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Development of Flavouring Ontology for Recommending the Halal Status of Flavours

Siti Farhana Mohamad Hashim*
Center for Artificial Intelligence Technology, Faculty of Information Science and Technology, Universiti Kebangsaan Malaysia, Selangor Darul Ehsan, Malaysia
E-mail: p73051@siswa.ukm.edu.my

Shahrul Azman Mohd Noah
Center for Artificial Intelligence Technology, Faculty of Information Science and Technology, Universiti Kebangsaan Malaysia, Selangor Darul Ehsan, Malaysia
E-mail: shahrul@ukm.edu.my

Juhana Salim
Center for Artificial Intelligence Technology, Faculty of Information Science and Technology, Universiti Kebangsaan Malaysia, Selangor Darul Ehsan, Malaysia
E-mail: js@ukm.edu.my

Wan Aida Wan Mustapha
School of Chemical Science and Food Technology, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, Selangor Darul Ehsan, Malaysia
E-mail: wanaidawm@ukm.edu.my

ABSTRACT

There has been a growing interest in halal-related ontology research in recent years, as ontology has gained recognition in the halal industry. This paper discusses the development of a flavouring ontology that will assist halal management auditors in predicting the halal status of flavours in order to process food producers' applications for halal certification. The development of a flavouring ontology is based on multiple references, because the auditors of halal management divisions must consult a variety of sources independently in order to determine the halal status of flavourings. The process includes 1) determining the ontology goal and scope, 2) building ontologies, and 3) evaluating the ontologies. The researcher used Protégé to design the ontologies, and Phyton was used to develop a prototype based on flavouring ontology. The developed ontology consists of four classes, nine sub-classes, and 11 relationships. The evaluation of the ontology using the prototype revealed that the majority of experts were satisfied with the information generated by the ontology in the prototype, particularly in relation to synonyms and the hierarchical structure of a flavour. However, the experts suggest improvements in terms of flavour metadata, especially on raw materials and natural occurrence data, so that the flavour information retrieved is comprehensive and accurate.

Keywords: flavouring ontology, flavour, ontology development, halal status, flavouring traceability system, flavour metadata-Malaysia

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***Corresponding Author:** Siti Farhana Mohamad Hashim
https://orcid.org/0009-0009-9329-8638
E-mail: p73051@siswa.ukm.edu.my

1. INTRODUCTION

Ontology has gained acknowledgement from academics and industries in diverse fields (Brusa et al., 2006). Ramli and Noah (2016) assert that ontology represents entities that exist inside a certain domain of reality, such as health, agriculture, and manufacturing. Since ontology has gained acknowledgement from academics and industries, there are several definitions of what ontology is (Brusa et al., 2006). Ontology, in the fields of computing and information sciences, refers to a collection of fundamental elements that express concepts, such as classes, attributes, and relationships among class members. According to Gruber (2009), the definitions of representational primitives encompass details regarding their meanings and the constraints imposed on their logically coherent implementation.

Ontology is widely used in industries to improve knowledge management, integrate information, and facilitate decision-making processes. Ontologies are particularly beneficial in areas such as manufacturing, where they contribute to the standardization of product information and streamline communication among different stakeholders. Moreover, ontologies are crucial in enhancing the performance of intelligent systems, hence facilitating progress in domains such as robotics, process automation, and quality control.

1.1. Ontology in the Halal Industries

Nowadays, ontology has gained attention in the halal industry. According to Omar et al. (2013), the halal industry has experienced the most rapid global growth within the business landscape of Malaysia. Nevertheless, the issuance of the halal certificate is a time-consuming process (Muhammad et al., 2020). According to an interview with halal management auditors, the auditors encountered difficulties detecting the halal status of ingredients, notably flavourings, because most flavourings do not have halal certificates in the application of halal certification of food products. Thus, the absence of halal certificates required the halal management auditors to trace the halal status of the ingredients in order to process the application of the halal status. One significant limitation is the lack of uniformity in the terminology employed by food manufacturers and halal management auditors. This inconsistency poses challenges for halal management auditors in effectively verifying the halal status of ingredients, particularly in cases involving flavourings (Hashim et al., 2017).

1.2. Issues of Flavourings

In order to decide the halal status of flavourings, the halal management auditors need to identify the raw materials used together with their sources, whether they are derived from animals, plants, or chemicals (Ali et al., 2017). Determining the source of raw materials is crucial in the traceability of halal status (Ali et al., 2017; Hashim et al., 2017). Technical and sharia aspects are required to determine the halal status of raw materials for flavouring (Hashim et al., 2016; Omar & Jaafar, 2011; Shafii & Siti Khadijah, 2012). The technical components include ingredient specifications, production process charts, life storage duration, laboratory result analysis, allergy information, and storage methods. From a sharia perspective, it is imperative to adhere to certain restrictions pertaining to the cleanliness of materials, abstinence from alcohol, absence of blood, absence of pork, and ensuring their harmlessness. However, both technical and sharia aspects require the knowledge of experts to decide on the halal status of flavourings (Hashim et al., 2017). Various sources of information are required to suggest the halal status of flavourings, such as the Handbook of Fenaroli, Chemical Entities of Biological Interest (ChEBI), and academic journals related to flavouring. According to the halal management auditors, they have to refer to the sources separately as the sources are not aggregated in a single repository. Thus, there is no integration of the sources for halal auditors to refer to in order to determine the halal status of flavourings.

