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## A new semantic resource responding to the principles of Open Science: The meat thesaurus as an IT tool for dialogue between sector actors

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1       A NEW SEMANTIC RESOURCE RESPONDING TO THE  
2               PRINCIPLES OF OPEN SCIENCE: THE MEAT  
3               THESAURUS AS AN IT TOOL FOR DIALOGUE  
4               BETWEEN SECTOR ACTORS.

5

6       Running title: THE MEAT THESAURUS: A NEW RESOURCE ACCESSIBLE TO ALL

7

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13

14      **Abstract:**

15      Nowadays, it is important to make the results of scientific research accessible in a simple and  
16      understandable way according to the Open Science policy. This movement uses tools to enhance  
17      findability and interoperability of data. This paper describes the transformation of the meat dictionary  
18      published by the French Meat Academy as a book into a machine actionable and freely accessible  
19      terminological resource based on the SKOS standard format. This thesaurus contains 1567 concepts  
20      describing the meat production chain. This work was carried out by experts in semantic web, meat  
21      biology and meat vocabulary. This thesaurus can be used to index articles, journals and datasets, thus  
22      facilitating consultation; it can also be used to facilitate interoperability of the indexed datasets and  
23      provide contextual definitions for building ontologies, i.e. formal descriptions of knowledge for  
24      reasoning on data. The thesaurus can be useful to enrich other vocabularies with new knowledge, such  
25      as French specificities in terms of meat cuts or definitions.

26

## 27        **1. Introduction**

28

29    Around the world, meat industries have become highly diversified with new products and  
30    technologies. Despite a decline in consumption in Europe, World meat production continues to grow  
31    globally, driven by increased population (Hocquette and Chatellier, 2011). These changes have brought  
32    a wide variety of products and manufacturing processes for which it has become necessary to have  
33    definitions that are as clear as possible (Seman et al., 2018) and regularly updated. Indeed, some terms  
34    used in the sector remain ambiguous and their usage may also vary between countries or between  
35    scientists, consumers, journalists or industrial actors (Seman et al., 2018). This lack of consensus on  
36    shared definitions can have an impact on research work, particularly for predictive biology approaches  
37    (Hocquette et al., 2020). The need for clear definition is also essential for commercial trade, and  
38    particularly for international trade where local source or purchase descriptions may differ widely. The  
39    word meat is itself the subject of controversy with the appearance of meat substitutes, notably  
40    “cultured meat”, which some prefer to call “muscle fibres” or “cultured muscle” (Chriki and Hocquette,  
41    2020).

42    Various resources have therefore been created with the aim of clarifying the vocabulary of the field.  
43    For instance, the UNECE (United Nations Economic Commission for Europe) provides standardised  
44    descriptions of cuts from different butchery animals ([www.unece.org/trade/wp7/Meat-Standards](http://www.unece.org/trade/wp7/Meat-Standards)) for  
45    international meat trade. The Encyclopedia of Meat Sciences (Dikeman and Devine, 2014), designed  
46    by an international team of experts, covers various important aspects such as animal husbandry,  
47    physiology, slaughter, meat preparation, packaging, welfare, food safety and many others. In France,  
48    Georges Chaudieu (Chaudieu, 1970) and Eric Glatre (Glatre, 2008) developed the first meat dictionaries  
49    and then the French Meat academy published the Meat dictionary in 2012. The latter contains clear  
50    and concise definitions of the names of cuts, professional butchery terms (including utensils), breeds  
51    of livestock, as well as technical or peripheral terms, applicable to livestock: cattle, veal, lamb, pork,  
52    poultry and game. It also lists the terms relating to the taste and texture of meat, as well as an  
53    inventory of some French and international dishes traditionally made with meat. Finally, it contains  
54    terms specific to the meat trade as well as French specificities of meat such as cuts and organisations  
55    of the sector. It contains 1357 entries, it is available as a book in French and English and also includes  
56    some terms in Spanish. Its most recent version was edited in 2019. Although they are well-known  
57    references, these dictionaries have been published in paper form and are therefore limited to human  
58    reading. The widespread use of digital approaches in research as well as in industry is creating new  
59    needs that require the use of semantic resources at the heart of information systems.

60 In the current context of Open Science development, with its challenges related to knowledge transfer  
61 and innovation, it is more necessary than ever to have terminological repositories that facilitate:

- 62 1) collaboration between disciplinary and linguistic communities,
- 63 2) the discovery of information and data from various sources,
- 64 3) the development of methods and tools for decision support based on the integration of  
65 heterogeneous data and domain knowledge. To achieve objectives 2) and 3), these repositories  
66 must be available in formats that can be used by a software.

67 The research communities in agriculture, food and environment are particularly active in the creation  
68 and provision of these semantic resources as evidenced by the study conducted by the Agrisemantics  
69 working group in the framework of the "Research Data Alliance" (Aubin et al., 2017). These scientific  
70 communities are now also part of the FAIR approach; a set of principles broken down into actions that  
71 make data easier to find, more accessible, more interoperable and therefore more easily re-used  
72 (Wilkinson et al., 2016). One of the FAIR principles puts vocabularies as a cornerstone centre of the  
73 approach: "*I2: Data and metadata use vocabularies that respect the FAIR principles*", I2 being the  
74 second principle supporting data interoperability, that is, the ability for a software to exchange and  
75 process data with heterogeneous representations as they originate from several information systems.  
76 A number of vocabularies for agriculture and food are thus accessible from public portals, including  
77 Agroportal (Jonquet et al., 2018) where the Meat thesaurus is exposed. This type of portal facilitates  
78 the discovery of existing ontologies and thesauri, the reuse of which helps to harmonise the definitions  
79 given to the objects handled by each community.

