PROPOSAL OF A DOMAIN ONTOLOGY FOR SPECIALTY COFFEE

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Abstract: *Coffee represents one of the main products marketed in the world. It has scientific relevance related to human health as well as economic importance to several countries in the world. Around 12.5 million coffee growers in the world are directly involved in its production. It is a product that can easily lose quality throughout its productive chain, which – although already mapped – does not include knowledge relevant to the preservation of quality that is explicit and easily accessible to agents in the coffee agribusiness system. Representing the knowledge necessary to preserve the quality of coffee and allowing its sharing through intelligent systems can help agents in the coffee agribusiness system. The representation of the formal and explicit knowledge of high-quality coffee – called specialty coffee – through an ontology for the specialty coffee domain is presented as a proposal in this paper.*

Keywords: *specialty coffee, domain ontology, knowledge representation, knowledge engineering, agribusiness system.*

1 INTRODUCTION

Global coffee industry revenue for 2019 is forecast at US$ 429,477.90 million (Statista, 2019), and world coffee production for the 2018/2019 harvest is estimated at 168.05 million 60Kg bags (ICO, 2019). This represents a significant amount to the international economy, as presented in Figure 1. Despite these figures, the quality of coffee as a final product, specifically its chemical properties that are beneficial to human health, tends to be unreliable (Biotto, De Toni, & Nonino, 2012; Kasai, 2014).

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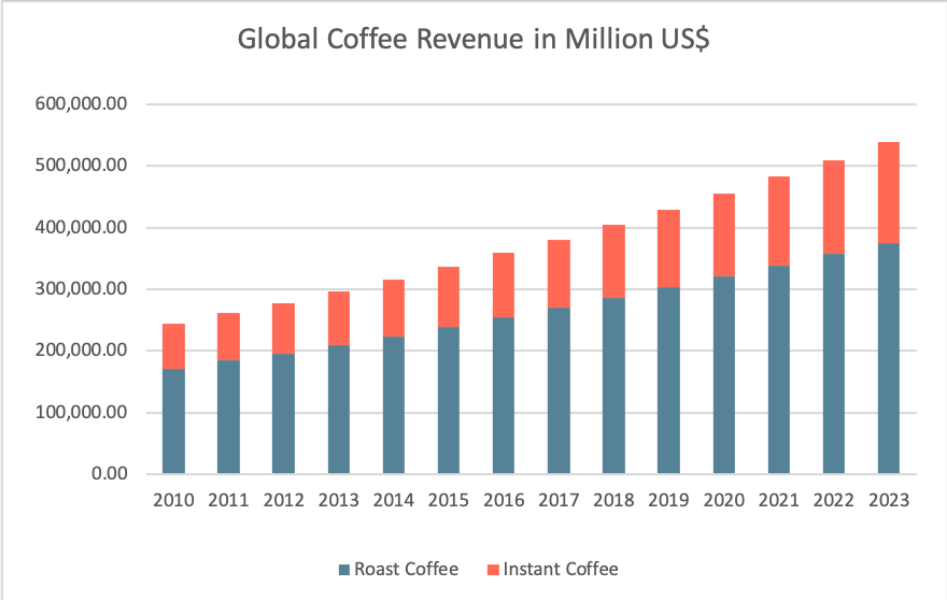

Figure 1: Global Coffee Revenue in Million US$. Source: (Statista, 2019)

In the segment of high-quality products, specialty coffee stands out. In the North American market in 2017, 59% of the cups of coffee consumed were specialty coffee (SCA, 2017a) as shown in Figure 2.