1.3. Problem Statement and Scope of Research

Due to the variety of sources used to determine the halal status of flavourings, which may cause conceptual inconsistencies between the terms used in the resources, ontology is one of the practical ways to solve the issue. This phenomenon is also evident in a previous study undertaken by Omar et al. (2013) regarding the development of a system for verifying the halal status of ingredients, which engaged in constructing an E-Numbers ontology by integrating data from multiple databases. Their research sought to assist the Muslim community in confirming the halal status of products in the market with E-Numbers. The integration of several E-Numbers databases was facilitated through the utilisation of ontology. This approach was motivated by Jagadish (1990)'s assertion that ontologies play a crucial role in integrating heterogeneous databases while providing a consistent vocabulary. The rationales behind the variety of reference sources used in developing a flavouring ontology are as follows:

1) It gives comprehensive coverage that provides different perspectives and coverage of a domain.
2) It allows users to cross-validate information, such as if multiple sources confirm the same facts or relationships, which increases confidence in the accuracy of the ontology.
3) It helps to reduce the risk of missing important concepts or relationships.
4) It can avoid bias if users do not rely solely on a single source.

As a result, in this research, the ontology provides a standardised and formal representation of knowledge, allowing for the harmonisation and integration of diverse flavouring databases. By establishing a common vocabulary and a shared understanding of the relationships between different terms, ontology facilitates accurate and consistent determination of the halal status of flavourings. It enables halal management auditors to effectively analyse and interpret information from multiple sources, reducing the complexity and subjectivity involved in assessing the halal compliance of flavourings. Ultimately, an ontology-based approach empowers the halal management auditors to make informed decisions and streamline the process of determining the halal status of flavourings, thus enhancing the efficiency and reliability of the halal certification process for food producers. The research aims to answer the following research questions:

1) What are the steps for developing the flavouring ontology?
2) What are the concepts and rules of the flavouring ontology for supporting the halal certification process?
3) How does the flavouring ontology meet the requirements and needs of the halal auditors?

This paper aims to describe the process of developing a flavouring ontology by adapting the steps suggested by Noy and McGuinness (2001). The paper is organised as follows: Section 2 discusses the flavouring domain, Section 3 discusses the methods involved in developing the flavouring ontology, and Section 4 discusses the implementation of the ontology with Protégé and the evaluation of the flavouring ontology. Finally, Sections 5 and 6, respectively, present the discussion and the conclusions of this work.

2. THE FLAVOURING DOMAIN

Flavourings are substances or mixtures of substances that are added to foods and beverages to enhance or modify their taste or aroma. They are used to provide specific flavours or mimic the natural flavours of various ingredients. Flavourings can be derived from natural sources, such as fruits, vegetables, herbs, spices, or animal products, or they can be artificially synthesised using chemical compounds. Flavourings are extensively used in the food and beverage industry to enhance or modify the taste and aroma of various products. They are commonly found in processed foods, beverages, confectionery goods, baked goods, snacks, sauces, and seasonings. Flavourings can be categorised into three main types (U.S. Food and Drug Administration, 2022):

- Natural Flavourings: These are derived from natural sources and undergo physical processes such as extraction, distillation, or fermentation. They can be obtained from plants, animals, or microorganisms.
- Artificial Flavourings: Also known as synthetic or artificial flavours, these are chemically created to mimic natural flavours. They are often produced through laboratory processes and can provide a wide range of flavours.
- Nature-Identical Flavourings: These are synthesised in the laboratory using chemical compounds to mimic specific natural flavours. They are chemically identical to the flavour compounds found in nature.

Flavouring plays a significant role in determining the halal status of a food product (Rahman et al., 2021). In the context of halal certification, flavourings must comply with specific guidelines and criteria to ensure they are permissible and suitable for consumption according to Islamic dietary laws. The following are some reasons why flavouring is important in halal status:

1) Ingredient Compliance: Flavourings, whether natural or artificial, can be derived from various sources, including both halal and non-halal origins. Verifying the origin of flavouring ingredients is of utmost importance in order to ascertain the absence of any forbidden compounds, such as alcohol or animal-derived ingredients, that fail to meet the criteria for Islamic slaughtering.
2) Cross-Contamination: Flavourings may be processed or manufactured in facilities that handle non-

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halal ingredients or products. This can lead to cross-contamination, where traces of non-halal substances can inadvertently be present in the flavouring. It is essential to ensure that the flavourings used in halal-certified products are free from any cross-contamination with non-halal ingredients.

3) Awareness of Halal Sensitivities: Flavourings can be complex mixtures of various compounds, and it is important to ensure that all the ingredients used in the flavouring are halal. Even a small percentage of non-permissible ingredients can impact the overall halal status of the product. Understanding the sensitivities and requirements of halal consumers regarding flavourings is essential to maintain the integrity of halal certification.
4) Traceability and Transparency: The halal certification process requires meticulous traceability of ingredients and their sources. This includes verifying the origin and halal compliance of flavourings used in the product. Transparent documentation and information about the flavouring ingredients and their sources are vital for auditors and certification bodies to ensure compliance with halal standards.
5) Consumer Confidence: Halal certification provides assurance to Muslim consumers that the product meets their dietary requirements and religious beliefs. Ensuring that the flavourings used in halal-certified products are compliant with halal guidelines builds trust and confidence among consumers, leading to increased market acceptance and demand.

By considering the halal status of flavourings and ensuring their compliance with halal requirements, food producers can uphold the integrity of their halal-certified products and cater to the needs of Muslim consumers seeking halal options.