80 Among resources publicly available for the agri-food domain, we found the physical and chemical  
81 characteristics of beef and pork muscles (<https://bovine.unl.edu/> and <https://porcine.unl.edu/>) and  
82 generalist thesauri such as the FAO's Agrovoc (<http://www.fao.org/agrovoc/fr>) or the National  
83 Agricultural Library Thesaurus (<https://agclass.nal.usda.gov/>). Another interesting resource is the  
84 Languag thesaurus (<https://www.languag.org>), which provides a standardised language to describe  
85 food, in particular to classify food products for information retrieval. The FoodOn ontology (Dooley et  
86 al., 2018), derived from Languag provides a more formal representation of Languag, which allows  
87 reasoning to be constructed. During our research, we were unable to identify a semantic resource that  
88 was both precise enough and covering completely our specific needs and that was easily reusable for  
89 the meat sector. On the field of meat, let us mention the work of (Pizzuti et al., 2017a, 2014) which  
90 focused on the construction of ontologies within the framework of the FTTO (Food Track and Trace  
91 Ontology) project to represent traceability in the meat industry without, however, making the result  
92 accessible and reusable.

93 In line with the “Open Science” approach, our aim is to convert the Dictionary of the French Meat  
94 Academy, which provides us with terms and precise definitions specific to the meat sector in French  
95 and English, into a thesaurus to make these terms and concepts freely available to the professional  
96 and scientific meat community. A thesaurus is an “organised authority list of descriptors and non-  
97 descriptors that obey their own terminological rules and are linked together by semantic relationships  
98 (hierarchical, associative, or equivalence). This list is used to translate concepts expressed in natural  
99 language into an unambiguous artificial language” (AFNOR 1981). The thesaurus is a resource  
100 accessible to human readers, with a logical structure and textual definitions. By choosing to represent  
101 it using the standard SKOS (Simple Knowledge Organization System) schema, and to associate rich  
102 metadata and identifiers with it, we also make it usable by various computer applications carrying out  
103 the indexing of documents, datasets, content annotation, or the display of definitions in context.

104 In this article, we present our approach to the construction and online publication of the Meat  
105 Thesaurus through collaborative work between specialists in knowledge and data engineering on one  
106 hand and meat science and technology on the other hand.

107

## 108 **2. Material and methods**

109

110 The transformation of the dictionary from its documentary form to a structured thesaurus was carried  
111 out in three phases:

112 1) analysis of the data leading to the choice of the standard for representing the information contained  
113 in the thesaurus, that is, the SKOS model,

114 2) transformation of the data, carried out semi-automatically, and

115 3) intellectual and manual work on organising the concepts within the hierarchies

116

### 117 *2.1. Choice of the SKOS model*

118

119 The creation of the Meat Thesaurus is based on the terms of the Meat Dictionary by the French Meat  
120 Academy. The source data file provided was made of two Word documents, including one for French,  
121 with 1357 entries and inserts. The inserts were not kept in the resulting thesaurus. The content for  
122 English was integrated in a second phase of the project, after the transformation and organisation of

123 the data for French, as the English version was not available at the beginning. Similar though simpler  
124 procedures were used for English. In this paper, we will focus on the processing for data in French.

125 The structure for describing an entry in the source file for French is pretty regular (Figure 1), which  
126 allows some automation of the process, although this is made difficult by the presence of a large  
127 number of optional elements. On the first line, the term is followed by its grammatical characteristics  
128 (its nature, gender and number) and a definition as in the example shown in Figure 2. Some entries  
129 have one or more synonyms, notes, or a reference to one or more other entries indicated by the  
130 mention “**Voir**” (See). Except from the grammatical information, term properties are prefixed with the  
131 “|” (pipe) character. Synonymy is indicated heterogeneously either using the fields “Synonyme” or “See”  
132 or as part of the definition or the “To got further” information.

```
term (required) nature.gender.number (optional) | definition (optional)
| Pour aller plus loin : (optional)
| Synonyme : (optional)
| Notes : (optional)
| Voir : name (optional, several possible values separated by commas or full stops)
```

133  
134 *Figure 1: Structure of a dictionary entry (Pour aller plus loin = To go further =; Synonyme= Synonym; Notes = Notes; Voir = See)*

```
emboucheur n.m. | Éleveur ou marchand qui pratique l'engraissement du bétail à l'herbe sur des
pâtures.
| Synonyme : herbager.
| Voir : Embouche.
```

135  
136 *Figure 2: Example of a dictionary entry from the file source in French : emboucheur (grass finisher)*

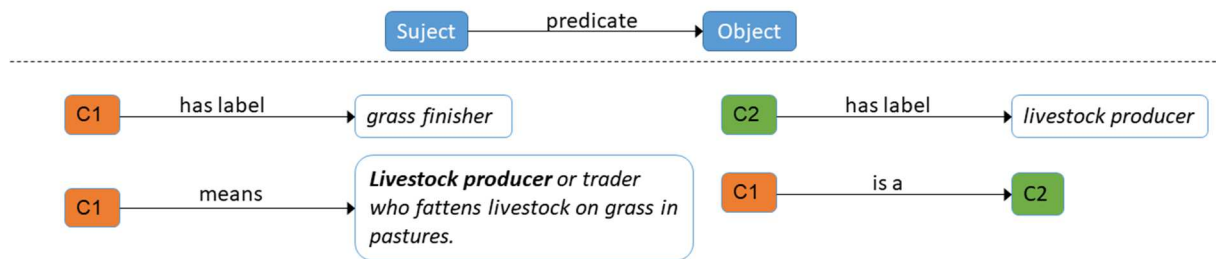
137 Considering the English version of the dictionary, the useful information to retrieve are the English  
138 term, its correspondancy in French, its definition and reference to other entries (« See » information)  
139 as shown in Figure 3.

```
Grass finisher/ Emboucheur
n.
Livestock producer or trader who fattens livestock on grass in pastures.
See: Grass Finishing.
```

140  
141 *Figure 3: Example of a dictionary entry from the file source in English : grass finisher. The equivalent term in French is indicated  
142 in red and preceded by the / character*

143 Considering the source data structure and the community practices, we chose the SKOS (Simple  
144 Knowledge Organisation System) model, a W3C standard (<https://www.w3.org/>) used to represent  
145 simple knowledge organisation systems, typically thesauri. We will see that choosing a concept-  
146 centered representation of the data implies some difficulties when working with a term-centered

147 source (dictionary). The SKOS model is based on RDF (Resource Description Framework), a framework  
 148 for describing structured data as a graph made of assertions of the form [Subject - Predicate - Object]  
 149 as shown in Figure 4.



