The Ontology for Nutritional Studies (ONS) and its future directions

Francesco Vitali

Institute of Agricultural Biology and Biotechnology (IBBA)
National Research Council (CNR)
Pisa, Italy

francesco.vitali@ibba.cnr.it

Consiglio Nazionale delle Ricerche
IBBA
Istituto di Biologia e Biotecnologia Agraria

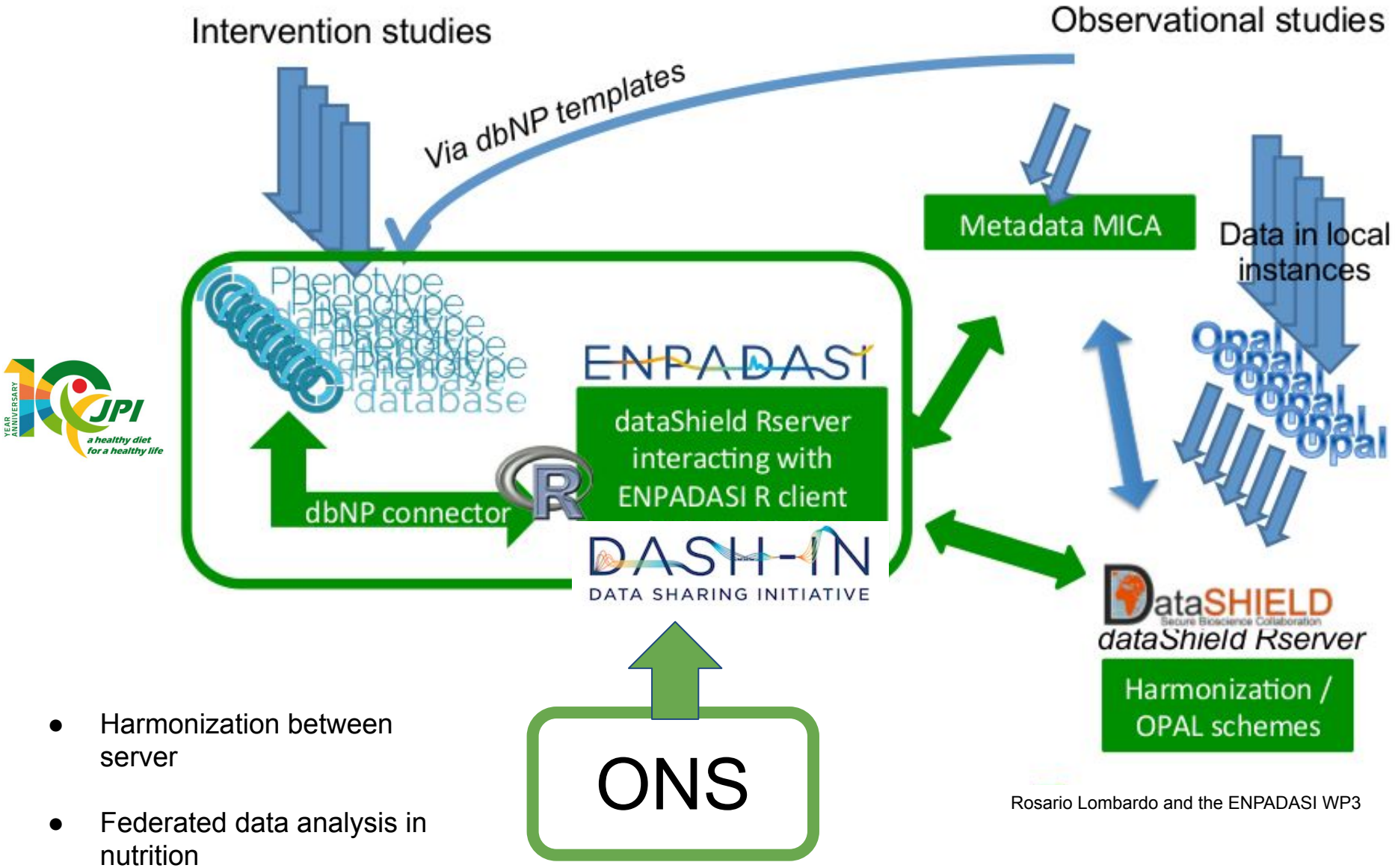
crea
Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria

UNIVERSITÀ DEGLI STUDI FIRENZE
BIO Dipartimento di Biologia

Summary

- **Introduction – ENPADASI project;**
- **Construction of a common ONTOLOGY for nutritional studies;**
- **Orthogonality in ONS;**
- **ONS overall schema;**
- **Consensus building over dietary terms - JFO workgroup;**
- **ONS - domain of interest and development;**
- **Future expansion ideas for ONS;**
- **Use case for fermented food - Kefir;**

Introduction – ENPADASI project



- Harmonization between server
- Federated data analysis in nutrition

Rosario Lombardo and the ENPADASI WP3

Development of Ontology for Nutritional Studies (ONS)

Vitali *et al. Genes & Nutrition* (2018) 13:12
https://doi.org/10.1186/s12263-018-0601-y

Genes & Nutrition

RESEARCH Open Access

ONS: an ontology for a standardized description of interventions and observational studies in nutrition

Francesco Vitali[1,4†], Rosario Lombardo[2*†], Damariz Rivero[4], Fulvio Mattivi[5,12], Pietro Franceschi[5], Alessandra Bordoni[6], Alessia Trimigno[6], Francesco Capozzi[6], Giovanni Felici[7], Francesco Taglino[7], Franco Miglietta[1], Nathalie De Cock[3], Carl Lachat[3], Bernard De Baets[8], Guy De Tré[9], Mariona Pinart[10], Katharina Nimptsch[10], Tobias Pischon[10], Jildau Bouwman[11], Duccio Cavalieri[1,4*] and the ENPADASI consortium

Developed following OBO foundry principles

- The ontology was named "**Ontology for Nutritional Studies**" with acronym **ONS**;
- **SHAREABLE:** The ontology was developed following the principles indicated by the OBO Foundry;
- **OPEN: ONS** was made openly available by copywriting under a Creative Commons CC-BY license;
- **COLLABORATIVE AND ACCESSIBLE: ONS** was hosted as a GitHub repository. In this way, the process of development, revision, and integration of new terms in ONS is fully traceable and public, stimulating and facilitating the development in a collaborative environment.

ONS repository can be found at
https://github.com/enpadasi/Ontology-for-Nutritional-Studies
https://bioportal.bioontology.org/ontologies/ONS
http://www.obofoundry.org/ontology/ons.html

Developed following OBO foundry principles

top level

Basic Formal Ontology (BFO)

mid-level

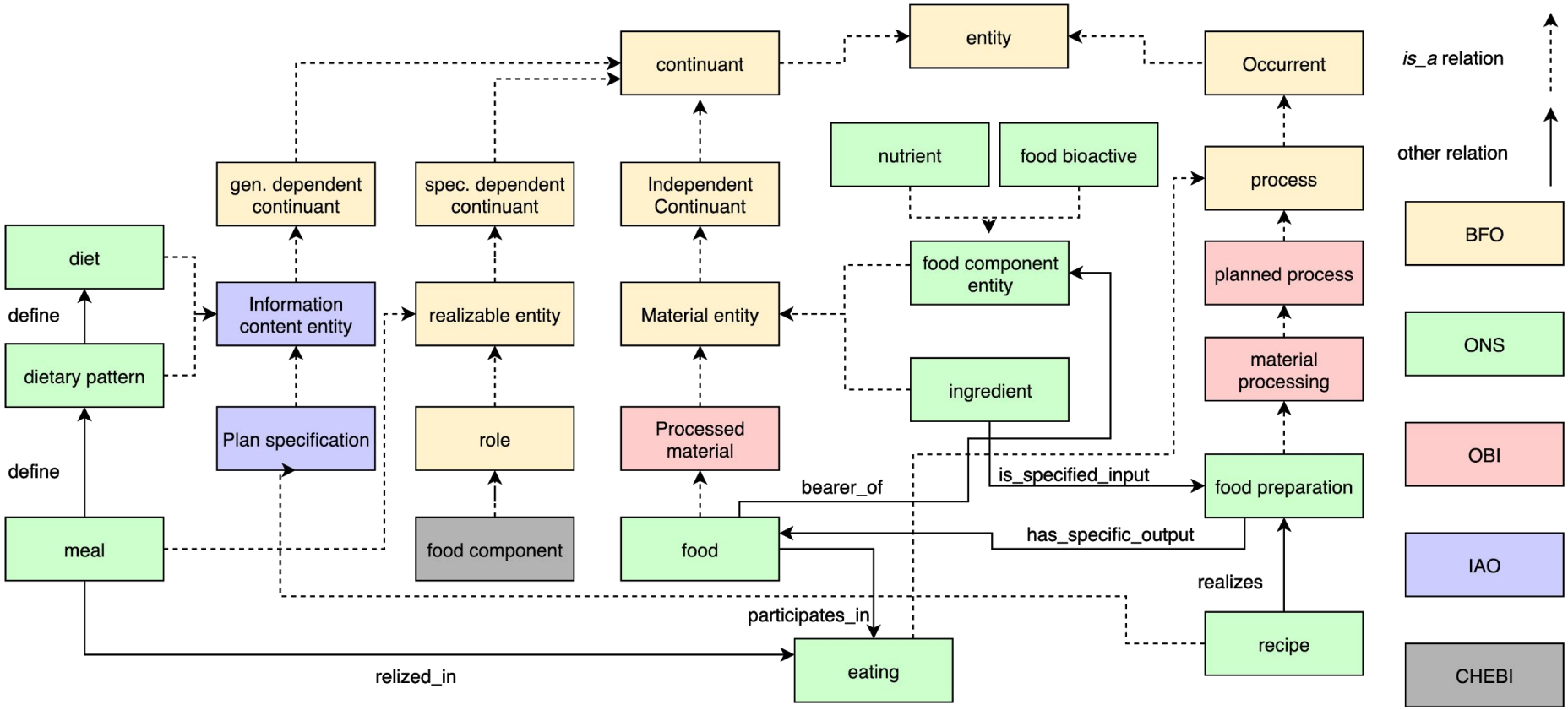
Information Artifact Ontology (IAO)	Ontology for Biomedical Investigations (OBI)

OBI

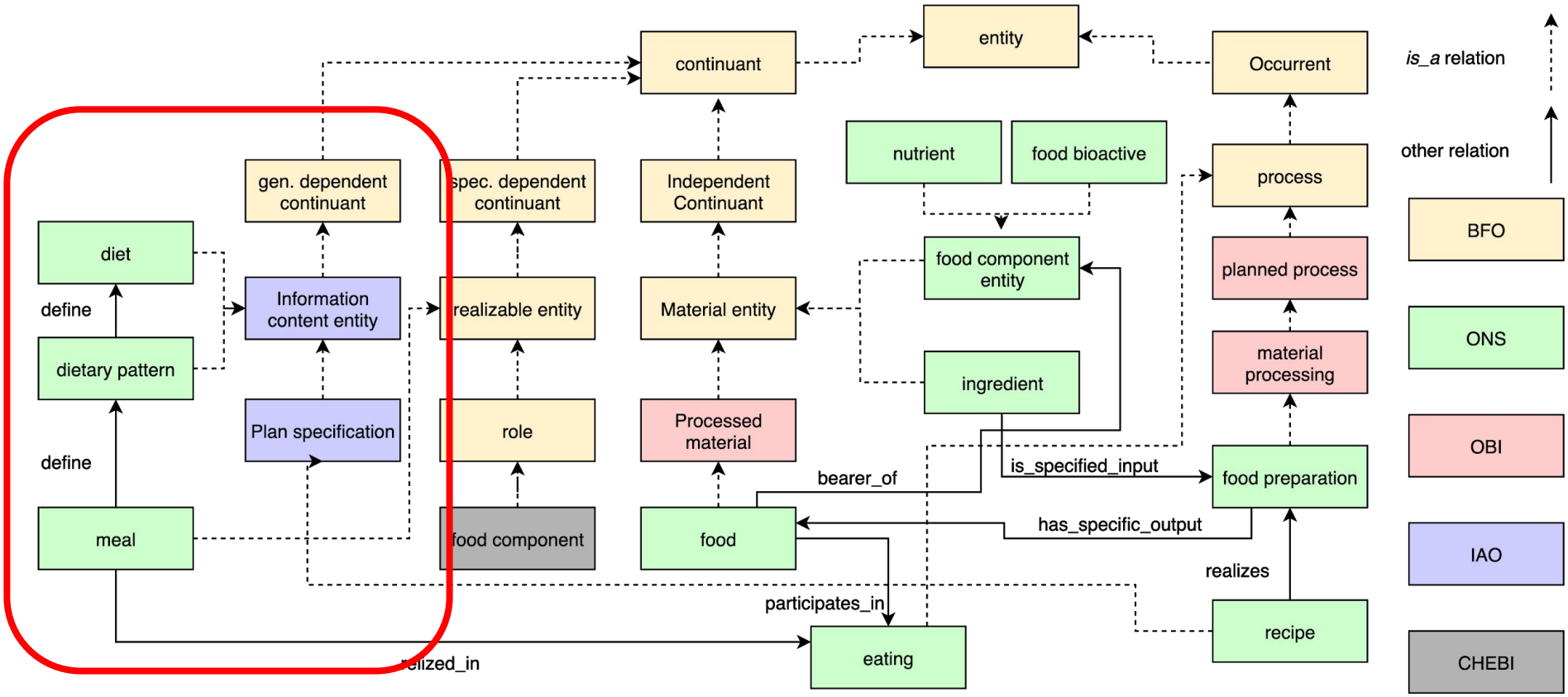
domain level

- Terms imported from various ontologies (FOODON, EFO, CMO, SIO, OBCS, CHEBI, OGMS);
- Terms of new definition (ONS_xxxxxx).