In this research, we proposed an ontology for flavouring designed to serve as a comprehensive and structured knowledge base, aiming to assist halal management auditors in their critical tasks related to ensuring compliance with halal standards in the food and beverage industry. Halal certification involves meticulous scrutiny of ingredients, production processes, and sources, with specific attention given to the presence of any non-halal or haram components, which can render a product non-compliant. By incorporating the flavouring ontology into their auditing procedures, halal management auditors can streamline the evaluation process, expedite ingredient assessments, and enhance the accuracy and consistency of halal certification decisions. The ontology's structured and interlinked nature facilitates quick and reliable searches, enabling auditors to identify potential non-compliant ingredients or cross-contamination risks more efficiently. Additionally, the ontology can aid auditors in monitoring the usage of permissible flavouring agents, ensuring that they are within acceptable limits and comply with halal guidelines. The following section describes the method for developing the flavouring ontology.

3. METHODOLOGY

This section presents the process of developing a flavouring ontology to determine the halal status of flavourings. Previous research has explored various methodologies for the methodical development of ontologies. For instance, among the proposed methodologies are Uschold and King (1995), Grüninger and Fox (1995), KACTUS (Bernaras et al., 1996), METHONTOLOGY (Lopez et al., 1999), SENSUS (Swartout et al., 1997), and the Ontology Development 101 Method (Noy & McGuinness, 2001). The aforementioned approaches successfully established ontologies in diverse domains, including enterprise (Grüninger & Fox, 1995; Uschold & King, 1995), chemistry and environment, knowledge management, and computer science (METHONTOLOGY; Lopez et al., 1999), military air campaigns (SENSUS; Swartout et al., 1997) and vinology (Noy & McGuinness, 2001). There are three approaches to identifying concepts: top-down (KACTUS; Bernaras et al., 1996) and (Noy & McGuinness, 2001), bottom-up (SENSUS; Swartout et al., 1997), and middle-out (Grüninger & Fox, 1995; Uschold & King, 1995). We chose to adapt the Ontology Development 101 method proposed by Noy and McGuinness (2001), as the methodology is generic and flexible to represent knowledge in various domains. Although the method was first introduced back in 2001, it is still relevant and popular among ontologies developers and widely used in various domains (Alsanad et al., 2019; Chimalakonda & Nori, 2020; Järvenpää et al., 2019; Siebra & Wac, 2023; Wu et al., 2021). Some key features in the Ontology Development 101 Method can be adapted in the development of flavouring ontology as follows:

1) It applies a top-down approach, which is identifying the most general and essential concepts before delving into more specific details.
2) It emphasizes the importance of consulting multiple reference sources to ensure the ontology is compre-

hensive and well-grounded. This variety of reference sources helps ontology developers to gather knowledge about the domain and verify the accuracy of their representation.

3) It encourages iterative development where developers iteratively enhance and optimise the ontology through feedback, new information, and evolving requirements.
4) It encourages input from domain experts that is considered valuable for ensuring the ontology is accurate and relevant.

The method to develop a flavouring ontology comprises four steps: Specification – Ontology Goal and Scope; Specification – Domain Description; Conceptualisation – Define the Classes and the Class Hierarchy; and Conceptualisation – Define the Properties of Classes. The following sub-sections provide a detailed discussion of each step.

3.1. Specification: Ontology Goal and Scope

The definition of ontology goal and scope is the first step of the specification phase, as illustrated in the 101 Method (Noy & McGuinness, 2001). The scope of the ontology determines the specific inclusions and exclusions. It is crucial to reduce the amount of data and concepts that need to be analysed for a certain field, particularly considering the intricacy of the semantic nuances. This ontology mainly focuses on determining the halal status of flavouring and the synonym of the flavouring term.

Enumerating the competency questions is a method for establishing the scope of the ontology. It can be accomplished by formulating a series of inquiries that an ontology-based knowledge base should possess the capability to provide answers for. Table 1 presents the competency questions pertaining to the topic of flavouring. The ontology must possess the capability to address these informal inquiries, which aim to evaluate the alignment between the ontology and its intended objectives.

Table 1. Sample of competency questions

No.	Competency question
1.	Find halal status for Isovaleric Acid
2.	Find synonyms for Fumaric Acid
3.	Find the type of raw material for Buchu
4.	Find a botanical name for Blackberry
5.	Find synthesis for Glycine
6.	Find natural occurrence for Benzyl Acetate

These competency questions are some of the required information that halal auditors need to know in order for them to check the halal status of flavourings that do not have their own halal certification. These competency questions also guide the researcher in developing the ontology within the scope. For the information on flavouring, there are some metadata elements that the halal auditors need to know, such as halal status, synonyms, type of raw material, botanical name, synthesis, and natural occurrence.

3.2. Specification: Domain Description

We begin with the domain analysis task, where the halal certification manual was studied and revised. We gathered information regarding the process of processing the application for halal certificates. Besides this, we also explored whether there are existing ontologies that serve as a reference for constructing our initial ontology. Through our efforts, we utilised the analytical task to convert listed terms into the conceptualised structure for the flavouring ontology. Drawing from the existing ontology with diverse listed terms served as a blueprint to steer the development of our inaugural ontology. In addition, we met with experts who are the auditors from Jabatan Kemajuan Islam Malaysia (JAKIM)'s Halal Management Division to corroborate the veracity of the issues raised. The halal management auditors were chosen because they were experts in the halal certification processing field. The halal management auditors and researchers who bring information to support these tasks have assimilated the issues. For instance, during the interview, the halal management auditors confirmed that flavouring information, such as types of raw materials and halal status, is an important element in the flavouring domain. At the same time, the researchers brought technical knowledge support, such as ontology mapping, to this task. Ontology mapping is a process of integrating information from various sources (Kazani et al., 2023). There are several sources involved in developing the flavouring ontology, as showsn in Table 2 (Jabatan Kemajuan Islam Malaysia, 2015).