150

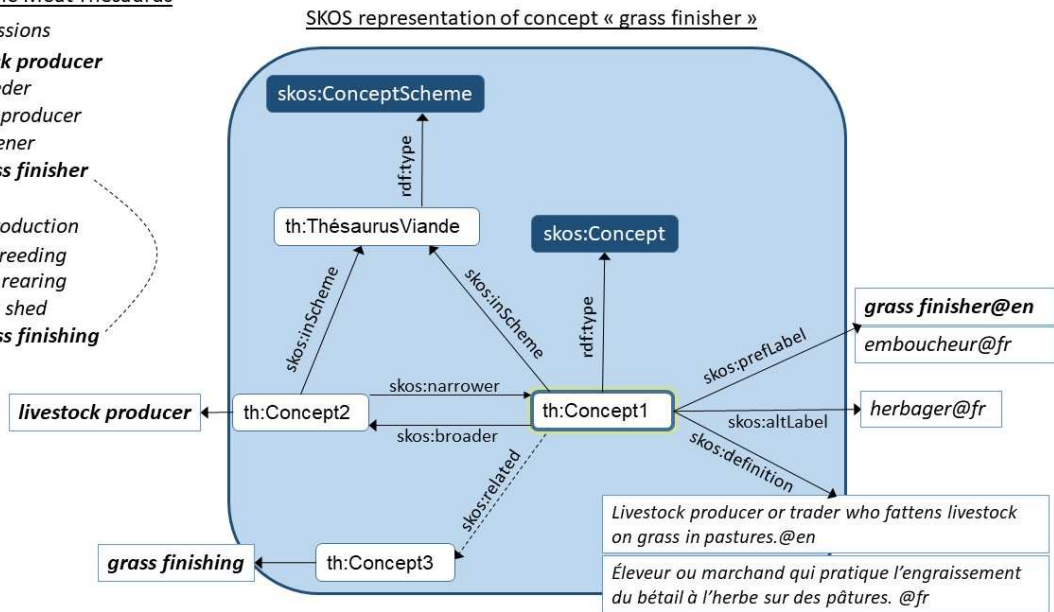
151 *Figure 4: Examples of information representation in the form [Subject - Predicate - Object] or RDF triplets*

152 A unique identifier called a URI is used to reference each concept. The URI is a global identifier, that is,  
 153 unique throughout the web space. When published, requesting the URI will allow to display or retrieve  
 154 information on a concept. This identifier is composed of a unique prefix for the thesaurus (here  
 155 <http://opendata.inrae.fr/ThViande/>) and a unique suffix for each resource described (for example C1  
 156 for concept 1).

157 A partial representation of the SKOS model is shown in Figure 5. The central object of the model is the  
 158 concept (*skos:Concept*) which can be seen as a unit of thought corresponding to a type of real-world  
 159 object (e.g. the notion of “herd”) or to an abstract entity (e.g. the notion of “meat quality”). It is  
 160 designated by a preferred term (*skos:prefLabel*) in one or more languages and possibly alternative  
 161 terms (*skos:altLabel*). The *skos:definition* property is used to add a textual definition to the concept.  
 162 Unspecified relationships between two concepts can be encoded in the *skos:related* relation, which is  
 163 equivalent to “see also” like between the concepts for “grass finisher” and “grass finishing” in our  
 164 example. The whole thesaurus is a *skos:ConceptScheme*, where concepts are organised in a hierarchy  
 165 using the relationships *skos:narrower* and *skos:broader*. For example, [livestock producer]  
 166 *skos:narrower* [grass finisher] means that “grass finisher” is a specific concept of “livestock producer”.  
 167 This hierarchical structuring did not exist in the dictionary and was built with the experts as discussed  
 168 in section 3.

Excerpt from the Meat Thesaurus

- meat professions
  - livestock producer
    - breeder
    - calf producer
    - fattener
    - **grass finisher**
- livestock production
  - cattle breeding
  - calf rearing
  - cow shed
  - **grass finishing**



169

170 Figure 5: Thesaurus data model based on SKOS

171

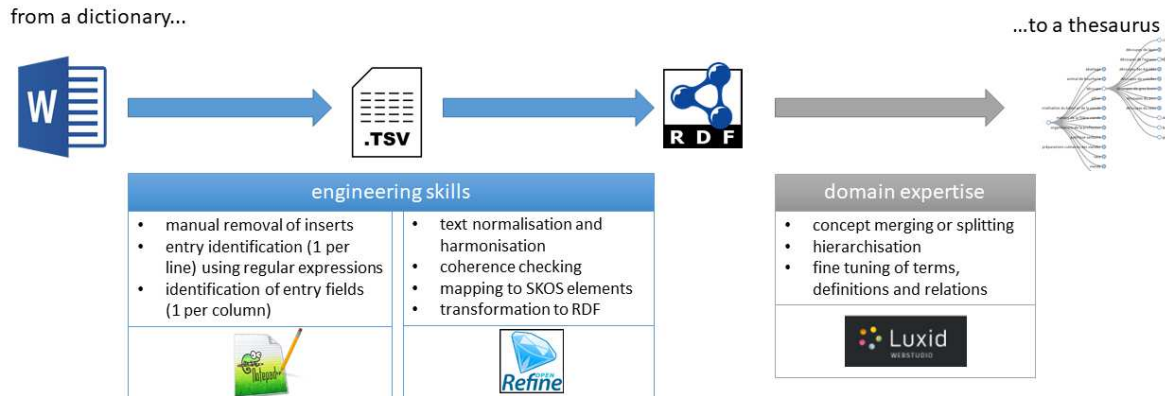
172

173 2.2. Conversion of the dictionary from its textual form into a structured and  
174 formalised resource

175

176 The work for the conversion of the dictionary into the thesaurus includes the recovery and  
177 formalisation of data (blue elements in Figure 6) which precedes the structuring phase (grey).





179

180 *Figure 6: Thesaurus construction process*

181

182 Much of the retrieval and transformation work was done semi-automatically and required the  
 183 following:

184 - An expertise in using regular expressions that we applied in a simple text editor (Notepad++) in order  
 185 to isolate the dictionary entries from each other (1 per line) and to organise their respective  
 186 information in a tabular format;

187 - OpenRefine, a free software for data cleaning and transformation. It allowed us to identify and  
 188 massively correct some encoding errors, and to refine the information segmentation of each entry.  
 189 Finally, the RDF extension of OpenRefine was used to transform the data from a tabulated format to  
 190 the standardised SKOS representation in RDF/XML. Openrefine allows the definition of a mapping  
 191 procedure from table cells to RDF predicates.