ONS overall schema



ONS overall schema

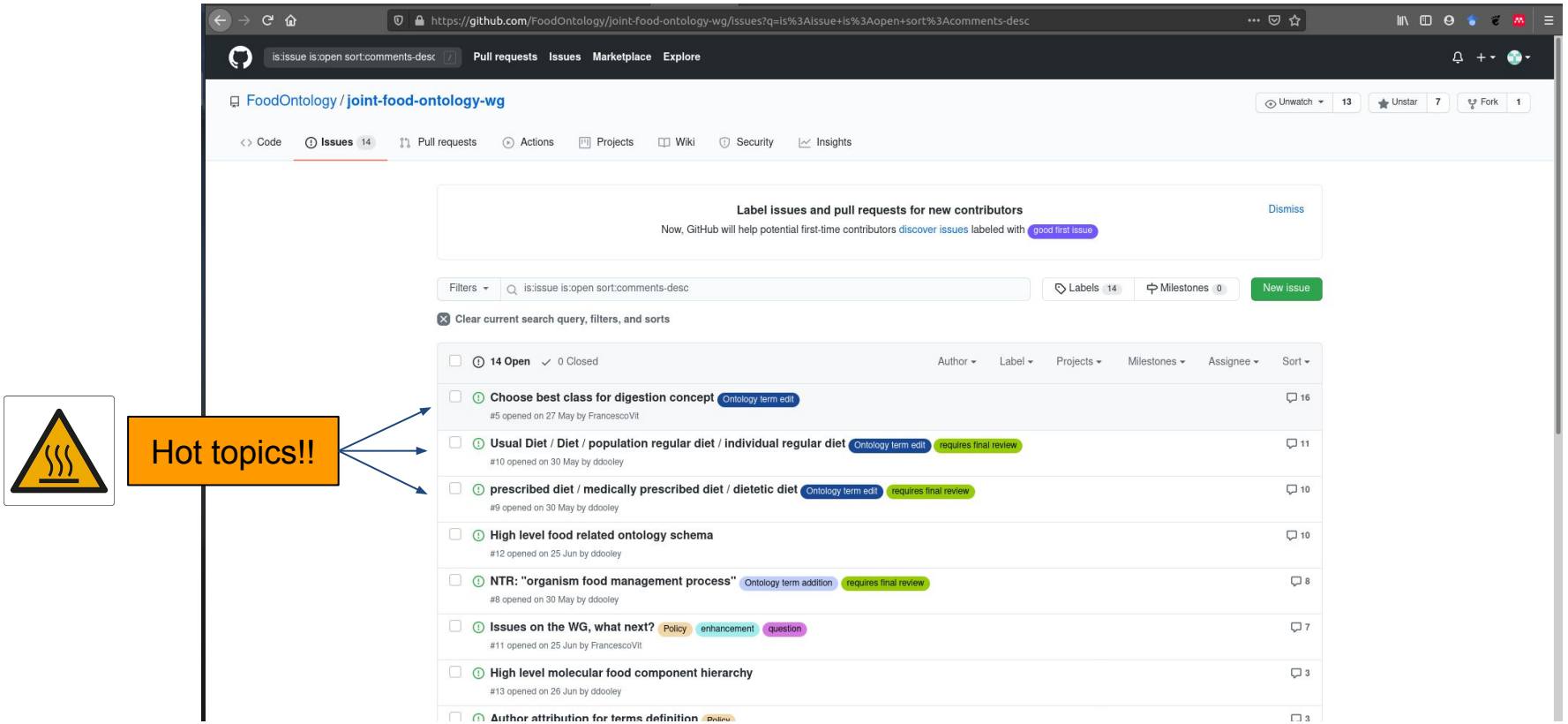


In ONS conceptualization:

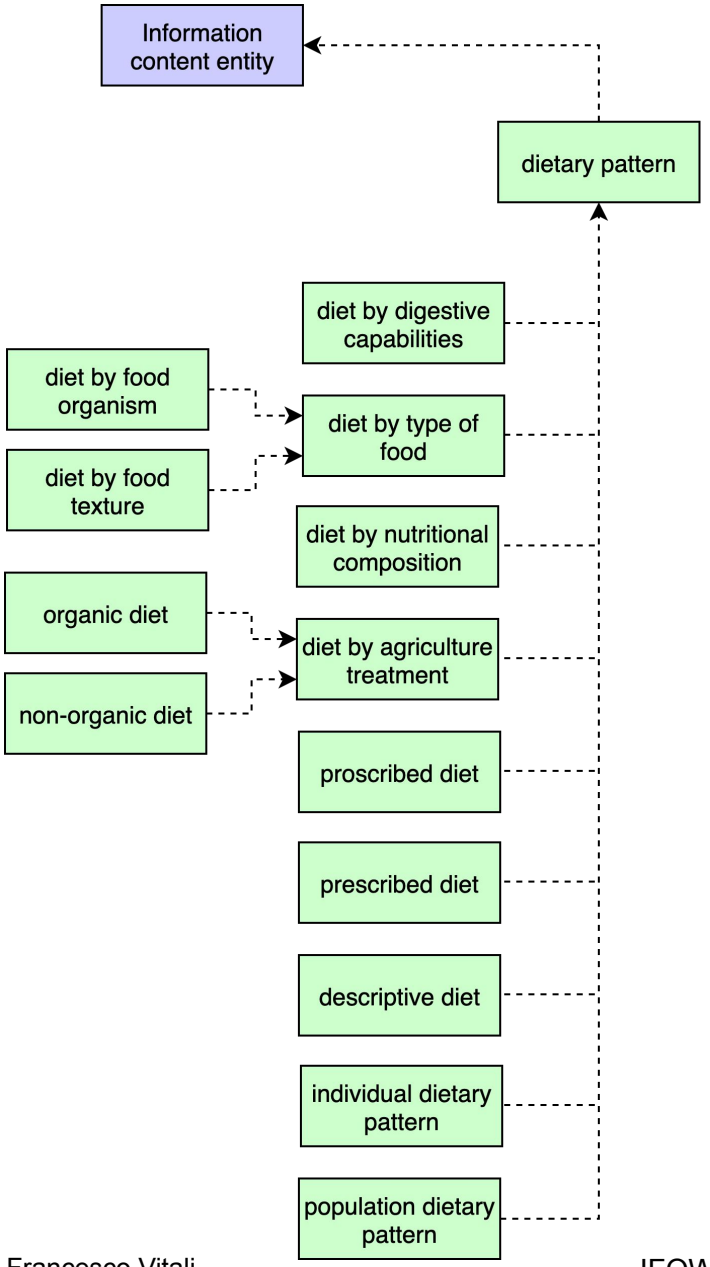
- **DIET** is defined by a certain **DIETARY PATTERN;**
- **DIETARY PATTERN** of a person/country/group is defined by what they eat through the succession of **MEALS** (realizable entity).

Consensus building over dietary terms - JFO workgroup

International consensus building over dietary term: discussion in the **joint food ontology** workgroup to define and organize the terms, which will be included in ONS