Ultimately, we established the intermediate representations utilised for knowledge acquisition, with Table 3 displaying fundamental terms within the flavouring domain.

From Table 3, the basic terms of the flavouring domain are the important metadata required for halal auditors to trace the halal status of flavourings. These basic terms of the flavouring domain were manually extracted and defined through brainstorming sessions with domain

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Table 2. Sources in developing the flavouring ontology

No.	Reference source	Description
1.	ChEBI Ontology: ChEBI Ontology was developed by EMBL's European Bioinformatics Institute, which is the centre for 'big data' in the field of biology	Researchers used the ChEBI ontology to look at the basic structure and hierarchy of flavouring agents, and to act as the existing ontology based on previous studies by Omar et al. (2013), who modeled the E-Numbers Ontology using the ChEBI ontology as an existing ontology
2.	Fenaroli's *Handbook of Flavours Ingredients*, published by CRC Press	Researchers used Fenaroli's *Handbook of Flavours Ingredients* as the main reference in modeling flavouring ontology
3.	E-Numbers websites: • http://www.faia.org.uk/e-numbers	Researchers used this E-Numbers website based on a previous study by Omar et al. (2013), who used the website that the authority has reviewed
4.	Manual procedure for Malaysia Halal certification (third revision) 2014 (JAKIM, 2015)-BPH, JAKIM	Researchers referred to the Halal Certification Manual to look at the halal regulations used to generate flavouring ontology rules
5.	Flavour domain expert at Faculty of Science and Technology UKM and Auditor at BPH JAKIM	Researchers consult experts to obtain expert knowledge and views regarding the metadata required to trace the halal status of flavours

ChEBI, Chemical Entities of Biological Interest; EMBL, European Molecular Biology Laboratory; BPH, Bahagian Pengurusan Halal; JAKIM, Jabatan Kemajuan Islam Malaysia; UKM, Universiti Kebangsaan Malaysia.

Table 3. Basic terms of flavouring ontology

Basic term	Description
Flavouring agent	Flavouring agents consist of flavour substances, extracts, or preparations that can provide taste, odour, or both to food products
E-Numbers	Food additive codes are typically present on food labels across the European Union
Types of raw materials	These refer to the three types of raw material: animal, plant, and chemical
Halal status	Refers to the halal status of flavouring agents, whether Halal, Haram, Syubhah, Unknown, or Halal with conditions (e.g. Halal if the content of alcohol is less than 0.5%)
Animal	Refers to the types of raw materials for a flavouring agent
Chemical	Refers to the types of raw materials for a flavouring agent
Plant	Refers to the types of raw materials for a flavouring agent
Description	Explanation about the flavouring agents
Synthesis	The production of chemical compounds by reaction from simpler materials
Botanical name	A scientific name of a particular plant species. It must conform to the system of botanical nomenclature as prescribed by the International Code of Nomenclature for algae, fungi, and plants
Natural occurrence	Natural and without artificial help, which refers to the occurrence of flavouring agents

experts and also by referring to the flavouring handbook, which is the Handbook of Fenaroli.

3.3. Conceptualisation: Define the Classes and the Class Hierarchy

The class hierarchy for ontology can be developed in three possible ways: top-down, bottom-up, or a combination of both (Noy & McGuinness, 2001). We chose the combination of both as a development process to define a few top-level concepts and a few specific concepts. The first step is to define the top-level concepts. The top-level concepts represent the most general concept, encompassing all entities or objects within the domain (Lopes et al., 2022). In the domain of flavouring as shown in Table 4, we identified four top-level classes through discussion with the domain experts regarding the competency questions mentioned in Table 1 and also from the output from brainstorming session with domain experts, which is a list

Table 4. Description of classes for flavouring ontology

Class	Description
E-Numbers	Classes for E-Numbers, which consists of several E-Numbers such as E620, E621, E630, E633, E637, and E640
Flavouring agent	Classes for flavouring agent, which consists of bitter agent, sour agent, sweetening agent, and salty agent
Halal status	Classes for Halal Status, which consists of Halal, Haram, Syubhah, Unknown, and Halal with conditions (Halal if alcohol less than 0.5%)
Types of raw materials	Classes for types of raw materials, which consist of animal, plant, and chemical

Table 5. Description of subclasses (Level 1) for flavouring ontology

Class	Subclass (Level 1)	Description
Flavouring agent	Bitter agent	Flavouring agents have a bitter taste Examples: Isobutyl salicylate, phenylacetaldehyde, benzyl acetate
	Salty agent	Flavouring agents have a salty taste Examples: Monosodium glutamate, sodium guanylate, inosinic acid
	Sour agent	Flavouring agents have a sour taste Examples: Octanoic acid, benzoic acid, allyl propanoate
	Sweetening agent	Flavouring agents have a sweet taste Examples: Allyl hexanoate, L-glutamic acid, ethyl maltol
Types of raw materials	Animals	Flavourings obtained from animal raw materials Examples: Glycine, pyrole, inosinic acid
	Plants	Flavourings obtained from plant raw materials Example: Buchu, cocoa, roselle
	Chemicals	Flavourings obtained from chemical processes Examples: 2-Acetylfuran, 2-octanone, sodium hexametaphosphate

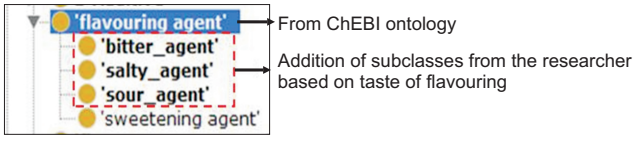

Fig. 1. Subclasses of flavouring agent. ChEBI, Chemical Entities of Biological Interest.