192 The data was finally uploaded into *Webstudio*, a vocabulary editor providing an ergonomic interface  
 193 for experts to curate and organise the concepts into a hierarchy.

194

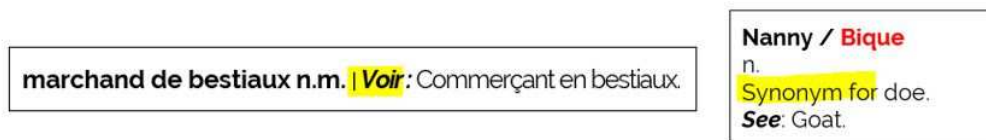
### 195 *2.3. Concept curation and organisation*

196

197 This part of the work was entirely manual and consisted in moving from a term-centered (dictionary)  
 198 to a concept-centred (thesaurus) representation, and in proposing a thematic organisation. This task  
 199 required in-depth knowledge of the field, which was provided by four experts, two from the French

200 Meat Academy and two from INRAE (French National Research Institute for Agriculture, Food and  
201 Environment). The experts from the French Meat Academy provided knowledge on cuts, cooking,  
202 trades and specificities of the sector as well as on the different breeds of meat animals. The INRAE  
203 experts provided knowledge on muscle biology. About 32 meetings of 2 hours each were held for this  
204 work. In some cases, the experts relied on other knowledge sources such as the AHOL ontology (Salaun  
205 et al., 2020) or the Animal Science Dictionary by CIRAD (Meyer et al., 2022).

206 When transforming the Meat dictionary into the Meat thesaurus, a major challenge was to either  
207 properly group terms into classes of synonyms, i.e. concepts, or on the opposite, split dictionary entries  
208 into unequivocal notions. Grouping terms into concepts was facilitated by either the “Voir” (See)  
209 information on entries with no definition or explicit mentions of synonymy in the definition as shown  
210 in Figure 7. In some cases, like “cabri”, experts had to select relevant parts of both definitions and  
211 merge into a single concept, e.g. “chèvre”.



212

213 *Figure 7: Two examples of means to indicate synonymy in the Meat dictionary*

214

215 Conversely, and in order to meet the meaning univocity constraint on SKOS concepts<sup>1</sup>, some dictionary  
216 entries had to be split into several concepts and their definition modified accordingly. This is the case  
217 for “protein”, the definition of which contained terms and definitions for various types of proteins.  
218 Concepts were created for each type of protein with its own definition.

219 Other concepts have been introduced to meet the needs of a meaningful hierarchy and to ensure a  
220 certain consistency within the thesaurus. In particular, the first level concepts (called “top concept” in  
221 SKOS) had to be generic enough to constitute thematic categories such as “breed” or “meat  
222 professions”. The ontologies AHOL - Animal Health Ontology for Livestock (<https://www.atol-ontology.com/en/a-ahol/>) and ATOL - Animal Trait Ontology for Livestock (Le Bail et al., 2014) provided  
223 some concepts initially absent from the meat dictionary.  
224

225 For this first version of the thesaurus, we chose not to introduce poly-hierarchy, an organisation in  
226 which a concept can have several generics. While this choice makes the classification work more  
227 difficult (because a non-obvious decision has to be made in case of difficult choice), it also makes it

---

<sup>1</sup> Know more about SKOS constraints : <https://www.w3.org/2004/02/skos/core/guide/2004-11-25.html#secappii>

228 more precise (because the best location has to be found). In order to organise the concepts in a  
229 hierarchical way, the experts relied on the generic terms already defined or mobilised their own  
230 expertise. In most of the cases where a concept could be located at several places in the hierarchy, the  
231 more generic solution was chosen. For instance, the branch “butchery animal” was chosen to  
232 encompass all animals slaughtered for their meat. A small number of cases were treated differently.  
233 For instance, “quarter” could be considered as a specific of “cutting” or of “half-carcass”. In this case,  
234 it was decided that it was more relevant to insert this concept under “half-carcass” in order to make  
235 its semantics more explicit.

236 This work was completed by the revision of some definitions more adapted in the context of the  
237 thesaurus, or that did not comply with definition writing good practices (Vézina, R. (2009)). Following  
238 the hierarchisation, some *skos:related* (“See”) relations present in the paper dictionary were removed  
239 in order to comply with the SKOS model that does not allow associative relations between concepts  
240 already in a hierarchical relation, i.e. belonging to the same branch of the thesaurus.

241 During this expertise work, some concepts were finally discarded from the thesaurus, like “VOF”  
242 (“Viande Ovine Française”), “VBF” (“Viande Bovine Française”) and “VPF” (“Viande Porcine Française”),  
243 keeping only official labels.

244

### 245 **3. Results**

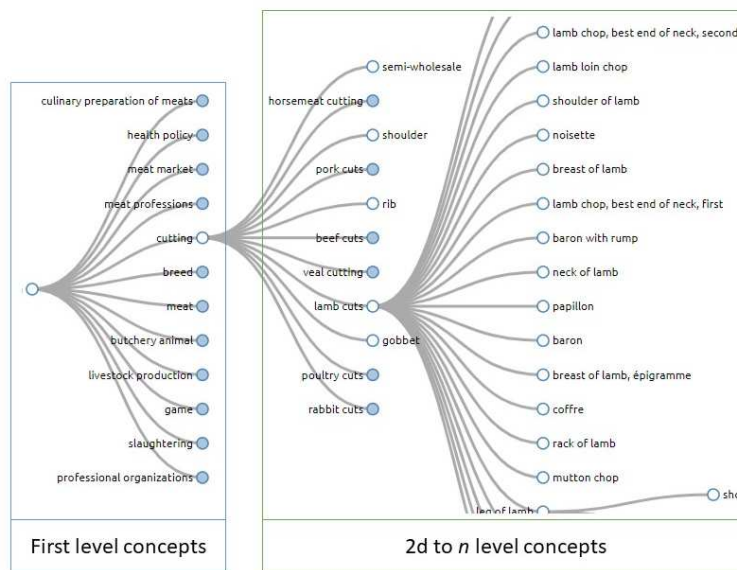
246

247 The result of this work is a bilingual thesaurus with terms and definitions in French and English, which  
248 is made publicly available for reuse in the following link: [http://agroportal.lirmm.fr/ontologies/MEAT-](http://agroportal.lirmm.fr/ontologies/MEAT-T)  
249 T. The Meat Thesaurus consists of 1519 concepts organised into 12 branches (or 1st level concepts)  
250 which are:

- breed
- butchery animal
- culinary preparation of meats
- cutting
- game
- health policy
- livestock production
- meat
- meat market
- meat professions
- professional organizations
- slaughtering

251

252 Each branch is divided in more specific sub-branches as shown in Figure 7, which allows navigating  
 253 from generic to specific concepts.



254

255 *Figure 8: Declination of the "cutting" concept*

256

257 **3.1. A thesaurus covering the main areas of the meat industry**

258

259 We present the first-level concepts in alphabetical order:

260 - "breed" includes the notions of hardy breed, standards as well as the different breeds of cattle, goats,  
 261 horses, sheep and pigs.

262 - "butchery animals" includes animals that are slaughtered for meat consumption. The animals are  
 263 divided into their major families which are cattle, goats, asses, horses, sheep, pigs and poultry. "other  
 264 animals for slaughter" lists animals whose meat is edible but not commonly consumed, such as  
 265 ostriches, bison and peacocks;

266 - "culinary preparation of meat" includes concepts that describe meat-based preparations,  
 267 preparations in which meat is an essential ingredient or some sauces. The second level concepts are:  
 268 tableware, charcuterie, salting, cooking, sauce, charcuterie-salting and culinary preparations based on  
 269 beef, game, pork, tripe products, veal, ovine meat, poultry, multi-meat.

270 - "cutting" describes all cuts for poultry, large cattle, lamb, equines, pork, rabbit and veal, in the French  
 271 context. It also defines in a general way the cuts common to several animals such as the rib, the half-  
 272 calf, the shoulder and the goblet. The rationale for this choice was to consider cuts at the butcher end

273 rather than muscle names as considered by scientists but the linkage between the two approaches  
274 remains to be developed.

275 - “game” includes all animals that are hunted for their meat and are not animals for slaughter, such as  
276 pheasants, kangaroos, hares, wild ducks and wood pigeons;

277 - “health policy” covers 7 second-level concepts including HACCP, diseases, veterinary inspection and  
278 traceability, which are themselves broken down into more specific concepts.

279 - “livestock production” includes both generic livestock farming practices (e.g. “zootechnics” or  
280 “animal welfare”) and practices specific to a type of livestock farming, for example “barn” (in “cattle  
281 breeding”) or “shepherd” (in “sheep-goat breeding”);

282 - “meat”; this is the core subject in this thesaurus. This branch covers the different types of meat such  
283 as beef, game, poultry, sheep and pigs. It also provides definitions of white and red meat and other  
284 notions such as packaging, preservation, processing of muscle into meat, meat industry and meat  
285 quality (which includes safety, sensory analysis, nutritional value, and official quality signs as well as  
286 beef grading at the consumer end).

287 - “meat market” describes the commercial exchanges within the meat sector, considering the French  
288 particularities. It contains 3 second-level concepts: wholesale meat market, livestock market and  
289 transport.

290 - “meat professions” includes all types of occupations in the sector as well as training and distinctions.

291 - “professional organizations” presents the different organisations divided into four categories:  
292 commercialisation-industry, distribution, interprofession, production.

293 - “slaughtering” contains the actions carried out in the slaughterhouse (stunning, killing, throat cutting,  
294 dehairing, evisceration, etc.), the tools used (plucking, hide, trocar, splitting, etc.), ritual slaughter  
295 (halal and kosher), concepts relating to the carcass (carcass yield, meat yield, atlas, fifth quarter,  
296 trapping, etc.) and carcass grading;

297 The Meat Thesaurus is therefore a resource that covers a wide range of concepts in the meat sector.  
298 The thematic organisation offers a navigation path that facilitates its discovery and use. The integration  
299 of definitions from the French Meat academy dictionary makes it a reliable source of knowledge that  
300 is representative of French practices. This can be extended to other global practices to provide  
301 connection and accurate relationships across global practices.

302

303 3.2. A FAIR resource

304

305 In order to allow its reuse by third parties, the Meat Thesaurus is made freely available to the  
 306 community on a public portal, Agroportal, and in an open format. It is part of the FAIR approach where  
 307 a set of principles provide a framework to ensure that a digital resource can be reused by third parties  
 308 (humans and machines). Solutions proposed by the DipSO INRAE Open Vocabularies service have been  
 309 combined to ensure that the meat thesaurus complies as far as possible with FAIR principles.

310 The analysis proposed in Table 1 was carried out in the framework of the ANR FooSIN project  
 311 (<https://foosin.fr/>) and the questionnaire developed by the RDA SHARC working group (David et al.,  
 312 2020).