Consensus building over dietary terms - JFO workgroup



Different “flavours” of the diet concept

Dietary terms spreadsheet

↓

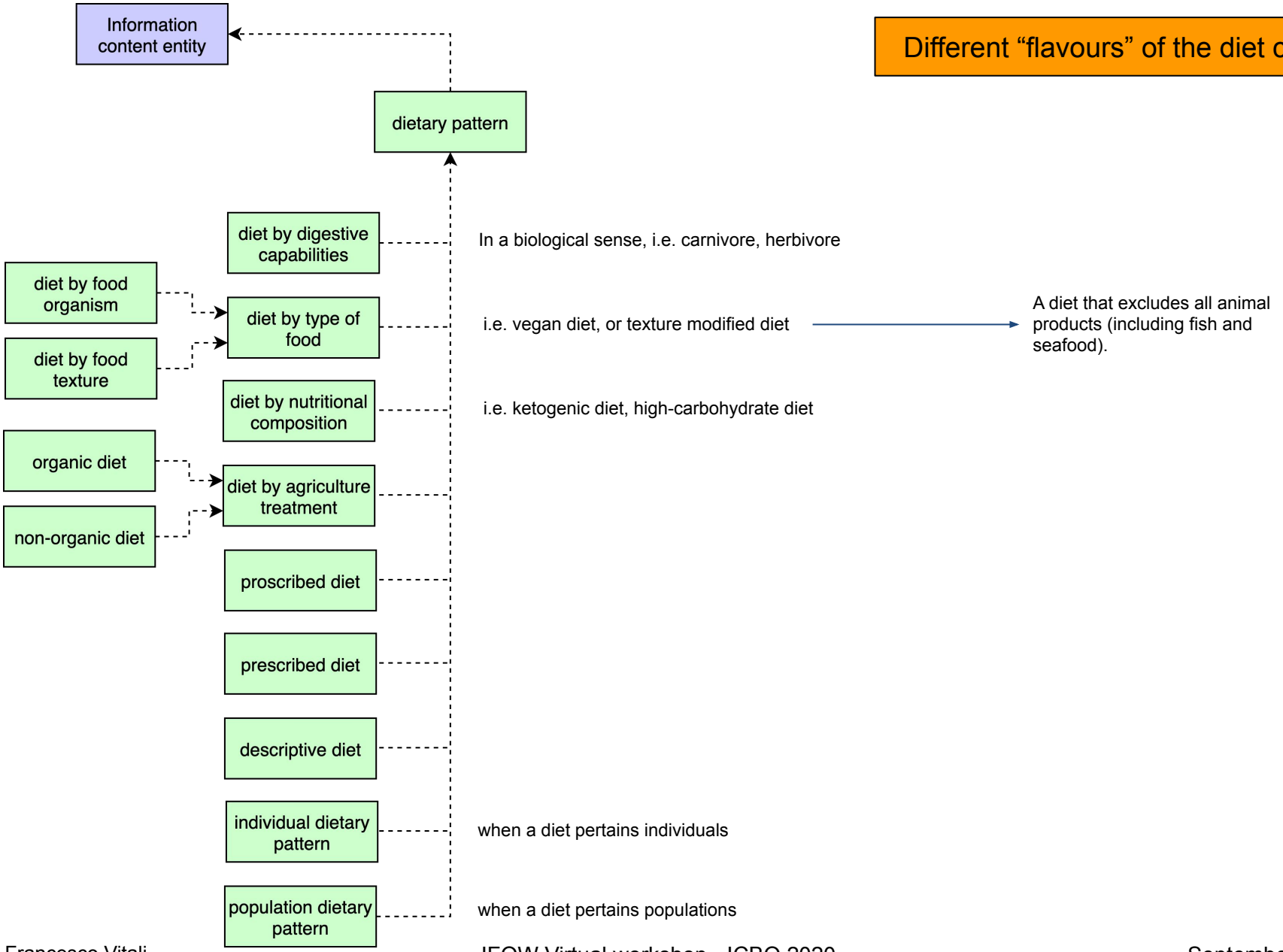
ROBOT

↓

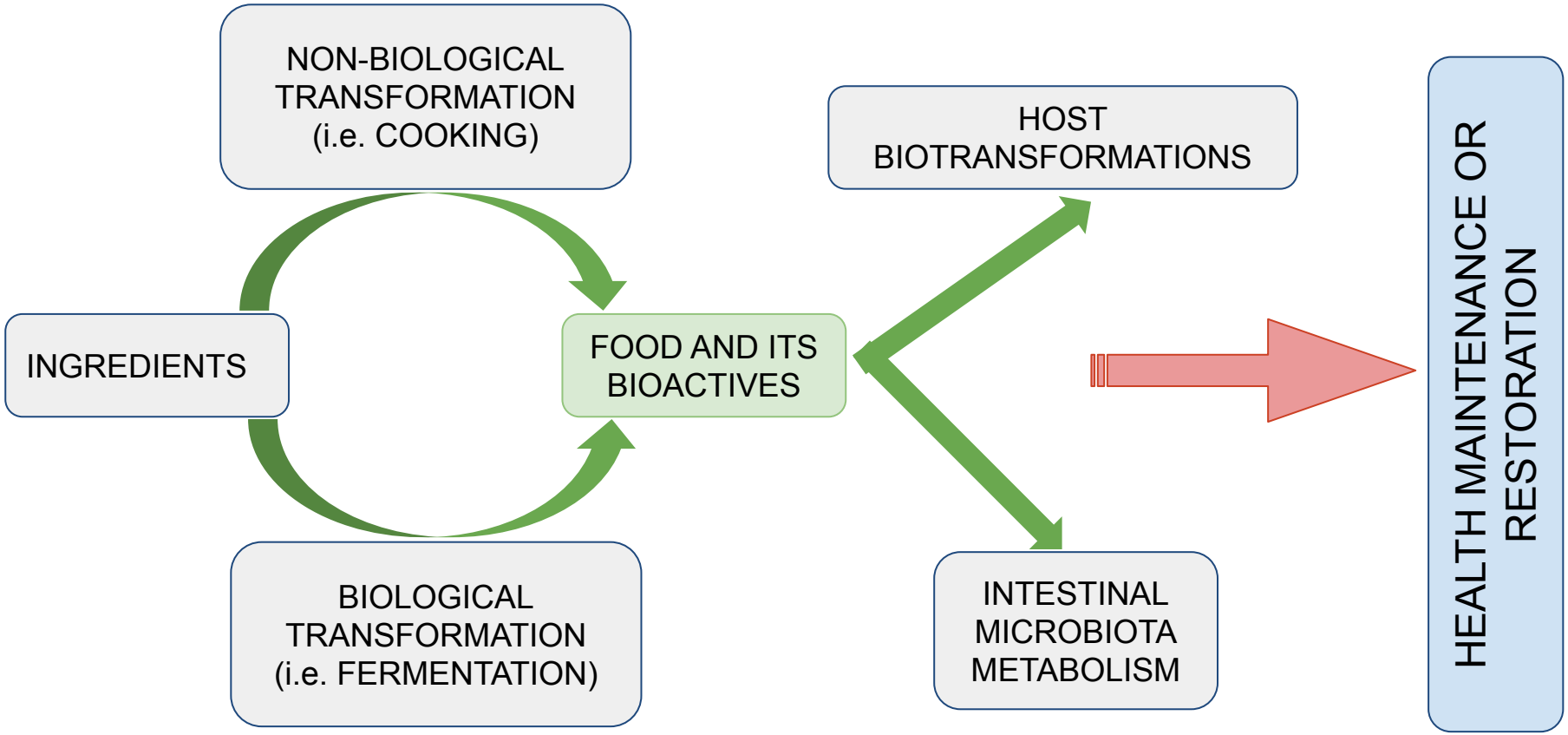
JFOW_dietary_terms.owl

Addition of 63 diet classes to ONS

Consensus building over dietary terms - JFO workgroup



MAIN "AXIS" OF INTEREST



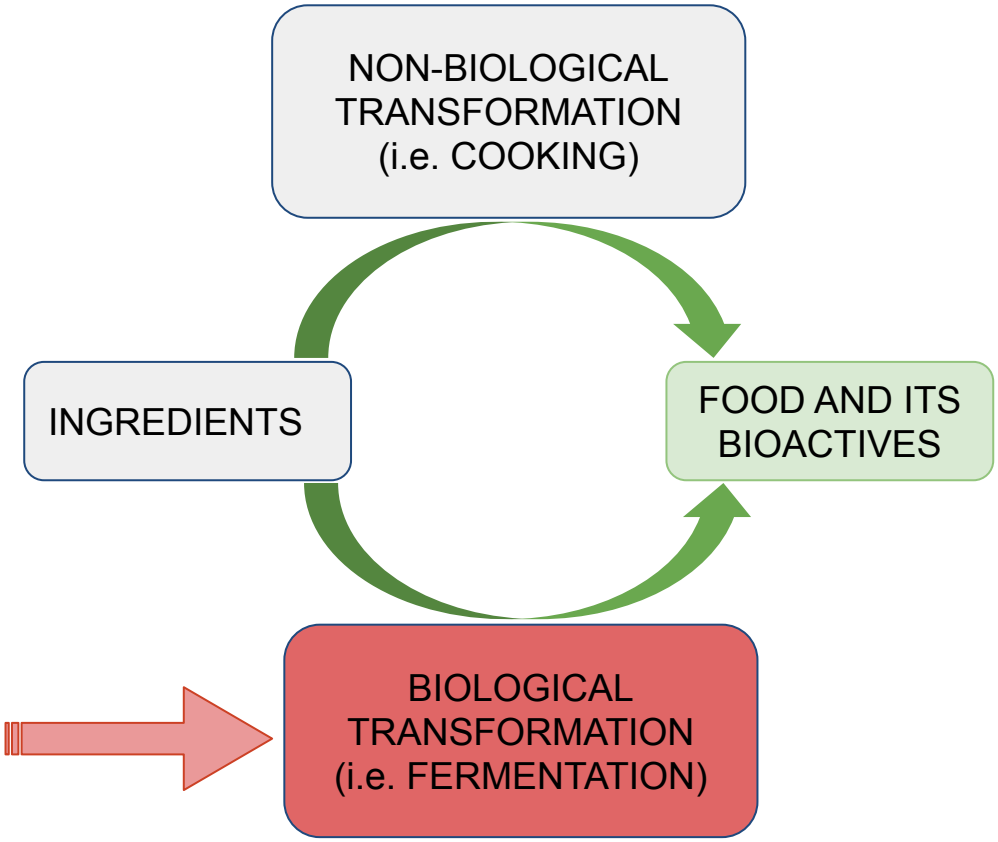
CONCEPTUAL LAYER

DATA LAYER

- METABOLOMIC
- EXPERIMENTAL MICROBIOLOGY

- METABOLOMIC
- METAGENOMIC
- TRANSCRIPTOMIC

Future expansion of ONS



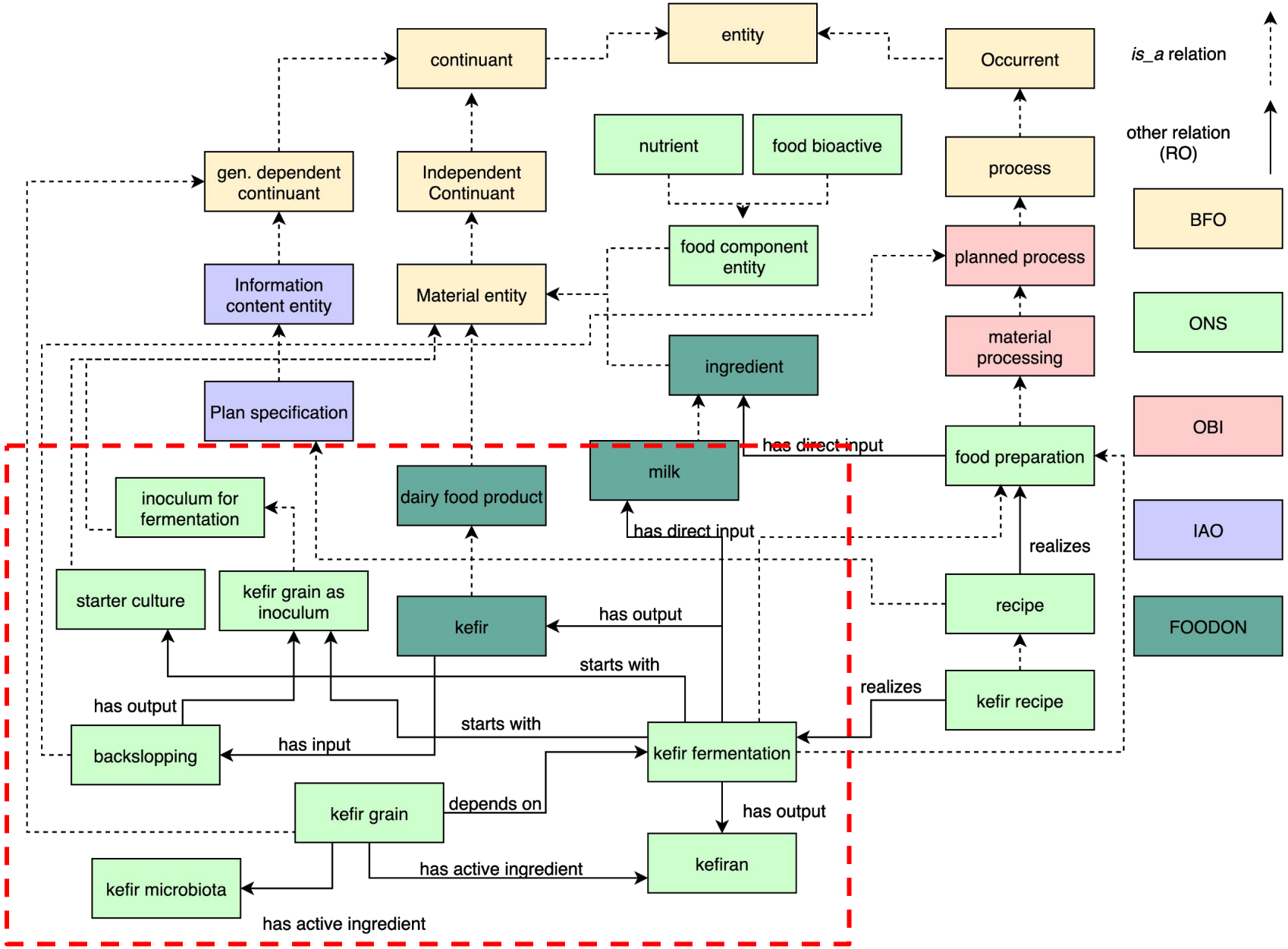
Bioactives in food **are not** simply the sum of the bioactives in the ingredients

as some biological and/or non biological transformation occurs.