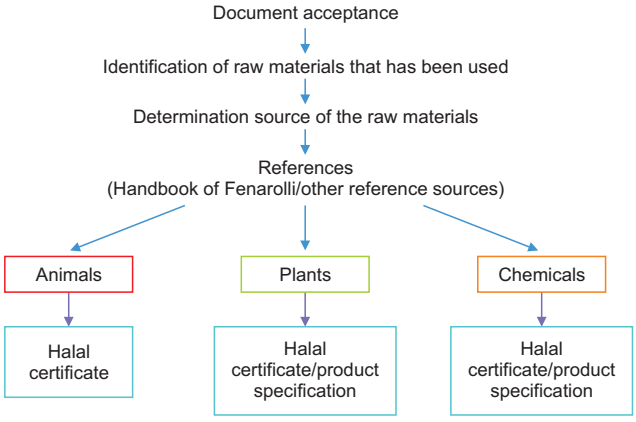

Fig. 2. Structured flow to trace halal status of flavouring.

of basic terms for the flavouring ontology. The four top-level classes for the flavouring ontology are E-Numbers, Flavouring Agent, Halal Status, and Types of Raw Material.

These four top-level classes of flavouring ontology give a general picture to the researcher for building this flavouring ontology and play an important role as the main hierarchy in the ontology development. The next step is to define the subclass (Level 1) for the top-level concepts, as shown in Table 5.

The subclasses (Level 1) for Flavouring Agents consist of four types: Bitter Agent, Salty Agent, Sour Agent, and Sweetening Agent. The 'Sweetening Agent' subclass was obtained directly from the hierarchy in the ChEBI ontology (Fig. 1). In contrast, the remaining subclasses were classified based on the taste criterion of the flavouring. The researcher also acquired consent from the expert regarding adding the remaining subclasses during the interview.

The subclasses of raw materials in Table 4 include animals, plants, and chemicals. The categorisation of raw

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materials was determined by the specific raw materials utilised in the production of the flavouring. These raw materials were acquired through an interview conducted with the halal management auditors in order to establish a systematic process for verifying the halal status of the flavouring (Fig. 2).

After this, the researcher also needs to define the subclass (Level 2) for the concept 'Chemicals,' as shown in Table 6.

For the subclass of 'Chemicals,' the researcher obtained the concept of 'Chemicals,' which consists of 'Alcohol' and 'Non-Alcohol,' through an interview with the halal management auditors.

3.4. Conceptualisation: Define the Properties of Classes

The properties of classes need to be defined, because the classes themselves do not offer sufficient knowledge to address the competency questions listed in Table 1. Therefore, once we have defined the classes, we must also define the properties of the classes as well. There are two types of properties: data properties and object properties. The sources of information for these two types of properties are based on Fenaroli's *Handbook of Flavours Ingredients*, ChEBI Ontology, and E-Numbers websites. The data properties connect individuals with some values. The list of data properties is shown in Table 7.

On the other hand, the object properties connect individuals with individuals. The list of object properties is shown in Table 8.

The object property hasSuggestedHalalStatus is obtained through an inferencing process where the researchers developed five rules to generate the halal status for a flavour. These rules were developed based on the halal conditions in the Malaysian Halal Certification Manual, which the halal management auditors explained to the researchers. The rules and their explanation are shown in Table 9.

The primary factor involved in predicting the halal status of flavourings is the raw components used. These five rules were formulated based on the categorisation of raw elements found in the flavouring agents, including animal, plant, and chemical substances. Regarding flavouring agents derived from animals, we establish two rules: If the flavouring agent is obtained from an animal other than pork, the halal status of the flavouring is likely halal; nevertheless, if the flavouring agent is derived from pig, the halal status of the flavouring is haram. Then, regarding flavouring agents derived from plants, we provide a single rule: If a flavouring agent is derived from a plant, its halal

Table 6. Description of subclasses (Level 2) for flavouring ontology

Subclass (Level 1)	Subclass (Level 2)	Description
Chemicals	Alcohol	Chemicals contain varying percentages of alcohol Examples: Allyl alcohol, isobutyl acohol, nerol
	Non-alcohol	Chemicals which are free from alcohol Examples: Acetic acid, monosodium phosphate, nitric acid

Table 7. Description of data properties for flavouring ontology

Property	Description	Example
hasBotanicalName	Refers to the botanical name of flavouring. An object property defining a relation between flavouring agents with their botanical name	Blackberry hasBotanical Name Rubus L
hasDescription	Refers to the description of flavouring. An object property defining a relation between flavouring agents with their description	Glycine hasDescription odourless and has a slightly sweet taste
hasNaturalOccurence	Refers to the natural occurrence of flavouring. An object property defining a relation between flavouring agents with their natural occurrence	Glycine hasNaturalOccurence: gelatine and silk fibroin are reportedly the best natural sources of this amino acid
hasSynthesis	Refers to the synthesis of flavouring. An object property defining a relation between flavouring agents with their synthesis	Glycine hasSynthesis from chloroacetic acid and ammonia; from protein sources, such as gelatine and silk fibroin