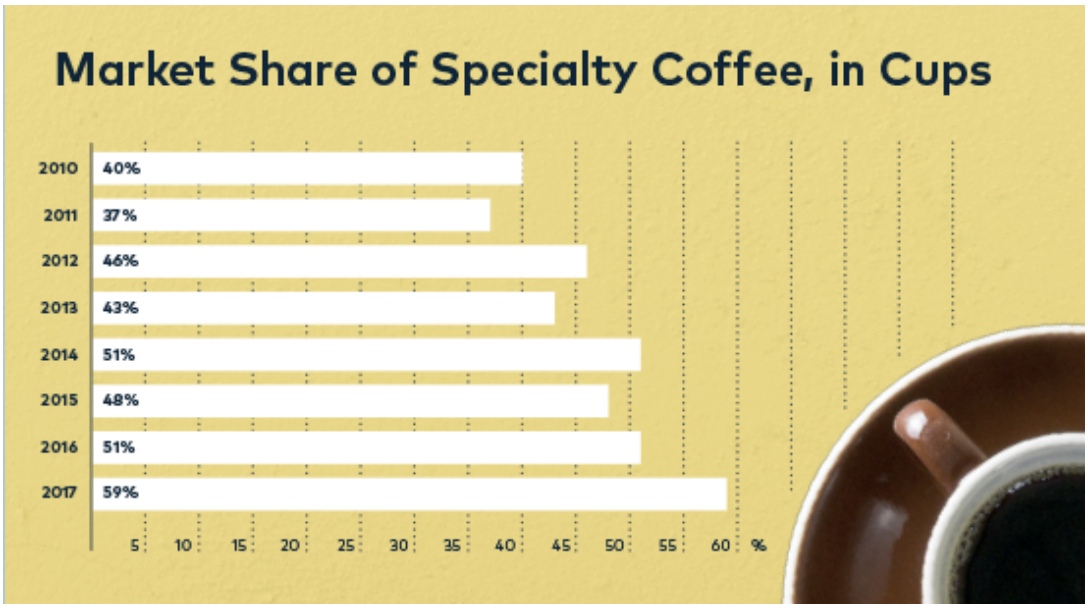

Figure 2: Market Share of Specialty Coffee in cups (USA). Source: (SCA, 2017a)

Although the economic importance of coffee and its production chain has already been mapped, the knowledge necessary for the transformation of the commodity into a high quality final product has not been fully explained, necessitating further processes and making it difficult

to maximise the value of the final product (Trauer, Valdati, da Costa, Trzeciak, & Varvakis, 2017; Trauer, Valdati, Todesco, & Costa, 2018). Representing this knowledge can both add value to the final product and contribute to more efficient and effective processes throughout the Specialty Coffee Agribusiness System (SCAS).

Despite being apparently simple, there are particularities in SCAS that contribute to the cumulative degradation of coffee at each of its production stages. The poorer the explanation of the knowledge in the SCAS processes, the greater the risk of damaging the quality of the final product. Trauer et al. (2017) emphasize that the search for knowledge and scientific data about the peculiarities of coffee demands a lot of individual initiatives from the professionals involved in the production chain who seek to improve the processes of transformation of the commodity coffee into a high quality final product: the transformation of green coffee into roasted coffee (specialty coffee).

The representation of tacit, implicit and explicit knowledge about specialty coffee production through a domain ontology may serve as a basis for knowledge-based systems that facilitate the acquisition of this knowledge by agents in the agribusiness system of specialty coffees. As ontologies can be interpreted by human and non-human agents, the formulation of conceptual frameworks is an example of the final product to be developed. In this paper, knowledge is defined through the lens of the Graduate Programme in Knowledge and Management Engineering, UFSC, Brazil: “knowledge is content or process effected by human or artificial agents in activities that generate scientific, economic, social and/or cultural value” (Pacheco, 2016, p. 37, our translation).

Ontologies can be used to represent the knowledge needed to obtain specialty coffee and the conceptual framework will facilitate understanding of the dynamics of this complex system and assist the various actors in the chain of specialty coffees with its demands (Trauer, Todesco, Costa, & Dávila, 2019).

2 THEORETICAL FOUDATION

2.2 COFFEE AGRIBUSINESS SYSTEM

The coffee production chain is complex mainly because it works to transform a commodity into a product that can have a very high added value in the end. Given that it is a natural product, all external factors throughout the production chain (environment and handling,

for example) can contribute to deterioration of the chemical properties beneficial to human health. From a general point of view, external factors may elude human control.

The basic concept of agribusiness was first disseminated by Davis e Goldberg (1957) as

> the sum of all operations in the manufacture and distribution of farm supplies; production operations on the farm; and the storage, processing, and distribution of farm commodities and items made from them (Davis & Goldberg, 1957, p. 2) .

The agribusiness system is composed of interrelated subsystems that aim to provide products and services to consumers around the world (Biotto et al., 2012; Gunderson, Boehlje, Neves, & Sonka, 2014; Satolo, Hiraga, Goes, & Lourenzani, 2017). These subsystems are maintained by support services that provide logistics, coordination, finance, labour, technology, information, policies, programmes, incentives amongst others.

2.2 SPECIALTY COFFEES

Coffee is one of the most consumed beverages in the world, surpassing 3 billion cups daily (Illy, Alessandre, McDowell, & Codice, 2015). It is ingested primarily for the stimulating effects of caffeine as well as for social bonding and for its aromatic properties but is rarely drunk because of its beneficial properties to human health (Shaposhnikov et al., 2018). World coffee production forecast for 2019/2020 is 169.1 million bags of 60 kg (USDA, 2019).