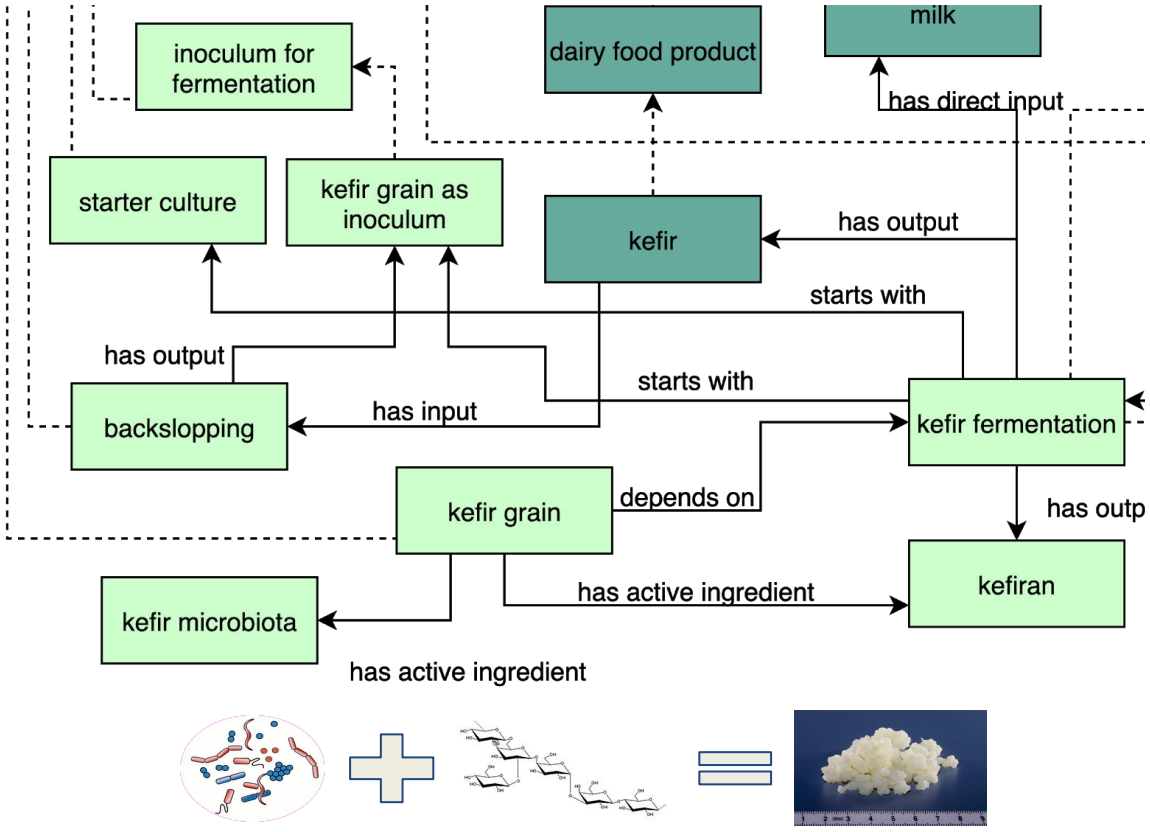
Use case for fermented food - Kefir

- **Kefir** is a dairy product that can be prepared **from different milk** types, such as goat, buffalo, sheep, camel, or cow via microbial fermentation (inoculating milk with kefir grains);
- Kefir is proposed as **one of the factors associated with the long life expectancy** of the people of Caucasus; owing to its **many health benefits**
- anti-stress properties, immune-modulation, cholesterol-lowering, anti-allergenic, anti-asthmatic, anti-microbial, anticancer properties and chemoprevention against colon cancer, aside from its gastrointestinal beneficial effects;
- the fermentation process enriches the content of vitamins B1, B12, K, folic acid, calcium and amino acids, adding to kefir health benefits.

Use case for fermented food - Kefir



MODELLING KEFIR STARTER/INOCULUM: the chicken or the egg….



kefir microbiota kefiran polysaccharide

Kefir fermentation is best/usually started with **inoculum of kefir granules in milk**;

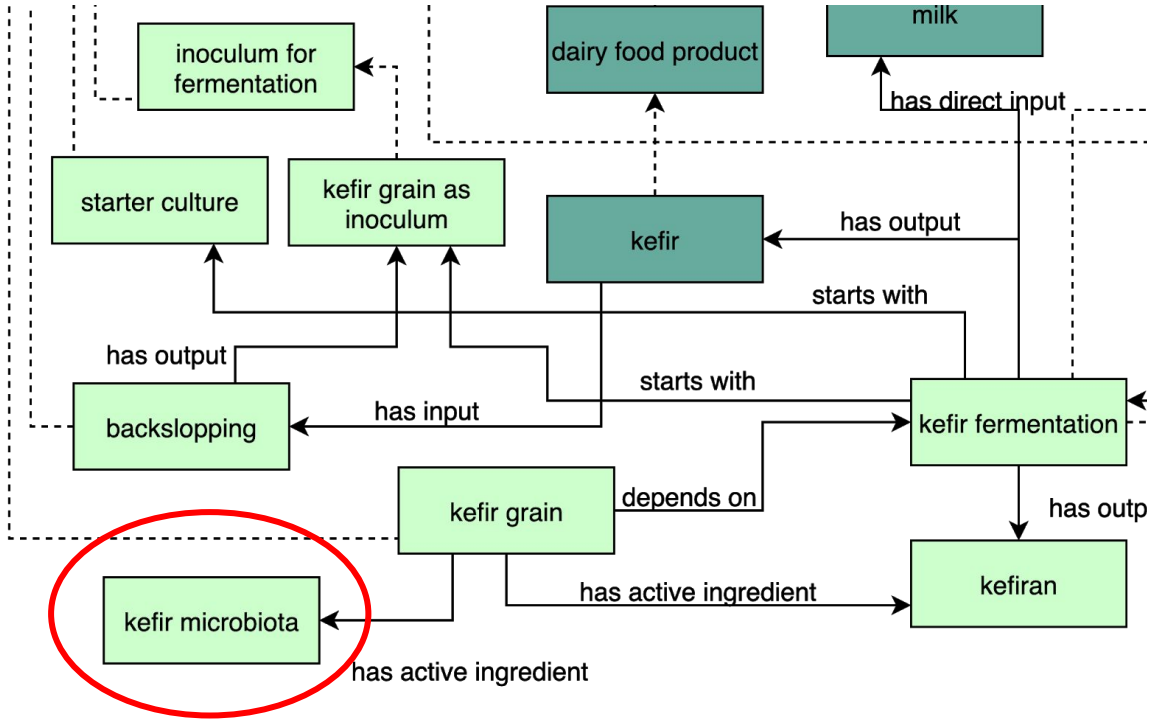
Kefir granules are formed during kefir fermentation by aggregation of microorganisms and kefiran; a polysaccharide produced by *Lactobacillus kefiranofaciens;*

Difference between the concept of "**inoculum for fermentation**" and "**starter culture for fermentation**"

Starter culture for fermentation: a microbial community which is added to unprocessed ingredients to start a fermentation process.

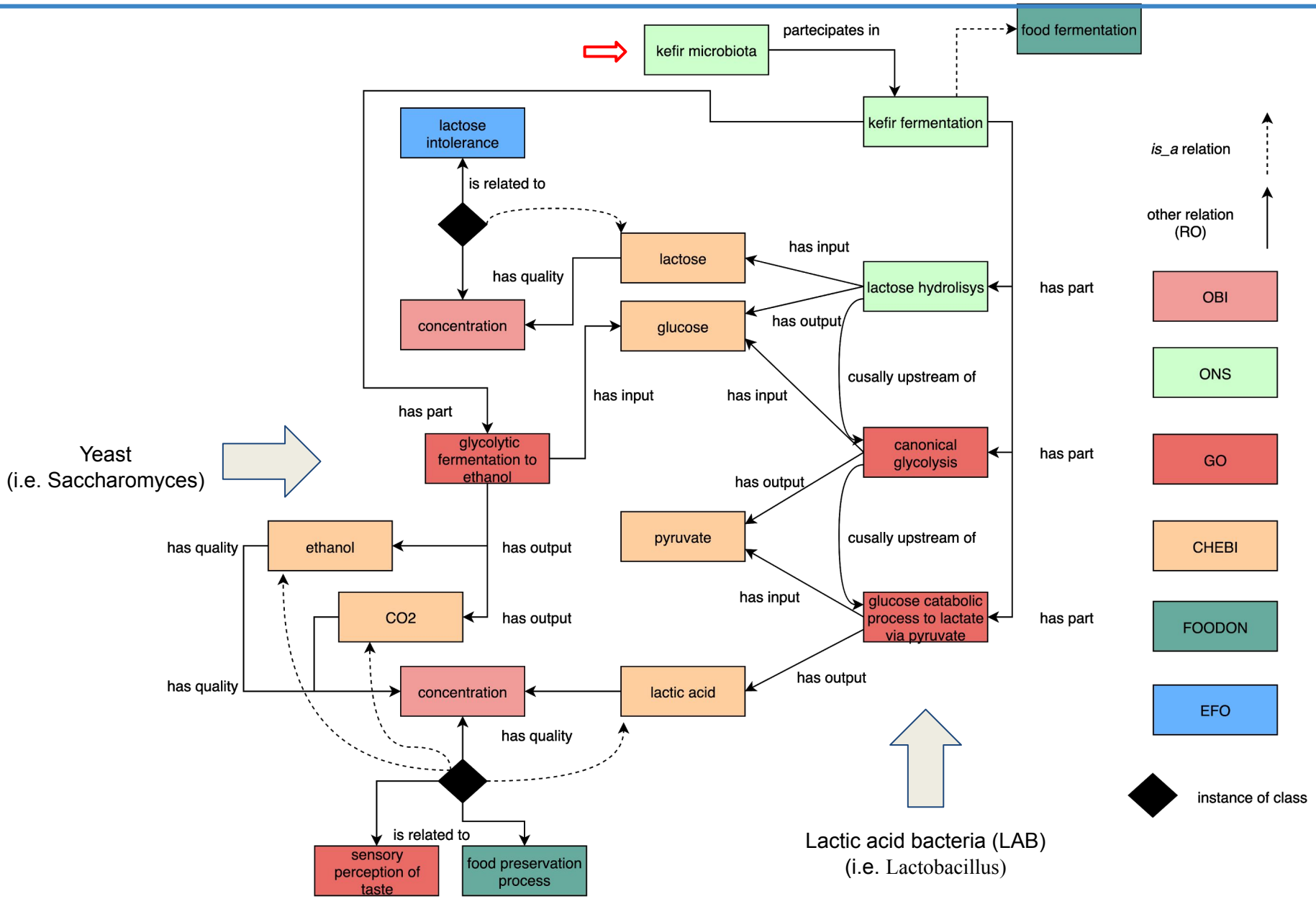
Inoculum for fermentation: the carrier of a starter culture

Use case for fermented food - Kefir



Kefir microbiota is the “performer” of fermentation

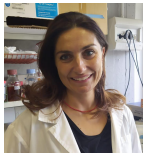
Use case for fermented food - Kefir



Francesco Vitali, PhD
Institute of Agricultural Biology and Biotechnology (IBBA)
National Research Council (CNR)

Agnese Gori, Post Graduate
Dept. of Biology
University of Florence

Emily Schifano, PhD
Centre for Food and Nutrition
Council for Agricultural Research and Economics (CREA)



Paola Zinno, PhD
Centre for Food and Nutrition
Council for Agricultural Research and Economics (CREA)

Chiara Devirgiliis, PhD
Centre for Food and Nutrition
Council for Agricultural Research and Economics (CREA)

Duccio Cavalieri, PhD
Dept. of Biology
University of Florence

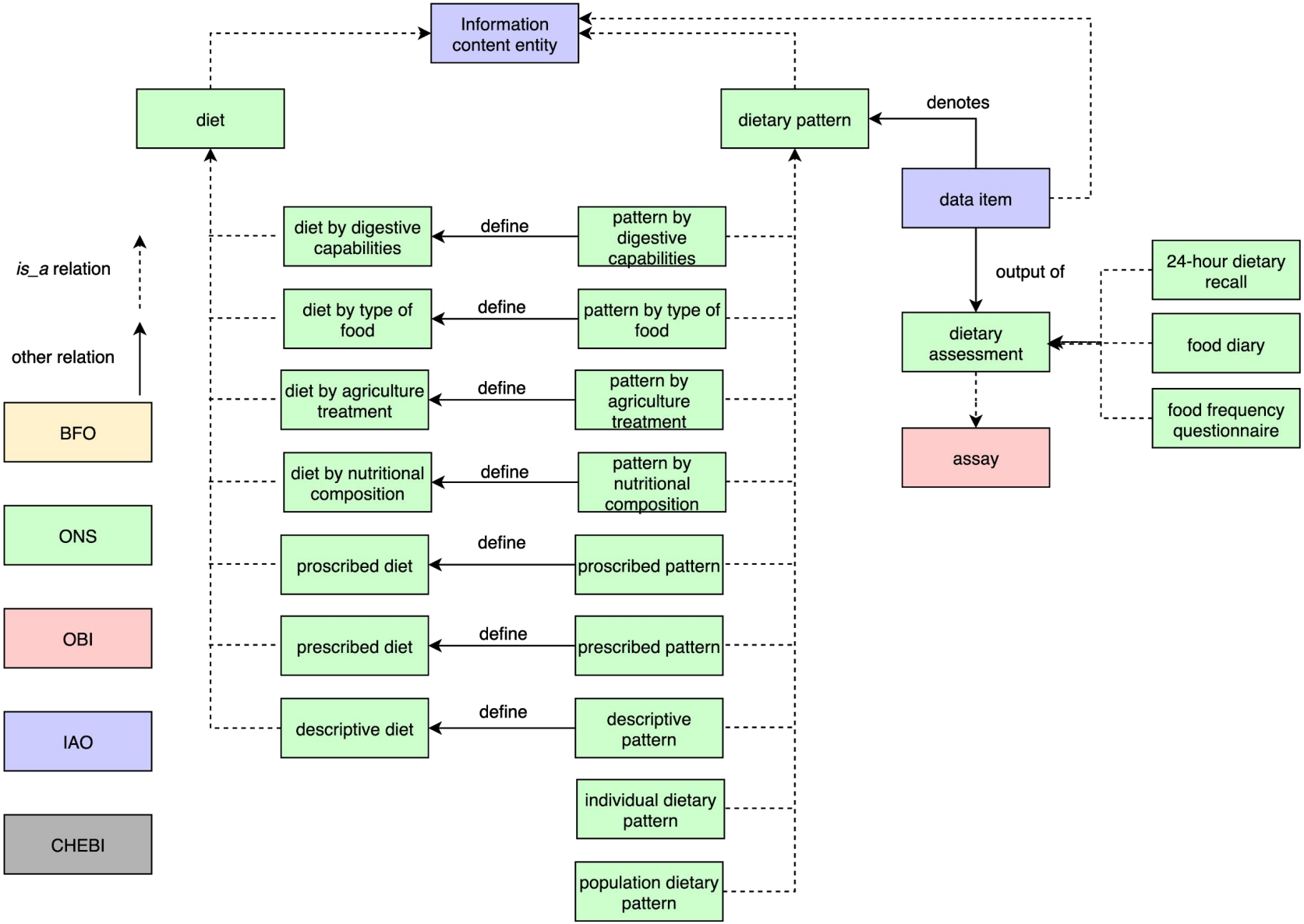
Consiglio Nazionale delle Ricerche
IBBA
Istituto di Biologia e Biotecnologia Agraria