313

FAIR Objectives	Solutions to meet the FAIR principles
<b>Findable</b>	<ul style="list-style-type: none"> <li>• The thesaurus is uniquely and globally identified by a DOI (Digital Object Identifier) which links it to its metadata accessible on Data INRAE (<a href="https://data.inrae.fr/">https://data.inrae.fr/</a>). The DOI also provides a mean to precisely cite the thesaurus;</li> <li>• The long-term preservation of DOI and URI identifiers are guaranteed by Data Cite and INRAE respectively;</li> <li>• The thesaurus is referenced in Data INRAE and displayed on Agroportal (<a href="http://agroportal.lirmm.fr/">http://agroportal.lirmm.fr/</a>), its metadata and content are indexed by Internet search engines;</li> </ul>
<b>Accessible</b>	<ul style="list-style-type: none"> <li>• The thesaurus is downloadable from Agroportal in various open formats (SKOS/XML, RDF/XML and CSV);</li> <li>• The description and content of the thesaurus are accessible via web services or API (<a href="http://data.agroportal.lirmm.fr/">http://data.agroportal.lirmm.fr/</a>);</li> <li>• The description of a concept is accessible via its URI, which is dereferenced (dereferencing service provided by the DipSO INRAE);</li> <li>• Accessibility is based on an institutional service operated by the DipSO.</li> </ul>
<b>Interoperable</b>	<ul style="list-style-type: none"> <li>• The content of the thesaurus is represented using the W3C SKOS standard, in RDF. A CSV version is also available;</li> <li>• Its metadata is represented using elements from standard schemas that can be interpreted by many information systems and search engines and are widely adopted by the community;</li> </ul>
<b>Reusable</b>	<ul style="list-style-type: none"> <li>• The thesaurus is displayable and usable using free and open source tools such as VocBench or Skosmos;</li> <li>• The conformity of the thesaurus with the SKOS model has been tested with the Skos Play tester (Sparna, <a href="https://skos-play.sparna.fr/skos-testing-tool/">https://skos-play.sparna.fr/skos-testing-tool/</a>) which is based on the qSKOS rules (<a href="https://github.com/cmader/qSKOS/wiki/Quality-Issues">https://github.com/cmader/qSKOS/wiki/Quality-Issues</a>);</li> <li>• The editorial choices and intentions of the authors are explained in this article</li> </ul>

314 Table 1 : Description of the FAIR objectives

315 Since this evaluation, the FooSIN project has contributed to a new service on Agroportal which  
316 computes and displays the FAIRness score of each resource it hosts. The methodology and criteria are  
317 explained by Amdouni and Jonquet (2021). The service provides score explanation and tips to improve  
318 the findability, accessibility, interoperability and reusability, which will guide us in enhancing the  
319 content, documentation and metadata of the Meat Thesaurus.

320

## 321 **4. Discussion**

322

323 Having performant information retrieval systems is important in any field including in the meat sector.  
324 A thesaurus provides a precise and controlled vocabulary which serves coordinating indexing and  
325 information retrieval (Clarke, 2017). Unfortunately, many terminological resources in the meat sector  
326 are either in paper format, in PDF or in tabulated format and, consequently, are not suitable. For  
327 example, the UNECE (United Nations Economic Commission for Europe) provides standardised  
328 descriptions of cuts for different butchery animals for the European Union  
329 ([www.unece.org/trade/wp7/Meat-Standards](http://www.unece.org/trade/wp7/Meat-Standards)) which is potential useful for meat trade but it is only  
330 available in PDF format. In addition, the University of Nebraska-Lincoln provides the physical and  
331 chemical characteristics of beef and pork muscles (<https://bovine.unl.edu/> ; <https://porcine.unl.edu/>).  
332 Nevertheless, this resource is only limited to cuts and not the meat sector as a whole. A digital tool  
333 with the possibility of doing linkages will therefore be of great benefit to integrate trade-based or cut-  
334 based standards with more specific scientific and more generalised industry terms.

335 The meat thesaurus is presented as a useful resource respecting the FAIR principles of open science  
336 for indexing specific databases in the meat sector including contextual and national characteristics and  
337 for information retrieval from these databases. This will also help to provide a semantic base for the  
338 construction of a meat quality ontology that will be further discussed.

339

### 340 *4.1. Indexing databases*

341

342 The meat thesaurus can be classically used in bibliographic databases to index journal articles, books  
343 or any document on meat, its processing, trade and related disciplines.

344 Technological advances over the last decades have dramatically increased the rate of collecting  
345 scientific information and data (Hughes et al., 2008). This has led to a proliferation of large biological  
346 databases that manipulate concepts like units, scales, or laboratory methods (Chriki et al., 2013) that  
347 are defined in different ways, or not defined at all. This is a huge limitation for meta-analysis and  
348 modelling approaches (Hocquette et al., 2012). It is therefore advantageous for researchers to use  
349 already defined concepts and add keywords to the metadata when feeding databases. This will also  
350 help in the reusability and interoperability of research databases. According to ISO 25964-1  
351 (International Organisation for Standardization 2011, Clause 4.1), a thesaurus has as prime function to  
352 support information retrieval by guiding the choice of terms for data indexing and information  
353 searching. This will enable an indexer and a searcher to choose the same term for the same concept.  
354 A thesaurus gives a unified and formalized representation of information in the information retrieval  
355 system, reflecting paradigmatic relations between terms. It is an effective tool for thematic retrieval  
356 as it provides search precision on specific subjects.

357 As an example, in 2002, the National Agricultural Library Thesaurus (NALT) was established to select  
358 controlled vocabulary terms for subjects indexing in databases such as AGRICOLA or PubAg  
359 (<https://agclass.nal.usda.gov/>). With the emergence of repositories and catalogues for other research  
360 products like data, software, and protocols, it has become crucial to use reference concepts to be able  
361 to query them in an efficient manner. Yet, thematic wide vocabularies like Agrovoc or NALT are  
362 generally not suited to precisely describe data, which often requires finer grained or specific  
363 vocabularies for a given scientific field.

364 Some experts who participated in this work are members of the International Meat Research 3G  
365 Foundation (<https://imr3g.org/>). The main aim of this foundation is to strengthen the link between the  
366 different actors in the beef sector (farmers, producers, slaughterhouses, wholesalers and retailers). To  
367 achieve this, the foundation is establishing an international database with a large number of  
368 consumers' scores related to beef palatability and related animal, carcass, cut and muscle data. These  
369 scores are obtained according to standard protocols of the most advanced beef grading system: The  
370 Meat Standards Australia methodology (MSA). This system has been undergoing development since  
371 the 1990s, always with the same protocols to record the most powerful determinants of beef eating  
372 quality on a large scale first in Australia and then across countries such as France, Ireland, Poland,  
373 South-Africa, South Korea or USA (Hocquette et al., 2020, Bonny et al., 2018). Using the MSA standard  
374 methodology already contributes to the strategy of the International Meat Research 3G Foundation  
375 but is not sufficient to achieve data interoperability and reusability at scale. These international  
376 collaborations emphasised the desirability of establishing common standards, description and  
377 protocols for data collection and physical collection of cuts, fabrication of consumer samples and



378 untrained consumer testing protocols and control software to ensure data were fully compatible and  
379 able to be aggregated. As a result, agreed descriptive terms and protocols reflecting global data have  
380 been endorsed for use in conjunction with the UNECE Bovine Language allowing free universal use in  
381 conjunction with IMR3GF accredited assessment training and providing the ability to develop 3G  
382 consumer prediction models from appropriate pooled data. To go in that direction, the Meat Research  
383 3G Foundation will ensure that the future database will allow its users to work using a shared language.  
384 The main objective of publishing the meat thesaurus was to provide a semantic base specific to meat  
385 quality that would sustain the future database.