After processing, coffee can have several quality standards, from very dark roast coffees, known as Italian or French roasted coffee (Melo, 2004; Lokker, 2016), coffee beans that are defective, green, burnt, mouldy or from old harvests to gourmet and specialty coffees. Specialty Coffees are those originating from special geographic microclimates, which have unique flavour profiles when properly fermented and roasted (Donnet, Weatherspoon, & Hoehn, 2007; SCAA, 2009) preserving the properties beneficial to human health.

Specialty Coffees are all those that reach eighty points or more on the scale of the American Specialty Coffee Association (SCA). The SCA methodology for sensorial evaluation establishes eleven important attributes for coffee (Cafeicultura, 2010; SCA, 2019b), being: Fragrance, Flavour, Aftertaste, Acidity, Body, Balance, Sweetness, Clean Cup, Uniformity, Overall and Defects. To achieve this score, the coffee bean has to be of excellent quality.

Artificial Intelligence is present in this stage through the proposal of Livio, Flores, Hodhod, e Umphress (2018); Livio e Hodhod (2018) of the "AI Cupper" that offers an intuitive way of representing the knowledge of the judge by linguistic modelling of his perception of the attributes of coffee through sensory evaluation using diffuse logic. This proposal was presented

at the most important global coffee event in 2018: 27th Bienal ASIC Conference[4], in Portland, USA. The Association for Science and Information on Coffee (ASIC) is the only independent, non-profit organization in the world whose scientific mission is specifically devoted to the coffee tree, the coffee bean and the coffee drink (ASIC, 2018).

2.3 ONTOLOGIES

In the quest to make knowledge shareable and explicit, ontologies play an important role as a form of representation. In their broadest definition they are treated as "a formal and explicit specification of a shared conceptualization" (Studer, Benjamins, & Fensel, 1998, p. 184).

> Ontologies have proven to be an essential element in many applications. They are used in agent systems, knowledge management systems, and e-commerce platforms. They can also generate natural language, integrate intelligent information, provide semantic-based access to the Internet, and extract information from texts in addition to being used in many other applications to explicitly declare the knowledge embedded in them. (Gómez-Pérez & Corcho, 2002, p. 54)

An ontology may take several forms, but it is agreed that it should include a vocabulary of terms and some specifications of the meaning of these terms and how these terms are related. This results in the structuring of the domain and the constraints of the interpretations of the terms (Uschold & Jasper, 1999).

Guarino (1998) classifies the types of ontologies according to the dependency levels of a specific task or point of view as: Top-level Ontologies; Domain Ontologies, Task Ontologies; Application Ontologies. Gómez-Pérez (1999) points out that Meta-Ontologies, Domain Ontologies and Application Ontologies capture static knowledge independently in problem solving and that the ontologies of problem-solving methods, such as Task Ontologies and Domain-Task Ontologies are focused on problem solving knowledge. The author further states that these types of ontologies can be combined to construct a new ontology.

The present work proposes the development of a domain ontology adopting the definition of Guizzardi (2000), which states that this type of ontology describes concepts and vocabularies related to particular domains.

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4 The ASIC conference is the premier symposium on coffee science in the world. Participants include hundreds of researchers, members of industry, students, and academics, all focused on sharing the most cutting-edge information and advanced coffee science in the world. Topics include chemistry, agronomy and pest management, genomics, sustainability, physiology, coffee and health, and sensory science.

In developing an ontology and designing a domain, there is no standard but there are viable alternatives that, according to Noy e McGuinness (2001), involve an iterative process. Some methodologies highlighted in the literature are Methontology, On-to-Knowledge and Method 101.

Methontology has as its starting point the knowledge of a domain for the construction of the ontology, and comprises five main activities: 1) specification of requirements; 2) conceptualisation of the domain of knowledge; 3) formalisation of the conceptual model in a formal language; 4) implementation of a formal model; and 5) maintenance of implemented ontologies. This methodology also has some support activities performed during the ontology construction process, such as knowledge acquisition, integration, evaluation, documentation and configuration management (Jones, Bench-Capon, & Visser, 1998).

On-To-Knowledge is based on five phases 1) Feasibility Study; 2) Kick-off; 3) Refining; 4) Evaluation; and 5) Maintenance (Sure, Staab, & Studer, 2004). In the Kick-off the requirements for ontology construction are captured and specified, competence issues are identified, potentially reusable ontologies are studied and a first version of the ontology is constructed. In Refinement, a more mature ontology is built. In the Assessment, the requirements and the competence questions are checked. Maintenance involves the activities of adapting the ontology to changes in requirements and correction of errors, as well as the definition of those responsible for maintenance and updating.