crea
Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria

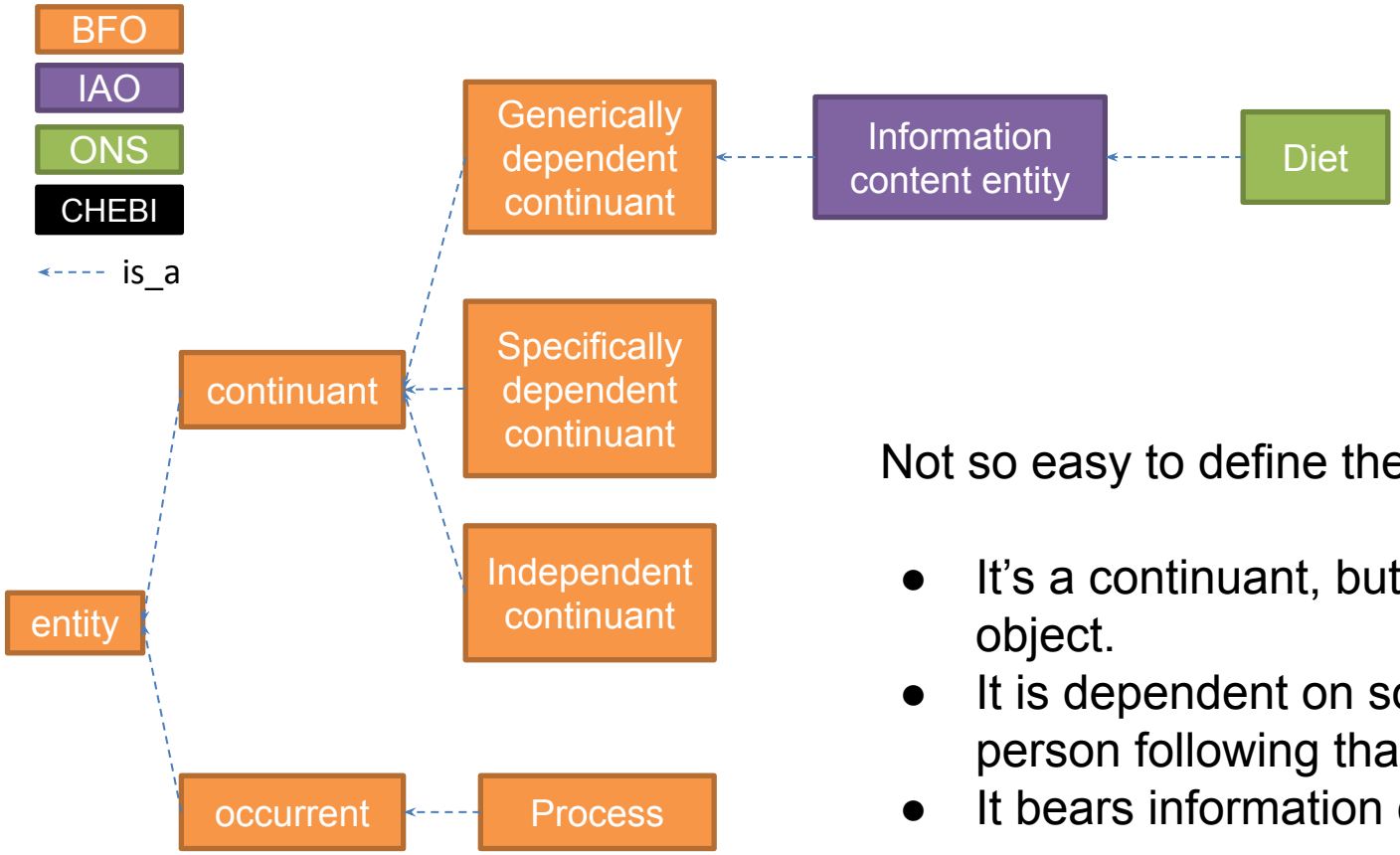
UNIVERSITÀ DEGLI STUDI FIRENZE
BIO Dipartimento di Biologia

Thank you

Consensus building over dietary terms - JFO workgroup



A look at ONS

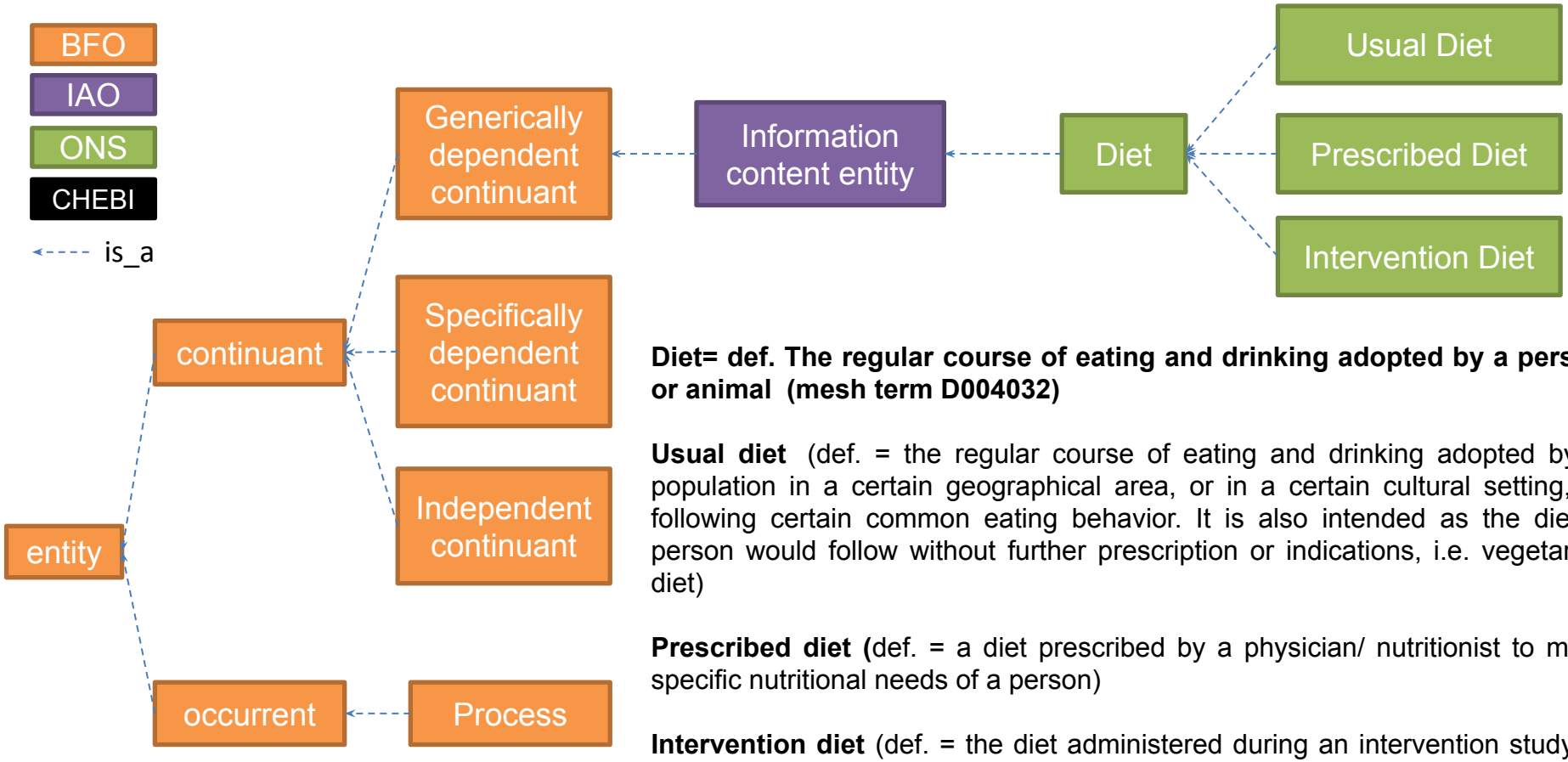


Not so easy to define the concept of diet…

- It's a continuant, but not a physical object.
- It is dependent on someone (i.e. the person following that diet)
- It bears information on eating habit

(Specifically dependent continuant in BFO is more about role)

A look at ONS



Diet= def. The regular course of eating and drinking adopted by a person or animal (mesh term D004032)

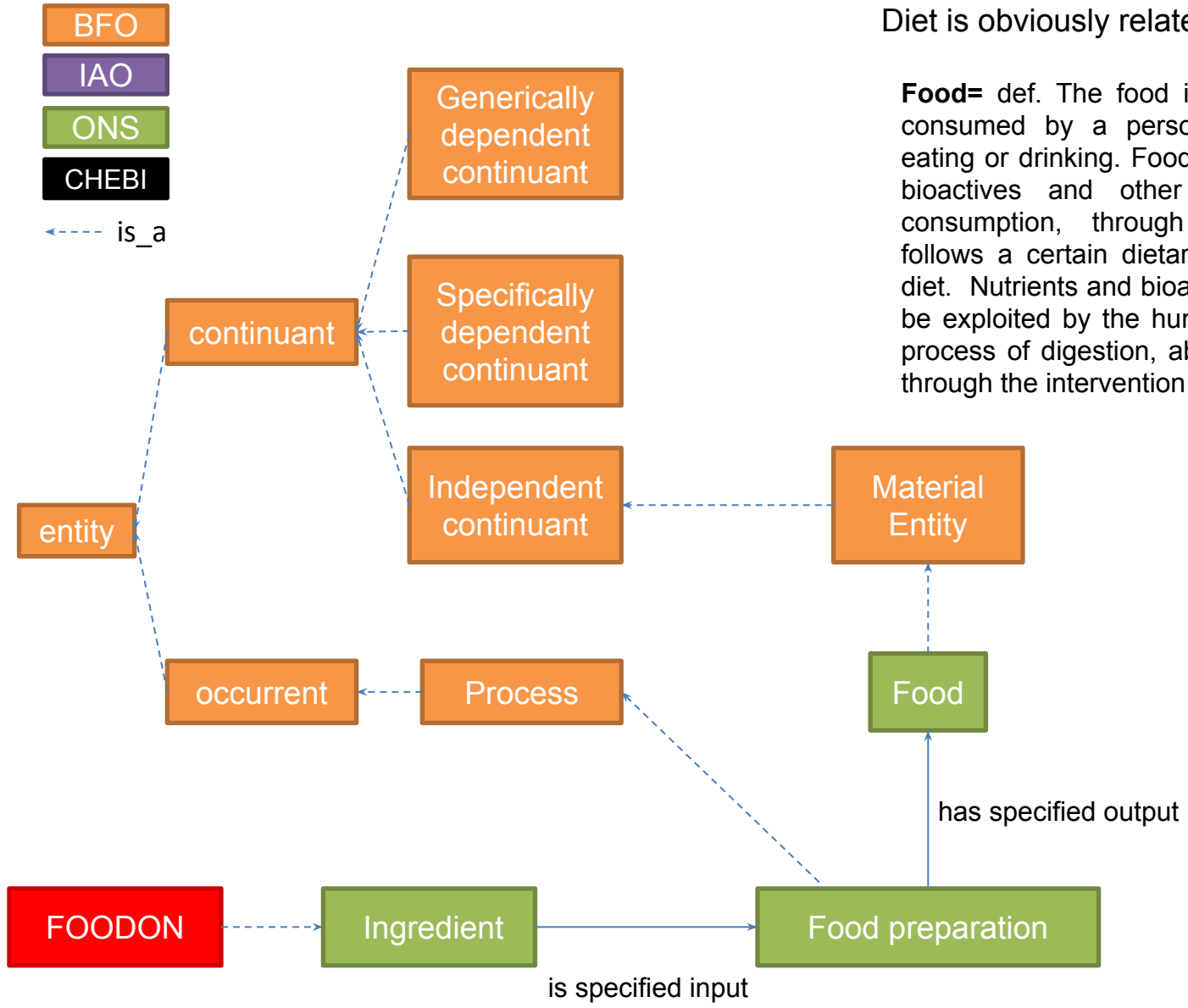
Usual diet (def. = the regular course of eating and drinking adopted by a population in a certain geographical area, or in a certain cultural setting, or following certain common eating behavior. It is also intended as the diet a person would follow without further prescription or indications, i.e. vegetarian diet)

Prescribed diet (def. = a diet prescribed by a physician/ nutritionist to meet specific nutritional needs of a person)

Intervention diet (def. = the diet administered during an intervention study. It usually comprises the adoption of a certain nutritional intervention, intended as the prescription of consuming or not consuming certain food, and follows a precise study design. Intervention studies usually compare at least two subgroups of a population, one control group receiving a null nutritional intervention, and one or more test groups receiving the intervention).