Table 8. Description of object properties for flavouring ontology

Property	Description	Example
hasENumbers	An object property indicates that some flavouring agents may have E-Numbers as ingredients	Glycine hasENumbers E640
hasFlavouring	An object property indicates that some E-Numbers have flavouring agents	E620 hasFlavouring L-glutamic acid
hasSuggestedHalalStatus	An object property that explicitly addresses the halal status of flavouring	Glycine hasSuggestedHalalStatus Haram
hasSynonym	An object property defining a relation between flavouring agents with their synonyms	Glycine hasSynonym glycocoll
hasRawMaterial	An object property that defines the type of raw material for flavouring	Glycine hasRawMaterial pork
hasRMHalalStatus	An object property defining a relation between raw materials of flavouring agents with their halal status	Pork hasRMHalalStatus Haram

Table 9. Ontology rules to predict halal status of flavouring

1) Rule 1: Animal≠Pork
IF instance **x** member-of Flavouring Agent, **y** member-of Animal, **y** is NOT a Pork, AND **x** hasRawMaterials **y**, THEN **x** hasHalalStatus Probably Halal

$$\forall x, \forall y, x \in Flavouring\ Agent \sqcap y \in Animal \sqcap y \neq Pig \sqcap x\ hasRawMaterials\ y \rightarrow x\ hasHalalStatus\ Probably\ Halal$$

Flavourings are derived from animals' raw materials, but if the animals are not pigs, then the halal status is 'Probably Halal'

2) Rule 2: Animal=Pork
IF instance **x** member-of Flavouring Agent, **y** member-of Animal, **y** is a Pork, AND **x** hasRawMaterials **y**, THEN **x** hasHalalStatus Haram

$$\forall x, \forall y, x \in Flavouring\ Agent \sqcap y \in Animal \sqcap y = Pig \sqcap x\ hasRawMaterials\ y \rightarrow x\ hasHalalStatus\ Haram$$

Flavourings are derived from animals' raw materials, but if the animals are pigs, then the halal status is 'Haram'

3) Rule 3: Plant
IF instance **x** member-of Flavouring Agent, **y** member-of Plant, **y** is a Cacao AND **x** hasRawMaterials **y**, THEN **x** hasHalalStatus Halal

$$\forall x, \forall y, x \in Flavouring\ Agent \sqcap y \in Plant \sqcap x\ hasRawMaterials\ y \rightarrow x\ hasHalalStatus\ Halal$$

If flavourings are derived from plants' raw materials, then the halal status is 'Halal'

4) Rule 4: Chemical=Alcohol
IF instance **x** member-of Flavouring Agent, **y** member-of Chemical, **y** is an Alcohol, AND **x** hasRawMaterials **y**, THEN **x** hasHalalStatus Halal with Condition

$$\forall x, \forall y, x \in Flavouring\ Agent \sqcap y \in Chemical \sqcap y = Alcohol \sqcap x\ hasRawMaterials\ y \rightarrow x\ hasHalalStatus\ Halal\ with\ Condition$$

Flavourings are derived from chemicals' raw materials, but if the chemicals are alcohol, then the halal status is 'Halal with Condition'

5) Rule 5: Chemical=Non-alcohol
IF instance **x** member-of Flavouring Agent, **y** member-of Chemical, **y** is a Non-Alcohol, AND **x** hasRawMaterials **y**, THEN **x** hasHalalStatus Halal

$$\forall x, \forall y, x \in Flavouring\ Agent \sqcap y \in Chemical \sqcap y \neq Alcohol \sqcap x\ hasRawMaterials\ y \rightarrow x\ hasHalalStatus\ Halal$$

Flavourings are derived from chemicals' raw materials, but if the chemicals are non-alcohol, then the halal status is 'Halal'

status is considered halal. Lastly, we have established two rules regarding the use of chemical-derived flavouring agents: If the flavouring agent is derived from alcohol, its halal status is considered halal under certain conditions, and if the flavouring agent is derived from a non-alcoholic chemical, its halal status is considered halal.

4. RESULTS AND DISCUSSIONS

4.1. Implementation of the Flavouring Ontology into the Halal Status Flavouring Traceability System

After completing the modelling of the flavouring ontology, the ontology is integrated into the Halal Status Fla-

 https://doi.org/10.1633/JISTaP.2024.12.2.2

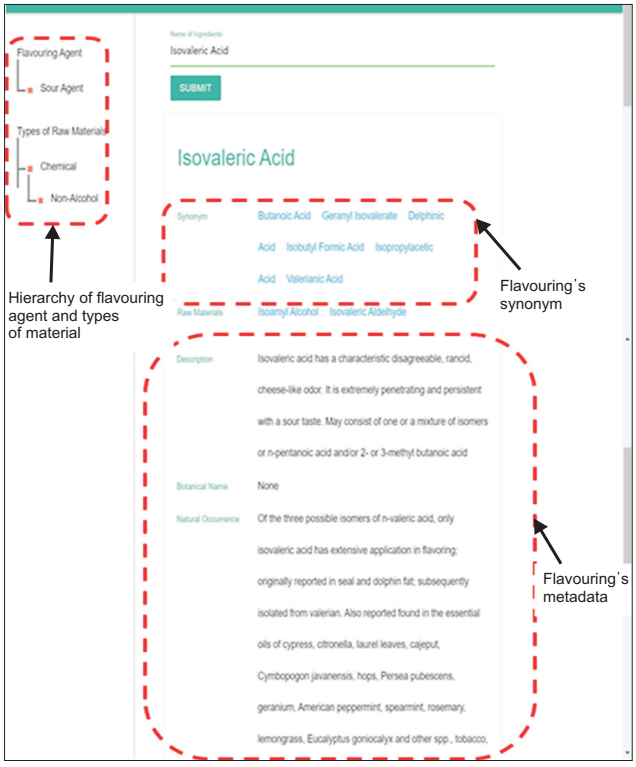

Fig. 3. Search result of flavouring agent from Halal Status Flavouring Traceability System.