Highlighting the Ontology Development 101 guide, proposed by Noy e McGuinness (2001), the process of constructing an ontology involves: 1) Definition of classes of this ontology; 2) Arrangement of classes in a taxonomic hierarchy with the existence of subclasses and super classes; 3) Definition of properties (attributes) and values for classes and 4) Filling in the property values for each instance.

For this paper, the methodology chosen as a base for the construction of the domain ontology is proposed by Rautenberg (2016). It brings together the best practices of the three ontologies mentioned above, as well as providing an aid tool, ontoKem, which contributes to the early developmental stages involving specification and conceptualisation, which will be the focus of this work. The methodology encompasses five activities: 1) Specification that seeks to know the costs of development, scope, purpose, sources of knowledge and reuse of ontologies; 2) Conceptualisation that describes the conceptual model of the ontology; 3) Formalisation that transforms the conceptual model into a formal one, enabling computational implementation; 4) Implementation that assigns value to data properties, relations and class restrictions, among

others, and finally, 5) Validation that evaluates the ontology with specialists and with the initial requirements.

3 METHODOLOGICAL PROCEDURES

The present work aims to propose the development of a domain ontology on Specialty Coffee. According to Cupani (2016), technology is the field of knowledge that is concerned with designing artifacts, planning their construction, operation, configuration, maintenance and follow-up, based on scientific knowledge.

The ontology proposal was based on the methodology developed by Rautenberg (2016). Secondary data collection will be carried out from scientific databases and, in particular, from expert journals on coffee production where the definitions of SCAS activities are found, as well as the standards and protocols of the Specialty Coffee Association (SCA), such as:

> Standards can be great tools for the coffee industry as they are trusted reference instruments established by knowledgeable subject-matter experts. An SCA standard is a high-quality recommendation by the Standards Committee. It is a quantifiable and qualifiable measure, based upon scientific testing, which set values and/or ranges of values for coffee. Currently, the SCA has standards for water, green coffee, and cupping (SCA, 2019a).
>
> A protocol is a specific process recommended by the SCA Standards Committee and Professional Development Department. An SCA protocol is a qualifiable recommended process that the standards committee has agreed upon and may include individual standards *(SCA, 2019b)*.

The domain ontology of specialty coffee may serve as a knowledge base for intelligent systems that will help agents in the coffee agribusiness system in the processes of transforming the commodity into a product with high added value.

4 DEVELOPMENT OF THE ONTOLOGY PROPOSAL

For the knowledge representation of Specialty Coffee, the methodology used was that of development of domain ontology through ontoKEM, a web-based case-study tool for academic purposes and aimed at assisting the development of ontologies (Rautenberg, 2016).

Some of the stages of the development of the Ontology of the Special Coffee, among them the Specification, Conceptualisation and, finally, Formalisation are presented.

4.1 SPECIFICATION

Specification is the first stage for the development of ontologies, in which the scope is defined, with the aim of "registering answers to the questions about the comprehensiveness of the domain and usefulness of the ontology" (Rautenberg, 2016, p. 141). In addition, will be defined the purpose, the sources of knowledge, the reuse of ontology and the questions of competence are defined.

Scope: covers the elements and characteristics of what comes to be called Specialty Coffee by SCA according to its standards and protocols.

Purpose: to represent the protocol of SCA necessary for the classification of coffee as specialty coffee.

Main Sources of Knowledge:

- Illy et al. (2015). A coffee dream.
- Illy e Viani (2005). Espresso coffee: The Science of quality.
- Ukers (2012). All about coffee;
- Qualitative interviews with coffee experts conducted in 2016;
- Trauer et al. (2017). Knowledge and the productive chain of coffee;
- Saes e Farina (1999). The coffee agribusiness;
- Andreotti-(org) (2014). Chefs Café;
- International Coffee Organization (ICO). The main intergovernmental body in the service of coffee which has numerous reports and publications on the sector.
- Specialty Coffee Association. A nonprofit, membership-based organization that represent thousands of coffee professionals, from producers to baristas all over the world (SCA, 2017b).
- Trauer, Valdati, Todesco, e da Costa (2018). Knowledge Representation of the Specialty Coffee Agribusiness System and its Impacts on the Improvement of the Final Product Quality.