Subclasses originally needed for the ENPADASI project to talk about a nutritional study.

A look at ONS



Diet is obviously related to food, but what is food?

Food= def. The food is a complex matrix that is consumed by a person through the process of eating or drinking. Food are bearer of the nutrients, bioactives and other food components. Food consumption, through the meal consumption, follows a certain dietary pattern, which define the diet. Nutrients and bioactives contained in food can be exploited by the human organism thanks to the process of digestion, absorption, metabolization, or through the intervention of the gut microflora.

A look at ONS

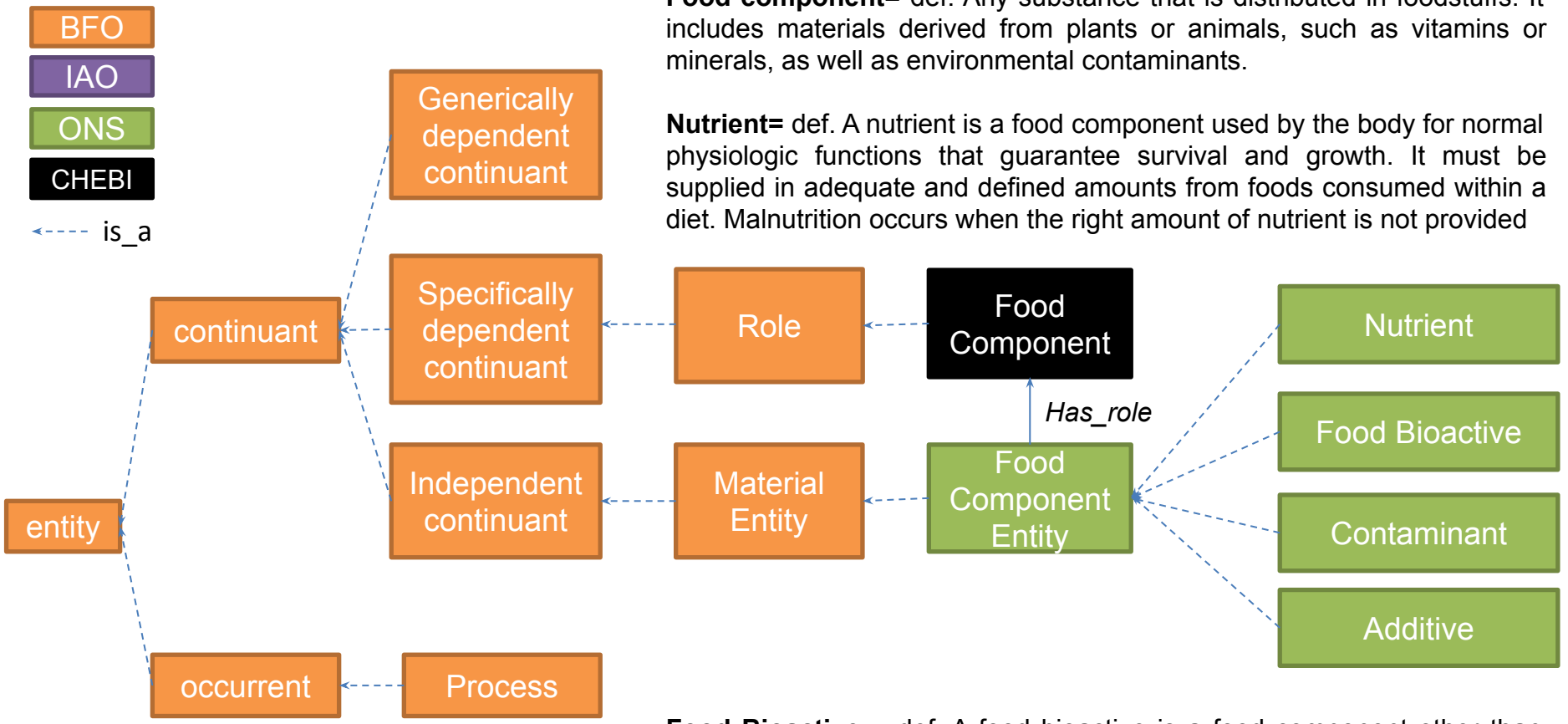
https://foodon.org/

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX obo: <http://purl.obolibrary.org/obo/>
PREFIX xmls: <http://www.w3.org/2001/XMLSchema#>
SELECT DISTINCT ?id
    WHERE {
        {?parent rdfs:subClassOf* obo:FOODON_03411297} #animal food source
        UNION {?parent rdfs:subClassOf* obo:FOODON_03411347} # plant food source
        UNION {?parent rdfs:subClassOf* obo:FOODON_03470107} #preservation type