386 Beyond its use in this database, the meat thesaurus is made available and thus expected to be adopted  
387 by the meat supply chain actors who need accurate definitions of specific concepts. Thanks to the  
388 access services provided by Agroportal, it can be incorporated directly in digital applications used by  
389 agricultural and consumer devices connected to the Internet. Such applications could then benefit  
390 from a standard food vocabulary with a global scope also including regional specificities, French ones  
391 in our case. Parts of the meat thesaurus can also be integrated into or mapped with other semantic  
392 resources. For instance, the Chinese Agricultural Thesaurus was mapped to AGROVOC to allow users  
393 to access the vast repositories of Chinese agricultural knowledge, previously inaccessible to non-  
394 Chinese speakers, by allowing them to use vocabulary in languages with which they are familiar as an  
395 entry point to the indexed resources (Liang and Sini, 2006).

396 To summarise, the meat thesaurus described here, freely accessible and following the open science  
397 principles is likely to be a useful resource for indexing specific databases in the meat sector. This  
398 thesaurus has the potential to include regional characteristics such as those of the French meat  
399 production up to now. On the other hand, its genericity and its detailed description of the meat sector  
400 make it potentially useful at the international level, especially in the area of meat quality.

401

#### 402 *4.2. Using the thesaurus to build an ontology*

403

404 Scientific research on meat eating quality has to answer complex problems, which can require working  
405 on heterogeneous data sometimes coming from various sources. One of the main obstacles to data  
406 integration is the variability with which producers name the objects studied, variables, units of  
407 measurement, etc. Integrating domain knowledge encoded in an ontology to data processes can be a  
408 solution to facilitate data integration and reason on these data. An ontology provides formal  
409 descriptions of domain knowledge and allows reasoning on data while a thesaurus focuses on how to  
410 name things and organises them thematically.

411 The authors are interested in developing an ontology dedicated to predict meat quality. Meat quality  
 412 can be defined as a set of properties that together identify what we appreciate about meat when we  
 413 purchase it, eat it, or select it for use as a raw material for processing into meat products (Purslow,  
 414 2017). Traditionally, meat quality traits are grouped in two sets: intrinsic and extrinsic traits. The  
 415 intrinsic traits are those associated with the product itself which include appearance, colour, water-  
 416 holding capacity, and odour, nutritional value (fatty acid composition, iron and vitamin contents, etc),  
 417 sensory perception (tenderness, flavour, juiciness). Other traditional quality factors normally  
 418 expressed as freshness or wholesomeness, or safety in terms of lack of pathogens, parasites, infections  
 419 agents, or toxins are also major intrinsic quality traits. The extrinsic quality traits are related to the way  
 420 meat is produced and therefore include issues related to the well-being of meat animals and the  
 421 sustainability of production systems in terms of environmental and economic performances. Starting  
 422 from the Meat Thesaurus will facilitate the construction of the ontology as it largely covers the notions  
 423 that are directly or indirectly associated to meat quality. These notions can be found within the meat  
 424 thesaurus under the following main concepts:

- nutritional values of meat	- health policy
- sensory analysis	- veterinary inspection
- conservation	- livestock production

425

426 Ontological classes can be derived from these concepts by adding formal properties and relation as  
 427 well as logical rules. In order to predict quality, i.e. to infer the level of quality as “unsatisfactory”,  
 428 “Good everyday quality”, “better than everyday quality” and “premium quality”, the ontology will have  
 429 to include formal definitions and specific rules, i.e. classes, for the animal type, the name of the cuts  
 430 and the cooking method. For example, a butcher may want to predict the level of quality of a beef cut,  
 431 or individual muscle portions, e.g. the sirloin from a famous beef breed. He may also want to know  
 432 what type of cooking method will be the best to maximise eating quality in order to provide the best  
 433 advice to consumers. Concepts of the ontology like the breed of the animal, the results of veterinary  
 434 inspection obtained from the farmer, the meat colour and marbling assessment (the ontology can give  
 435 precision on the assessment method) can be used. Finally using this information, the ontology can  
 436 provide recommendations for the cooking method and help to provide a potential level of quality.

437 Deriving ontologies from thesauri has been proven. Indeed, previous examples in which thesauri have  
 438 helped in the establishment of ontologies do exist. For example, the FoodOn ontology was constructed  
 439 using, among others, the Languag thesaurus which was published in 2017 (Møller and Ireland, 2018).  
 440 This work was carried out by a consortium to build a comprehensive open source ontology, consisting

441 of hierarchies of terms that cover raw foods, process conditions for packaging, cooking and  
 442 preservation, and a variety of product type schemes under which food products can be classified. The  
 443 description of each food is based on descriptive qualities, its components as well as the associated  
 444 processes. Other thesauri, including AGROVOC and the Aquatic Sciences and Fisheries Abstracts  
 445 Thesaurus (ASFA) have also been converted into ontologies in the same way, in order to improve their  
 446 expressiveness and take advantage of the tools made available by the semantic web community  
 447 (Lauser et al., 2008).

448 The future ontology will not only benefit from the Meat thesaurus but also from semantic resources  
 449 including ontologies and thesauri developed by other communities and shared in repositories like  
 450 Agroportal that offer facilities for reusing them. For example, when we search for the definition of  
 451 marbling (a key quality trait of beef) in AgroPortal, we have access to several definitions considering  
 452 different specificities of different regions of the World as shown in Table 2 For each class of the future  
 453 ontology, this feature will allow to pick-up the definition and terms most suited to our needs. For  
 454 instance, for the measurement of marbling, the definitions from ICAR or USDA differ and might not be  
 455 relevant to some users like French users for example. The thesaurus will therefore enable users to  
 456 access locally relevant definitions and provide clarity on how definitions compare across systems.

