0FAN	"Blue whitings"@en	"2023-10-16T18:09:12"

Figure 5. Querying FoodEx2 terms using SPARQL.

4. Conclusions and Future Work

In this paper, we described the process of constructing a food resource thesaurus by relying on semantic web technologies. The conceptual backbone of the produced

thesaurus is the W3C recommendation SKOS, while the source contents were derived using the FoodEx2 classification system. The results of this process are twofold; an automatic workflow supporting the construction and evolution of the thesaurus, and an advanced SKOSified version of FoodEx2, offering improvements in terms of interoperability, semantic integration, and resource exchange. SKOS-FoodEx2 resources are described in a non-ambiguous, machine-readable, and easy-to-share manner. Through the use of URIs, SKOS-FoodEx2 resources can easily be shared and referred to, making it compliant and easy to link and integrate with other datasets in the Linked Open Data Cloud (https://lod-cloud.net/ accessed on 17 April 2024). Finally, the adoption of SKOS as the core conceptual schema offers the possibility of using a variety of different tools for accessing, searching, and visualizing SKOS-FoodEx2.

Some future activities that are worth investigating are (a) the automatic construction of links between SKOS-FoodEx2 and other publicly available resources such as FoodOn, AGROVOC [9], DBpedia [10], etc., and (b) the description of FoodEx2 using an ontology that will enhance its expressiveness by introducing fine-grained differences between terms and facets.

Author Contributions: Conceptualization, Y.M., A.K., A.A., P.F., M.M. and Y.T.; methodology, Y.M., A.K., A.A., P.F., M.M. and Y.T.; software, Y.M, A.K. and A.A.; validation, Y.M., A.K., A.A., P.F., M.M. and Y.T.; formal analysis, Y.M., A.K., A.A., P.F., M.M. and Y.T.; investigation, Y.M., A.K., A.A., P.F., M.M. and Y.T.; resources, Y.M., A.K. and A.A.; data curation, Y.M., A.K. and A.A.; writing—original draft preparation, Y.M.; writing—review and editing, Y.M., A.K., A.A., P.F., M.M. and Y.T.; visualization, Y.M.; supervision, Y.T.; project administration, Y.M. and Y.T.; funding acquisition, Y.M. and Y.T. All authors have read and agreed to the published version of the manuscript.

Funding: This work was carried out between November 2022 and December 2023 and was funded by EFSA in the context of the project Ontology Roadmapping and Case Study Implementation [SC01 implementing FWC OC/EFSA/DATA/2021/01].

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

EFSA	European Food Safety Authority
SKOS	Simple Knowledge Organization System
RDF	Resource Description Framework
OWL	Web Ontology Language
URI	Uniform Resource Identifier

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