        ?id rdfs:subClassOf ?parent.
        OPTIONAL {?id rdfs:label ?label}.
        OPTIONAL {?id obo:IAO_0000115 ?definition.}
    }
ORDER BY ?label
```

SPARQL query in ONTOFOX, then import terms

A look at ONS

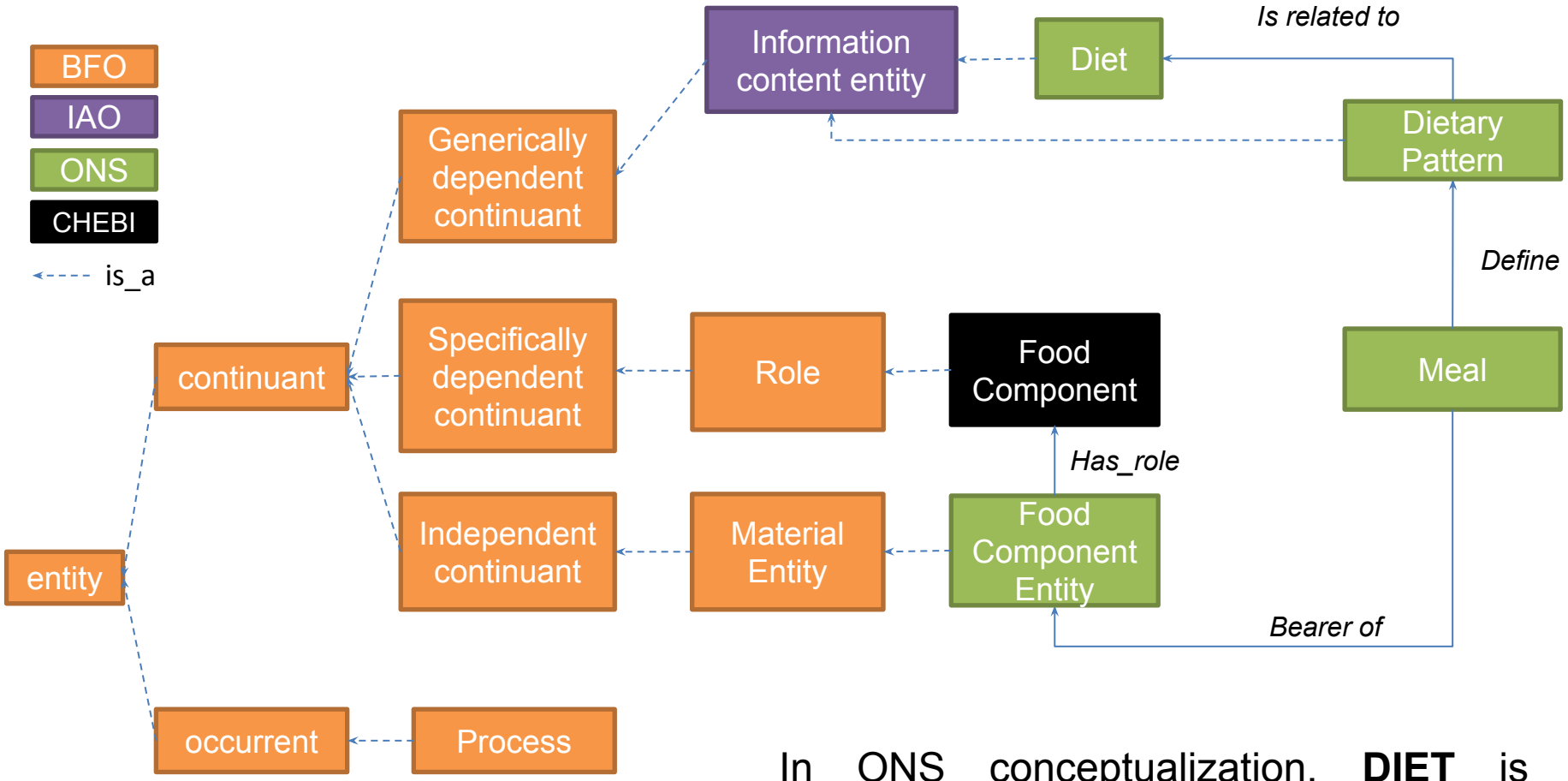


Food component= def. Any substance that is distributed in foodstuffs. It includes materials derived from plants or animals, such as vitamins or minerals, as well as environmental contaminants.

Nutrient= def. A nutrient is a food component used by the body for normal physiologic functions that guarantee survival and growth. It must be supplied in adequate and defined amounts from foods consumed within a diet. Malnutrition occurs when the right amount of nutrient is not provided

Food Bioactive = def. A food bioactive is a food component other than those needed to meet basic human nutritional needs (nutrients). Food bioactives modulates one or more metabolic processes, possibly resulting in the promotion of better health. The daily required intake for food bioactives is not established yet, and there is no demonstration that malnutrition occurs when the right amount is not provided;
Contaminant= def. Unwanted food component that makes the food no longer suitable for use; iv.
Additive= def. component added to food to improve or preserve it.

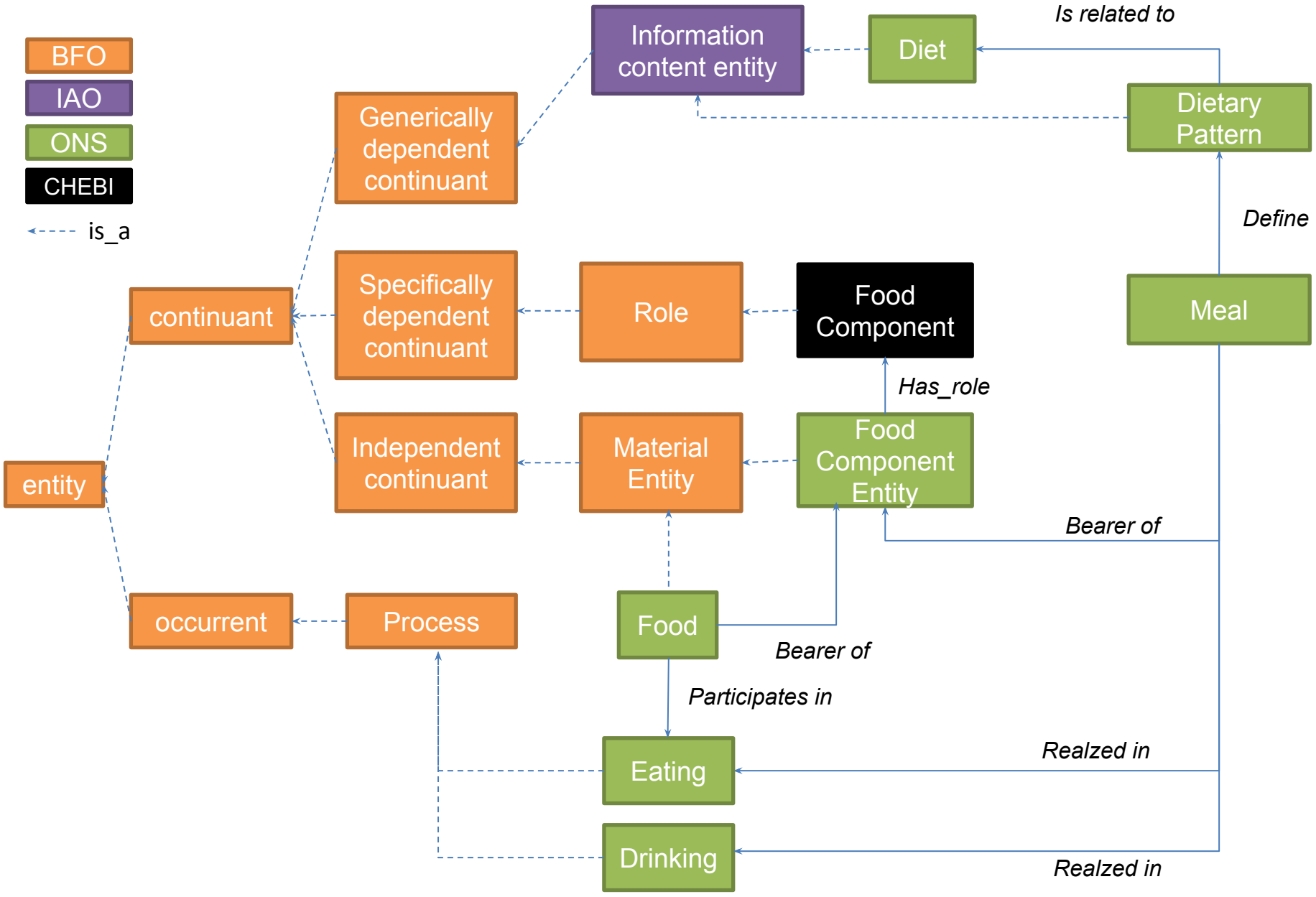
A look at ONS.... Adding complexity



In ONS conceptualization, **DIET** is defined by a certain **DIETARY PATTERN**

DIETARY PATTERN of a person/country/group is defined by what they eat through the succession of **MEALS** (realizable entity)

A look at ONS.... Adding complexity



Future expansion ideas for ONS

ELSEVIER

Food Research International

Volume 99, Part 2, September 2017, Pages 851-861

Home cooking and ingredient synergism improve lycopene isomer production in *Sofrito*

José Fernando Rinaldi de Alvarenga [a], Camilla Tran [b], Sara Hurtado-Barroso [a, c], Miriam Martinez-Huélamo [a, c], Montserrat Illan [a], Rosa M. Lamuela-Raventos [a, c]

Show more

https://doi.org/10.1016/j.foodres.2017.01.009

Highlights

- Onion enhances the production of lycopene Z-isomers in *sofrito*.
- Synergism effect of onion and time of cooking improve the lycopene Z-isomers.
- Combined effect of high content of oil and time of cooking decrease lycopene isomers.
- Time of cooking is the major factor in the lycopene Z-isomers production.

Abstract

There has been increasing interest in tomato products rich in lycopene Z-isomers since these carotenoids present greater bioavailability and antioxidant capacity than the all-*E* lycopene form. Intrinsic food properties as well as processing and the interaction between dietary components can all influence the content, type and bioavailability of carotenoids. The aim of this study was to evaluate whether carotenoid content and isomerization in tomato-based Mediterranean *sofrito* is affected by the process of home cooking and the presence of other ingredients such as extra virgin olive oil, onion and garlic. We used a full factorial design to clarify the contribution of each ingredient to the carotenoid composition of *sofrito* and to determine whether this can be improved by the cooking time and ingredient synergism. Cooking time and onion content were associated with a higher production of 5-Z-lycopene, 9-Z-lycopene and 13-Z-lycopene in *sofrito*. Onion proved to be the most interesting ingredient in the *sofrito* formulation due to their enhancing effect on lycopene isomerization. The use of onion combined with an adequate processing time may improve the bioavailability of lycopene in tomato products.

The aim of this study was to evaluate how the home cooking process and the additional ingredients such as extra virgin olive oil, onion and garlic used to prepare tomato-based Mediterranean sofrito may interact and improve carotenoid content and isomerization.

Tomato-based Mediterranean sofrito = Pomarola

?

Future expansion ideas for ONS

Food Research International
Volume 99, Part 2, September 2017, Pages 851-861

Home cooking and ingredient synergism improve lycopene isomer production in *Sofrito*

José Fernando Rinaldi de Alvarenga [a], Camilla Tran [b], Sara Hurtado-Barroso [a, c], Miriam Martinez-Huélamo [a, c], Montserrat Illan [a], Rosa M. Lamuela-Raventos [a, c]

Show more

https://doi.org/10.1016/j.foodres.2017.01.009

Get rights and content

Highlights

- Onion enhances the production of lycopene Z-isomers in *sofrito*.
- Synergism effect of onion and time of cooking improve the lycopene Z-isomers.
- Combined effect of high content of oil and time of cooking decrease lycopene isomers.
- Time of cooking is the major factor in the lycopene Z-isomers production.

2.4. *Sofrito* preparation

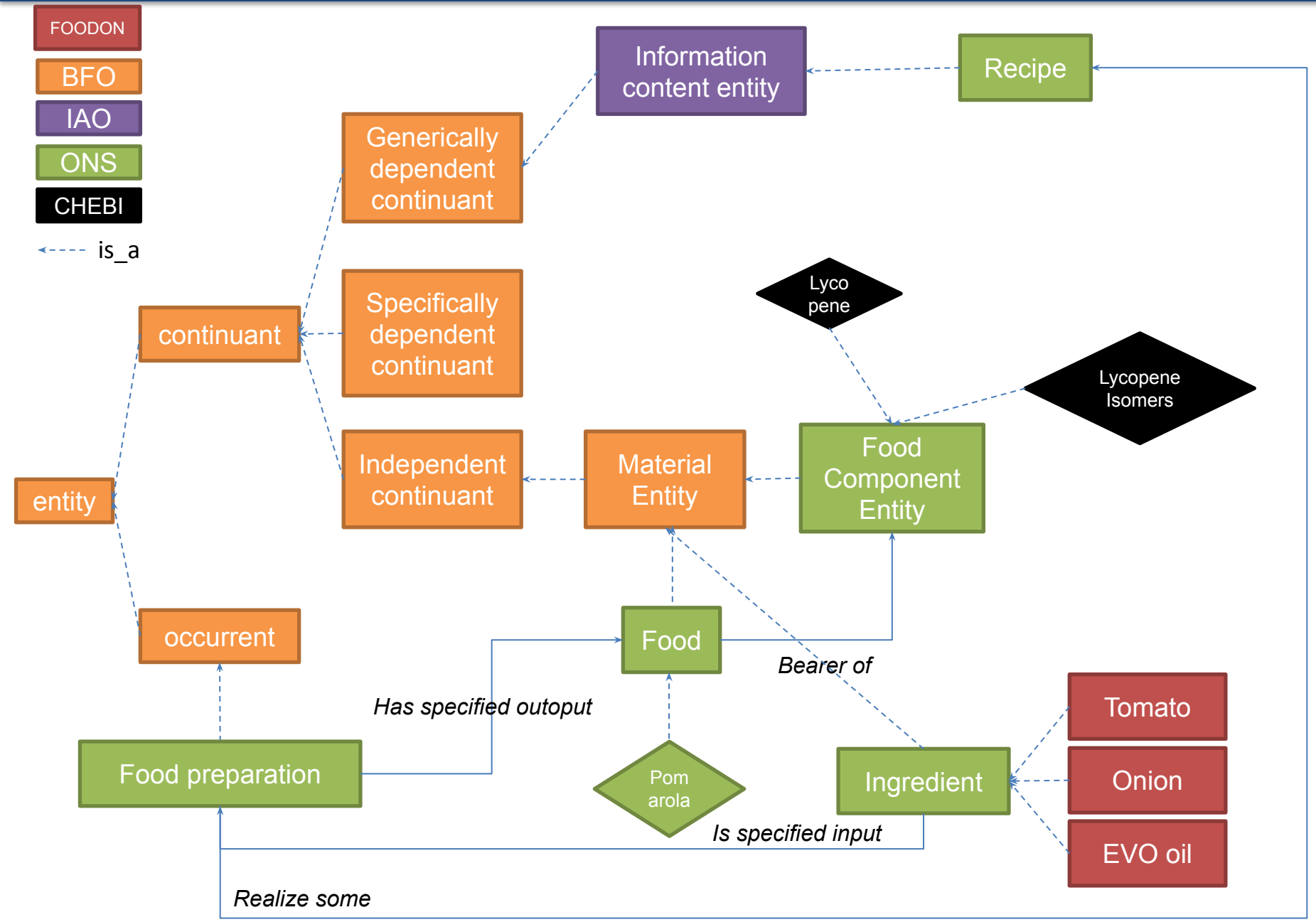
The *sofrito* was prepared at Torribera Campus, University of Barcelona (Santa Coloma de Gramenet, Spain), following a home cooking method. The tomatoes, garlic and onions were washed, cut into small pieces, mixed with a blender (model R5 Plus, Robot Coupe®) and weighed according to the FFD. The cooking process was based on the traditional Mediterranean diet: in an uncovered pan (24 cm diameter, 15 cm height, 6.3 L volume, thickness 1.59 mm, made of inox 18/10). The EVOO was heated on an electrical cooking plate (180 mm diameter, 1500 W, model Encimera EM/30 2P, Teka®) at potency 4 (ranging from 1 to 6) for 1 min. The onion and garlic were then added and fried for 1 min, before adding the tomato, at which point the cooking process was timed, and the temperature was reduced to potency 2 to provide constant heat throughout the process (100 ± 1 °C). After preparation, the 16 *sofritos* were weighed to quantify weight loss, frozen in plastic vacuum bags, and stored at – 25 °C (Table 1).

Some «*Food Bioactive*» (or their concentration) change in «*Food*» after some «*Food preparation*», which ultimately follows instruction encoded in a «*Recipe*»

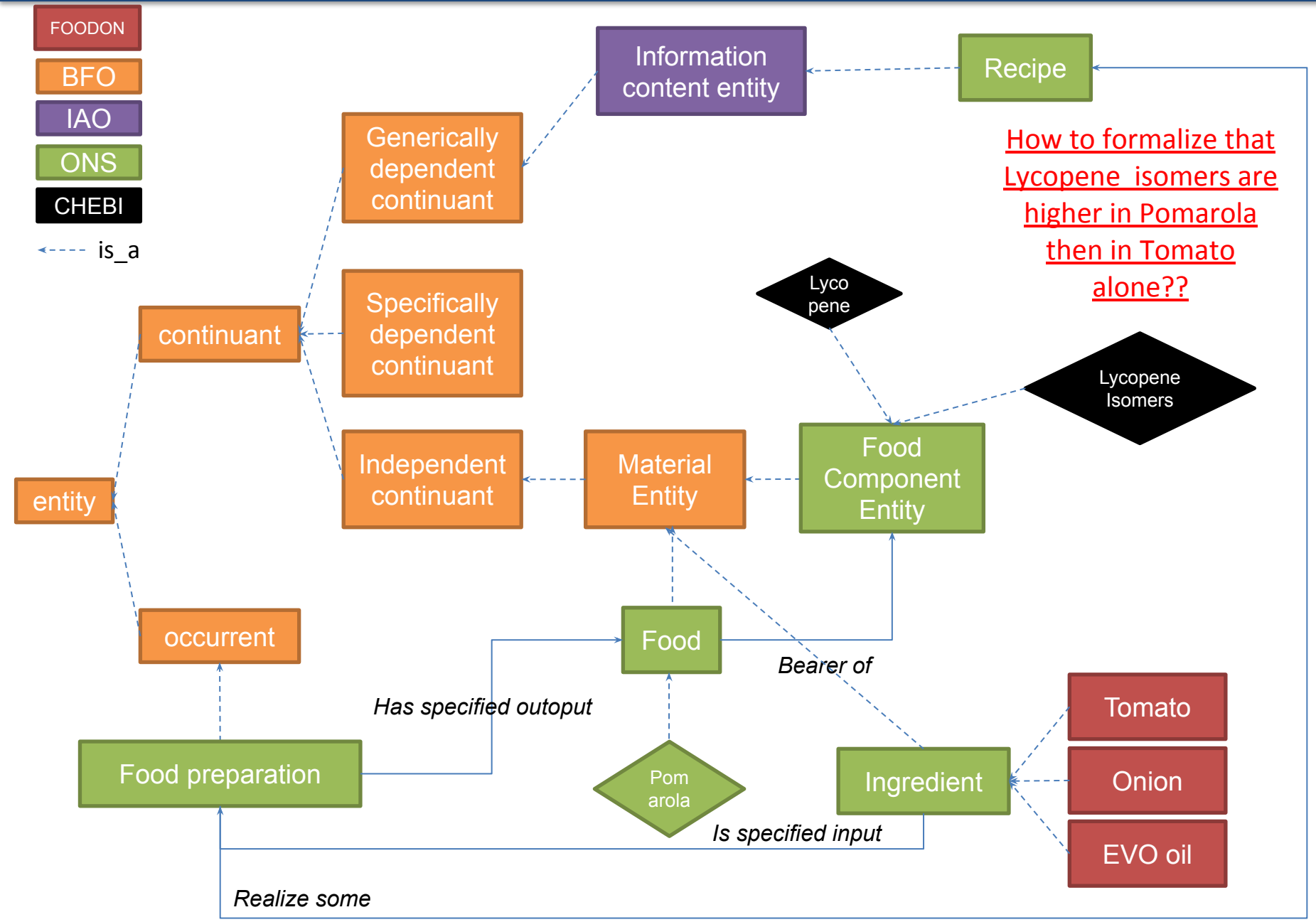