<b>ATOL</b>	Any measurable or observable characteristic of the degree of infiltration of intramuscular fat
<b>ICAR ICAR Recording Guidelines May 2014</b>	Marbling can be defined as the flecks of fat in the lean. Marbling is usually evaluated visually in the rib-eye muscle, which is exposed between the 12th and 13th ribs. Intramuscular fat (marbling) is the intermingling or dispersion of fat within the lean
<b>MSA www.mla.com.au</b>	It is the last fat to be deposited and the first to be utilised by the animal as an energy source ; marbling is the fat that is deposited between muscle fibres. Marbling is assessed from the 5th to 13th rib on the carcass and seen as intramuscular deposits of fat within the muscle. The term marbling refers to the small flecks of fat scattered throughout the muscle
<b>USDA www.meat.tamu.edu</b>	Marbling (intramuscular fat) is the intermingling or dispersion of fat within the lean. Graders evaluate the amount and distribution of marbling in the ribeye muscle at the cut surface after the carcass has been ribbed between the 12th and 13th ribs. The types and amounts of fat in the muscle the intermingling of fat deposits in muscle.
<b>JMGA (beef marbling standards) www.jmga.or.jp</b>	The amount and distribution of intramuscular fat. Marbling is flecks or thin strips of fat in beef
<b>CBGA www.beefgradingagency.ca</b>	Marbling is the fine white flecks of fat running through the lean meat. The amount of marbling in the rib eye defines the minimum standard for the top-quality grades Amount, size and distribution of intramuscular fat deposits in the Longissimus muscles of a livestock carcass that have been exposed by knife-ribbing
<b>Sistema Brasileiro de Classificação de Carcaças de bovinos www.uel.br</b>	This assessment of the quantity and of the intramuscular fat distribution is made visually in the muscle Longissimus dorsi, between the 12th and 13th ribs. For the classification of marbling, photographic standards produced by the USDA

457

458 *Table 2 : Results of the query with the word "marbling" on AgroPortal*

459 To summarise, addressing complex biological problems in meat science may be helped by using  
460 ontologies, which provide formal descriptions of domain knowledge and allows reasoning on data. The  
461 Meat Thesaurus provides names and definitions for concepts within the meat sector and organises  
462 them thematically. Among other uses, it is likely to help building a powerful ontology for the meat  
463 sector in combination with other existing resources in the same field.

464

## 465 **5. Conclusion**

466

467 Terminological, syntactic and semantic discrepancies between data sources need to be overcome so  
468 that it will be possible for researchers to have transparent access to different disparate data sources,  
469 and possibly integrate them to produce new knowledge. There is thus a growing awareness of the  
470 need for ontologies in life science. There is also a need to share a wealth of knowledge among different  
471 researchers and research or professional groups. As a result, a growing number of biological ontologies  
472 are being built in life science as information management is of paramount importance. Unfortunately,  
473 very few resources could be associated with this initiative in the field of meat. We propose a new  
474 resource as a thesaurus specific to the meat sector to fill this gap. As shown in this article, transforming  
475 textual content to a structured, machine actionable and organised resource requires time and specific  
476 competencies. To avoid data loss and expensive post-processing, it is important to adopt a FAIR-by  
477 design approach when developing dictionaries or any other terminological or semantic resource. This  
478 means to, right from the beginning of a project, adopt tools allowing data structuring, even a simple  
479 spreadsheet, and whenever possible including features for standard representation, modification  
480 tracking, and quality check (section 5 of Aubin et al. 2017 presents some of the most used tools in the  
481 agricultural community working with semantic resources). Making semantic resources easily findable  
482 and accessible is also a key for reducing duplicated efforts and costs, enhance reusability and thus  
483 allow better semantic interoperability of data in the domain.

484 The meat thesaurus described here represents all aspects of the meat supply chain from production  
485 to consumption and this has many advantages for all those wishing to use it, in particular professionals,  
486 consumers and researchers. It not only provides precise definitions of the different concepts specific  
487 of the meat sector, but also highlights relationships between them through categories and hierarchical  
488 and explicit associated links. This will contribute to a better knowledge of the sector, its organisations,  
489 its products, its policies, etc. The advantage of this thesaurus is that it can also be used to index  
490 databases and bibliographic resources.

491 This thesaurus covers various aspects of meat: meat-producing animals, slaughter and cutting,  
492 marketing, culinary preparations and consumption. The users of this thesaurus may therefore have  
493 different profiles: professionals of the sector, researchers, journalists, students or simple consumers  
494 who wish to better know the specificities of the meat sector, in particular in the French context. This  
495 thesaurus does exist in English while retaining the specificities of the French meat industry and having  
496 the potential to incorporate other regional specificities. In addition, the thesaurus will further be  
497 expanded into different languages. It has also the potential to be regularly updated. Indeed, it could  
498 happen that the thesaurus does not cover all the requirements of any database which may contain  
499 additional variables not defined yet or defined in a different way. In this case, it will be possible to  
500 request additions or modifications of concepts in the thesaurus.

501 In combination with other existing and freely available resources in the meat sector, this thesaurus will  
502 also serve as the basis for an ontology through specification of different classes that will be more  
503 formal and more precise. The meat ontology will make it possible to deepen a particular aspect of  
504 meat, such as its quality and will also enable reasoning for computers for a more automatic use. This  
505 is in line with the strategy of international initiatives such as the aims of the International Meat  
506 Research 3G Foundation. This is also in agreement with the open science policy promoted for instance  
507 in EU-funded research projects.

508

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513

#### 514 **CRedit authorship contribution statement**

515 Moise KOMBOLO: Data curation, Formal analysis, Investigation, Methodology, Software, Visualization,  
516 Writing – original draft. Jérémy YON: Data curation, Formal analysis, Investigation, Methodology,  
517 Software, Writing – review & editing. François LANDRIEU and Brigitte RICHON: Data curation, Formal  
518 analysis, Investigation, Writing – review & editing. Sophie AUBIN and Jean-François HOCQUETTE:  
519 Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision,  
520 Validation, Writing – review & editing.

521

522 **Declaration of Competing Interest**

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