Reuse of Ontologies: no ontologies were found that address the coffee production chain, the Coffee Agribusiness System and Specialty Coffee; a simple ontology of how to prepare coffee and consumption behaviour inside a coffee shop was found. At a future stage of

implementation of the ontology, other ontologies such as the Dublin Core Structured Value[5] (DCSV) can be incorporated.

Competence Issues: serve to aid identification of concepts, properties, relationships and instances (Rautenberg, 2016). Examples of competence issues for the Specialty Coffee Ontology are:

1) What is specialty coffee?

2) What are the fundamental stages of an agribusiness system of coffee for the production of specialty coffee?

3) What is the important knowledge for the production of a specialty coffee that is tacit and implicit present in the agents in the coffee agribusiness system?

4) What explicit knowledge is relevant to the production of specialty coffee?

5) How can the chemical substances present in coffee beans contribute positively to human health?

6) How can the chemical substances present in the seeds of the coffees be preserved or manipulated so that they are present and not degraded?

4.2 CONCEPTUALISATION

In this stage the construction of the conceptual model of the Ontology of Specialty Coffee following the specifications of the previous stage will be proposed. A segment of the specialty coffee mental map drawn from SCA knowledge sources is presented in Figure 3. These mental maps will support the conceptualisation of the specialty coffee ontology.

5 http://dublincore.org/documents/dcmi-dcsv/

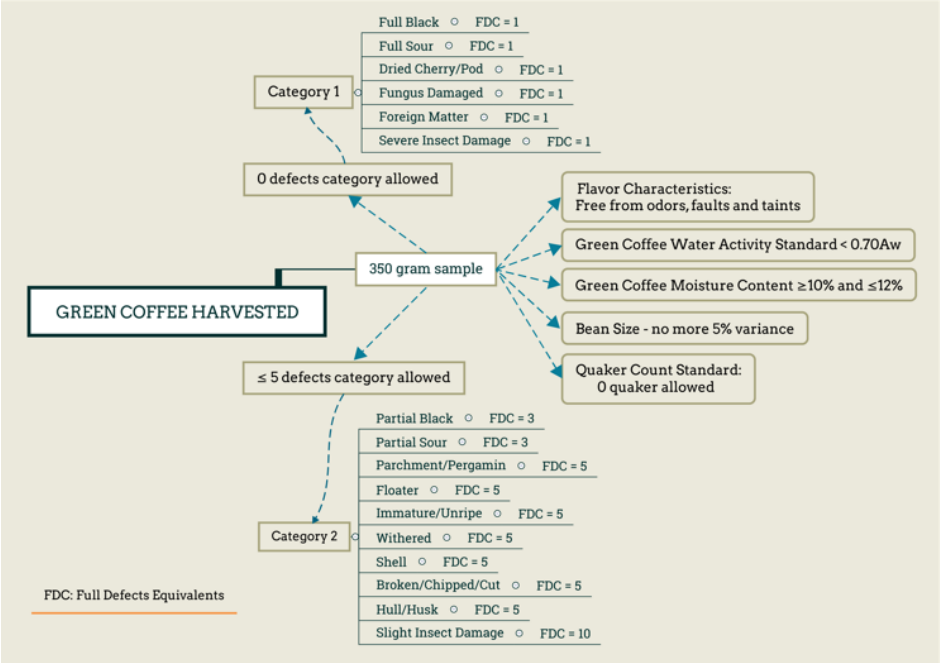

Figure 3: Whashed Arabica Green Coffee Defect Parameters Mind Map. Source: author with SCA informations

The following tasks will be developed:

Listing the terms of the ontology: Based on the questions of competences and the knowledge bases, the terms of the ontology of the specialty coffee will be listed.

Classification of terms: Terms will be classified as classes, relations (properties of objects) and data properties. Such information will be characterised as data properties in the specialty coffee ontology.

Definition of terms: The definition of terms will be used from the available knowledge bases.

4.3 FORMALIZATION AND IMPLEMENTATION

In this phase the conceptual model will be transformed into a formal model so that it can be implemented computationally (Rautenberg, Todesco & Gauthier, 2009).

5 FUTURE WORKS

The implementation of the specialty coffee ontology will enable the development of knowledge-based systems and will support the elaboration of the Conceptual Framework of Specialty Coffee.

This conceptual framework will have utility as a reference guide to agents in the agribusiness system of specialty coffee for the production of coffees with higher added values as well as the scientists involved with coffee research and its relation to human health. The latter will be a reference for the selection of coffees that have the highest quality, with substances beneficial to human health preserved, thus avoiding distortions in the final results of scientific research.

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