Text processing on cookbooks to obtain, and then formalize, information in ONS.

Connect this information to metabolomics and to known transformations of food bioactive after processing, to really understand what we are eating

A look at ONS.... Adding complexity



A look at ONS.... Adding complexity



Orthogonality in ONS

Table 1 Prefix and URL of the ontology of origin of the classes imported in ONS

	Prefix	No. of terms in ONS	URL
Basic Formal Ontology	BFO	45	http://florris.uni-saarland.de/bfo/
Chemical Entities of Biological Interest	CHEBI	14	https://www.ebi.ac.uk/chebi/
Clinical Measurement Ontology	CMO	5	https://bioportal.bioontology.org/ontologies/CMO
EMBRACE Data And Methods Ontology	EDAM	12	http://edamontology.org/page
Experimental Factor Ontology	EFO	30	https://www.ebi.ac.uk/efo/
eagle-i Research Resource Ontology	ERO	2	https://open.med.harvard.edu/wiki/display/eaglei/Ontology
Food Ontology	FOODON	2809	https://foodontology.github.io/foodon/
Human Phenotype Ontology	HP	2	http://human-phenotype-ontology.github.io/
The Information Artifact Ontology	IAO	63	https://github.com/information-artifact-ontology/IAO
Informed Consent Ontology	ICO	5	https://github.com/ICO-ontology/ICO
NCBITaxon ontology	NCBITaxon	17	http://www.obofoundry.org/ontology/ncbitaxon.html
The NCI Thesaurus	NCIT	26	http://www.obofoundry.org/ontology/ncit.html
Ontology of Biological and Clinical Statistics	OBCS	5	https://github.com/obcs/obcs
Ontology for Biomedical Investigations	OBI	265	http://obi-ontology.org/
Ontology for Biobanking	OBIB	4	http://www.obofoundry.org/ontology/obib.html
Ontology for General Medical Science	OGMS	11	http://www.obofoundry.org/ontology/ogms.html
The Ontology of Host-Microbiome Interactions	OHMI	4	https://github.com/OHMI-ontology/OHMI
Ontological Minimum Information About Biobank data Sharing	OMIABIS	3	http://www.obofoundry.org/ontology/omiabis.html
The Ontology of Medically Related Social Entities	OMRSE	1	https://github.com/ufbmi/OMRSE
The Semanticscience Integrated Ontology	SIO	33	https://github.com/micheldumontier/semanticscience
STATistics Ontology	STATO	4	http://stato-ontology.org/
An ontology of units of measurements	UO	18	https://github.com/bio-ontology-research-group/unit-ontology

FROM: Vitali, Francesco, et al. "ONS: an ontology for a standardized description of interventions and observational studies in nutrition." *Genes & nutrition* 13.1 (2018): 12.

Use case for fermented food - Kefir

20. WHY KEFIR?

WHY IT IS GOOD FOR OUR HEALTH?

HOW IS KEFIR MADE?

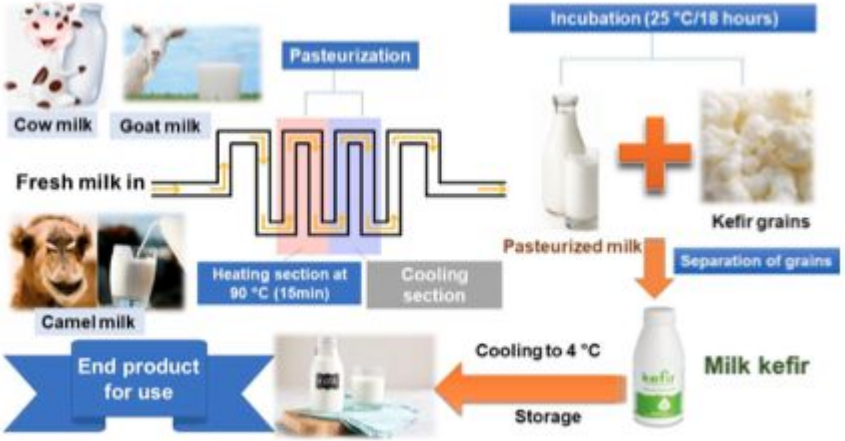


Figure 1. Outline diagram representing the backslopping method used for kefir production.

Kefir is a dairy product that can be prepared from different milk types, such as goat, buffalo, sheep, camel, or cow via microbial fermentation (inoculating milk with kefir grains). The traditional method of preparing dairy-based kefir used in private households is to incubate milk with kefir grains. The kefir grains are inoculated into sterilized milk and fermented at 25 ◦C until a pH of 4.4 is reached. The grain and milk are then separated using a sterilized plastic filter at the end of the fermentation process

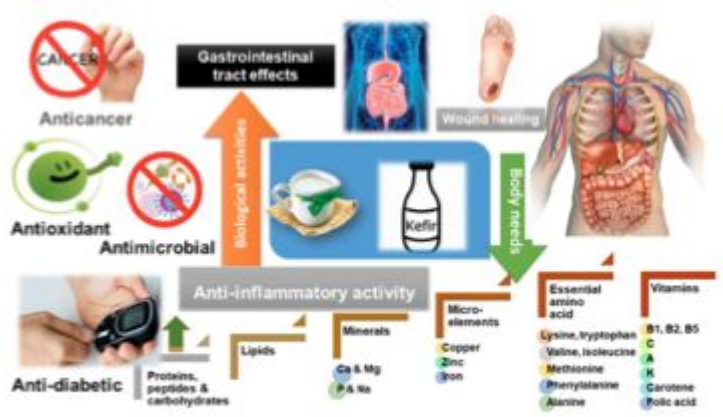


Figure 5. Biological properties, nutritional value, and macro- and micronutrient composition of kefir.

Kefir is proposed as one of the factors associated with the long life expectancy of the people of Caucasus, owing to its many health benefits such as anti-stress properties, immune-modulation, cholesterol-lowering, anti-allergenic, anti-asthmatic, anti-microbial, anticancer properties and chemoprevention against colon cancer, aside from its gastrointestinal beneficial effects. Such health benefits are attributed to kefir's protein, vitamin, lipid, mineral, amino acid, and microelement composition. Moreover, the fermentation process enriches the content of vitamins B1, B12, K, folic acid, calcium and amino acids, adding to kefir's health benefits.

Nutrients **2020**, *12*, 346; doi:10.3390/nu12020346

Use case for fermented food - Kefir

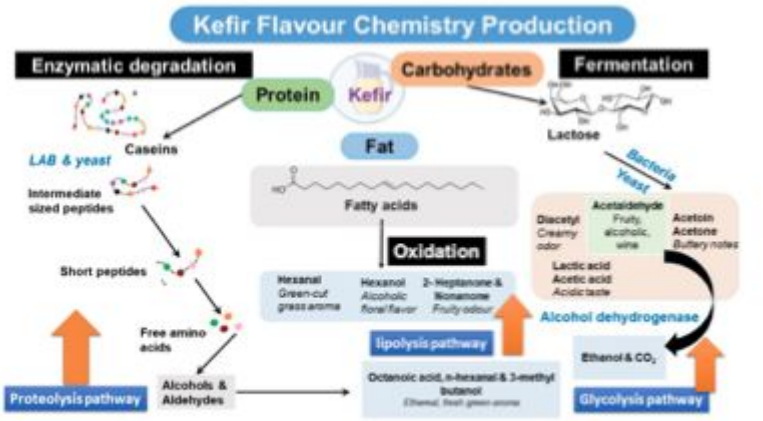


Figure 4. Kefir flavour chemistry production via proteolysis, lipolysis and glycolysis of milk macronutrients by the action of different microbes within kefir grains.

24. Several metabolic products are generated during kefir production and account for its distinct flavour and aroma: Lactic acid, ethanol, carbon dioxide, and aroma compounds such as acetoin and acetaldehyde. During the storage process, microbiological, physicochemical, and sensory characteristics of kefir can further undergo changes, some of which improve its shelf life.

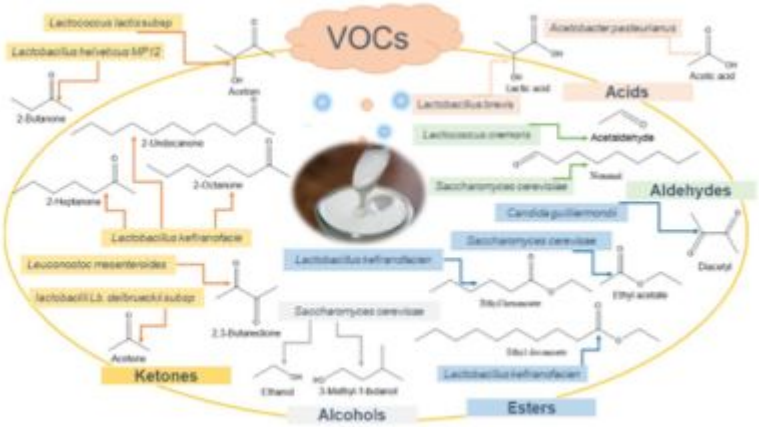


Figure 3. Major volatile aroma compound classes produced in kefir during fermentation.

The kefir microbial community encompasses a complex mixture of lactic acid bacteria (LAB) (*Leuconostocs*, *Lactobacilli*, *Streptococci*, *Lactococci*, *Enterobacter*, *Acinetobacter*, *Enterococcus*, and *Pseudomonas* spp.), acetic acid bacteria and yeasts (*Kluyveromyces*, *Candida*, *Torulopsis*,*Saccharomyces*, *Rhodotorula* and *Zygosaccharomyces*)

Nutrients **2020**, *12*, 346; doi:10.3390/nu12020346

- **Fermented foods and beverages** are generally defined as products **made by microbial organisms metabolism**, that make enzymatic conversions of major and minor food components;

- Fermentation in food processing is the process of converting carbohydrates to alcohol or organic acids by microorganisms —yeasts or bacteria— under anaerobic conditions.

Use case for fermented food - Kefir

WHY KEFIR?

WHY IT IS GOOD FOR OUR HEALTH?

HOW IS KEFIR MADE?

The whole working group...

Duccio Cavalieri, *Carlotta De Filippo*, *Monica Di Paola*, *Damariz Rivero*, *Francesco Vitali, Niccolò Meriggi*, *Agnese Gori, Stefano Nenciarini, Alessia Ciccione, Sonia Renzi*

Consiglio Nazionale delle Ricerche
IBBA
Istituto di Biologia e Biotecnologia Agraria

crea
Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria

UNIVERSITÀ DEGLI STUDI FIRENZE
BIO Dipartimento di Biologia