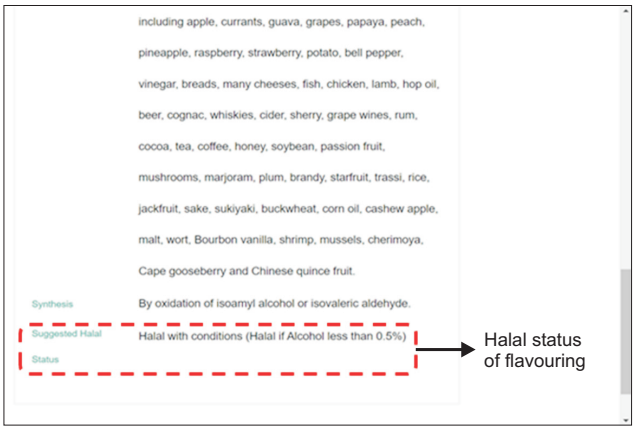

Fig. 4. 'Suggested Halal Status' metadata of flavouring agents from Halal Status Flavouring Traceability System.

vouring Traceability System. Fig. 3 shows an example of a search result for flavouring information.

Based on Fig. 3, the search result for the flavouring agent Isovaleric Acid consists of metadata of flavouring, which are: 'Synonym,' 'Raw Materials,' 'Description,' 'Botanical Name,' 'Natural Occurrence,' 'Synthesis,' and 'Suggested Halal Status' (Fig. 4). The search result for flavouring agent also provides information about the flavour's hierarchy that helps auditors to know the classification of flavouring agents, and also the hierarchy about types of raw material for flavouring agent that helps auditors to know the raw materials of flavouring agent. As for the metadata regarding 'Suggested Halal Status' as shown in Fig. 4, it is generated due to the inferencing rules discussed in Table 9.

4.2. Evaluating Flavouring Ontology through Halal Status Flavouring Traceability System

The flavouring ontology was evaluated using a Halal Status Flavouring Traceability System prototype. An evaluation of use in an application was proposed by Noy and McGuinness (2001) and implemented in the works of Porzel and Malaka (2004) and Kalfoglou and Hu (2006). The evaluation was carried out by soliciting comments from domain experts purposively selected after using the prototype. The involvement of domain experts during the evaluation process was to ensure the usability and practicality of the ontology for the Halal Status Flavouring Traceability System. The domain experts may evaluate the compatibility of the ontology with their processes in predicting the halal status of flavours, specifically for processing applications for halal certification from food manufacturers, by providing valuable comments on this matter. A total of nine experts participated in this evaluation: three lecturers from the Faculty of Information Science and Technology, Universiti Kebangsaan Malaysia, who are experts in ontology engineering; three lecturers from the Faculty of Science and Technology Universiti Kebangsaan Malaysia, who are experts in the flavouring domain; and three experts from the Halal Management Division of Department of Islamic Development Malaysia, recognized for their expertise in the halal certification process. The involvement of nine experts for this evaluation is to ensure a comprehensive and diverse assessment of the ontology. By involving a panel of experts with varied backgrounds and expertise, including auditors from JAKIM's Halal Management Division and researchers with technical knowledge in ontology mapping, the evaluation process can benefit from a range of perspectives and insights. This multi-faceted evaluation approach allows for a thorough examination of the ontology's effectiveness in predicting the halal status of flavours and its practical utility in the context of halal certification processes. Additionally, the inclusion of multiple experts helps in validating the ontology and ensuring its credibility and trustworthiness. Assessing the ontology based on using a prototype involved three evaluation criteria: Completeness, Clarity, and Pre-

ciseness.

According to Tankeleviciene and Damasevicius (2009), completeness refers to the condition where all parts of an ontology are present and each element is thoroughly explained. The completeness of the flavouring ontology is assessed based on the comprehensiveness of the concepts found. The evaluation results provided by experts indicate that the flavouring ontology lacks sufficient data on flavouring and requires improvement. For instance, raw materials and natural occurrences require more information. Other recommendations by the experts are as follows:

1) To include information like "What method is used in the manufacturing of the commercial flavours? Either extracts from natural ingredients or completely synthetically derived." This information is very important in order to determine the halal status of flavourings.
2) In halal certification, sharia is the pillar in determining the law/status of raw materials. This means that raw materials must comply with the halal criteria stipulated by Islamic law.
3) In the context of food hygiene and safety, authoritative sources such as the Food Act 1983 and Food Regulations 1985 are required to ascertain the appropriateness of items used in food handling. Hence, the experts have recommended the inclusion of both Acts/Regulations in the flavouring data.

The concept of clarity can be described as the measure of how successfully the intended message is conveyed (Tankeleviciene & Damasevicius, 2009). The clarity of the flavouring ontology is determined by the degree to which the terminologies contained within it are clear and comprehensible. The experts' evaluation findings indicate a need for more clarity in the flavouring ontology's representation of flavouring data. For example, for the 'Suggested Halal Status' data, if the status of a flavouring is 'Haram' (i.e. forbidden), it is necessary to state the reason why the flavouring is 'Haram.'

Lastly, the concept of preciseness is characterized by the presence of accurate definitions and hierarchies within an ontology, resulting in a reduced number of unwanted models (Tankeleviciene & Damasevicius, 2009). The preciseness of the flavouring ontology is evaluated based on the presence of appropriate terms inside the ontology. However, some of the metadata about flavours are not accurate. For example, Butanoic Acid is listed as a synonym for Neryl Isovalerate, which is incorrect. Another example is the categorization of glycine as haram, which is not factually correct, as glycine is an amino acid that may be found in a wide range of sources, not exclusively derived from pigs. In order to ensure precision, it is advisable for researchers to collaborate with professionals to acquire reputable references that may be utilised for the development of the flavouring ontology.

5. DISCUSSION

This study aims to construct a flavouring ontology that can recommend the halal status of flavours. This flavouring ontology was implemented into the Halal Status Flavouring Traceability System. This implementation aids halal management auditors in predicting the halal status of flavours to facilitate the processing of food producers' applications for halal certification. The methodology employed in this study for developing the flavouring ontology is based on the approach described in the publication "*101 Methods*" by Noy and McGuinness (2001). Several advantages of incorporating the Ontology Development 101 Method into the development of the flavouring ontology include:

1) It provides a structured approach to ontology development, which helps to ensure that the resulting ontology is well-organised, coherent, and easy to understand.
2) It promotes a comprehensive representation of the domain by starting a top-down view and emphasizing the use of reference sources.
3) It is reliance on multiple reference sources, and iterative refinement helps improve accuracy and reliability.
4) It supports the involvement of domain experts in the ontology development in order to enhance the ontology's quality and relevance.
5) It helps reduce bias by referring to multiple reference sources and consulting the domain experts, leading to a more balanced representation of the domain.

The definition of fundamental concepts during the specification phase is the most crucial work in the technique. The acquisition of knowledge during the specification phase serves as the foundation for conceptualisation. Consensus among domain experts is necessary for the establishment of this conceptualisation. An additional crucial factor to contemplate in the development of an ontology is the validation procedure employed to assess

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the precision and integrity of the information. The validation procedure involved experts assessing the flavouring ontology using a prototype that has been integrated with it. This is important because when domain experts are involved in the evaluation process, they are more likely to endorse the ontology, increasing its acceptance and adoption within the domain. This endorsement process can be done by identifying inconsistencies, inaccuracies, or missing elements within the ontology structure and content. Their validation also adds credibility and trustworthiness to the ontology (Howell et al., 2021).

The findings of the analysis pertaining to the assessment of the flavouring ontology revealed that a majority of the experts expressed satisfaction with the ontology-driven generated information by the prototype, particularly with regard to the inclusion of synonyms and the hierarchy of a flavour. Nevertheless, several experts have expressed the need for caution while constructing synonym metadata for flavouring to prevent the inclusion of inaccurate or misleading data. Most experts said there is room for enhancement in flavour metadata, aiming to achieve greater completeness and accuracy in the retrieved flavour metadata. Enhancement of flavour knowledge could be achieved through consultation with multiple references and by engaging in comprehensive discussions with domain experts. The acquisition of comprehensive and precise data pertaining to flavours holds significant importance in ascertaining the halal status of a certain flavour. Furthermore, experts have recommended that verifying the flavouring ontology should be repeated in consultation with domain experts, specifically regarding the synonyms, despite the fact that researchers have already consulted authoritative sources. According to the evaluation regarding the flavouring ontology, it revealed that the ontology can provide some advantages:

1) Ontologies ensure consistency and standardization of terms, concepts, and relationships within a domain (Azram et al., 2018). This advantage can resolve concerns pertaining to the inconsistent use of terms between food manufacturers and halal management auditors.
2) Ontologies enhance the integration of heterogeneous data sources by facilitating the integration of data from multiple sources, which are consolidated by offering a common lexicon and structure for arrangement of the data (Promthong et al., 2023). This advantage has already addressed the concerns highlighted about halal management auditors manually referring to multiple sources of flavouring to obtain precise information on them.
3) Ontologies enhance consistency in reasoning by supporting automated reasoning, which involves establishing explicit rules for deducing new information from existing knowledge (Promthong et al., 2023). This advantage enables the halal management auditors to predict a halal status of flavouring because most flavourings do not have halal certificates in the application of halal certification for food products. This automated prediction can expedite the process of the application for halal certification.

6. CONCLUSION

Constructing domain ontologies becomes challenging when domain experts are unfamiliar with knowledge engineering techniques and lack the ability to conceptualise the domain. This paper demonstrates the process of developing a domain ontology using the approach introduced by Noy and McGuinness (2001). This technique offered comprehensive guidance in delineating the scope and establishing the core concepts essential for specifying and conceptualising this new ontology. The evaluation results of the prototype by the experts revealed that they are satisfied with the information produced by the prototype's ontology in terms of synonyms and hierarchy of a flavour. Sharing the best practices on ontology development can benefit the whole community, especially domain experts in particular areas. The primary focus of this study was building the flavouring ontology, which involves the integration of multiple reference sources using the 101 Ontology development technique.

Soliciting comments from domain experts, specifically those involved in halal certification processes at the Department of Islamic Development Malaysia, allows us to align the ontology's functionalities with practical requirements for predicting the halal status of flavours in food manufacturing applications. Their insights were invaluable in gauging the compatibility of our ontology with industry practices and certification procedures. All of the concerns from the experts will be put forward in the direction of our future work. Besides this, our future works will also include using the improved version of the developed ontology designed to facilitate semantic document retrieval of flavouring documents. Here, the concepts within the flavouring ontology will be aligned with the textual content of scientific articles that relate to the flavourings. We expect to achieve a promising outcome

whereby the scientific articles regarding flavouring can be retrieved based on users' input queries.

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CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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