VOL. 9, NO. 9, SEPTEMBER 2014 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

ONTOLOGY-BASED KNOWLEDGE ACQUISITION FOR THAI INGREDIENT SUBSTITUTION

Pimsupa Saengsupawat, Thara Angskun and Jitimon Angskun
School of Information Technology, Suranaree University of Technology, Nakornratchasima, Thailand
E-Mail: pim.saengsupawat@gmail.com

ABSTRACT

Cooking is an important activity because food is one of the basic necessities of life. However, some ingredients are difficult to find in some seasons or some regions, therefore ingredient substitution is needed for real taste. This article presents a knowledge acquisition model for ingredient substitution by applying Thai cuisine recipe for a case study. The main purpose of this research is to substitute rare Thai ingredients using existing ingredients. The proposed model is applying the concept of domain ontology to design the entities and relations among these entities which are related to ingredient substitution in Thai cuisine recipe. In addition, a set of rule bases by Semantic Web Rule Language (SWRL) is designed and embedded into the ontology to apply for discovering the existing ingredients that can substitute the rare Thai ingredients.

Keywords: ingredient substitution, ontology, knowledge acquisition.

INTRODUCTION

A question, like "I want to cook Tom Yum Kung but I have not Lime juice, then what ingredient can be substituted?" is frequently asked on internet web-board when persons want to cook food but some ingredients are unavailable. Therefore, the main purpose of this research is to design and develop the knowledge base to substitute rare ingredients for remaining original sensory properties by using the existing ingredients.

The work of ingredient substitution needs to apply a semantic searching technique. Ontology is a specification of conceptualization which supports information exchange based on the semantic search. It can provide hierarchical and associated results for users and also reduce searching times for attaining the information. Moreover, the intelligent knowledge will be inferred by an inference process (Gruber, 1993), (W3C, 2004). Since the capability of knowledge inference, this work supposes that the knowledge of Thai ingredient substitution can be explicit by the ontology concept and inference process.

There are many research works related to food ontology. For example, Villarías (2004) developed a cooking ontology to resolve a problem of un-pattern recipe from cooking websites. Batista *et al*. (2005) developed food ontology as the knowledge base of dialogue system. Koenderink *et al*. (2005) developed a food ingredient ontology using ingredient properties on Food Informatics project for supporting food researchers. Kimura *et al*. (2008) developed method to translate and replace ingredients from foreign recipes to Japanese recipes. Vadivu and Hopper (2010) developed a food ontology to support semantic search based on natural food and chemical compounds and related diseases. Moreover, several researchers developed the food ontology to support a menu recommendation system, such as Badra *et al*. (2008), Demiguel *et al*. (2008), Fudholi *et al*. (2008), Herrera and Iglesias (2008), Lee *et al*. (2008), Snae and Bruckner (2008), Garcia (2009), Wang *et al*. (2009), Suksom *et al*. (2010), and Kiryakov and Penev (2011). However, the purpose of those research conducted for different problems; for instance, Lee *et al*. (2008) developed Taiwanese menu planning system for individual diabetic patient. Snae and Bruckner (2008) developed the food ontology for a menu-planning system to be suitable each clinical patient and restaurant customer based on individual disease and dietary. Garcia (2009) developed the food ontology for a meal recommender to support individual requirement, like vegetarian or celiac. In addition, Kiryakov and Penev (2011) developed food ontology on EDAMAM project to support the menu recommender system on a smartphone device.

This research objective is to discover ingredient substitution knowledge based on each dish and ingredient properties by applying domain knowledge in Thai cuisine recipe and also embedding Semantic Web Rule Language (SWRL) for knowledge inference. Following the objective, the design of food ontology for Thai ingredient substitution could not apply the existing food ontologies owing to the different purposes. The entities and relations among these entities of proposed food ontology are obviously different from previous work, including the rules for substitution knowledge inference.

The rest of article consists of following sections. Section 2 describes a domain knowledge overview. Section 3 proposes a knowledge capture by food ontology. Section 4 provides a knowledge inference model using the SWRL. Section 5 shows results and discussions, while the conclusions are presented in the last section.

DOMAIN KNOWLEDGE OVERVIEW

Domain knowledge is the valid knowledge related to an area humans are working in. In this research, the domain knowledge is concerned in Thai food characteristic and food sensory knowledge. The Thai food characteristic knowledge benefits this work as ingredient characteristic clarification. The food sensory knowledge is applied for constructing the ingredient substitution approach because this research hypothesis is that an

VOL. 9, NO. 9, SEPTEMBER 2014 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

ingredient can substitute another ingredient, if sensory properties between them are equivalent. For example, if Green-Mango has taste sour like Lime, Lime can be substituted by Green-Mango. The sensory properties of food in this research refer to flavor, taste and texture. The following basic knowledge overview is summarized from many sources. Basic Thai food characteristics are summarized from Nardpinit (1999). Taste and flavor sensory characteristics are summarized from Fisher and Scott (1997). Texture sensory characteristic is summarized from Szczesniak (1963). Ingredients used in this case study are collected from The Cook'sBook of Ingredient (2010).

Thai Food Characteristic Knowledge:

Ingredient functions or using purposes of Thai food ingredient are divided into 4 purposes: 1) Ingredient consumed as Vegetable 2) Ingredient consumed as Meat 3) Ingredient consumed as Carb and 4) Ingredient consumed as Seasoning. There are 7 tastes in Thai food: Sour, Sweet, Creamy or Oily, Salty, Spicy, Bitter, and Astringent. Flavor is classified into 2 types based on the two following purposes: 1) Pungent or spice aroma for reducing a bad smell which is mostly derived from plants, such as garlic, parsley root, torch ginger, etc. and 2) Specific odor which is mostly derived from animals, such as shrimp paste and fish sauce.

Food Sensory Characteristic Knowledge:

Food sensory characteristic is a quality of food which is concerned in three aspects: 1) Taste, 2) Flavor, 3) Texture, and 4) Appearance. Basic taste has classified into 5 tastes as sweet, sour, salty, bitter, and umami. Hot and Capsaicin is not the basic taste but it is mouth sensation when taste-bud has burned. Flavor has been classified based on food sources into 9 main classes and 23 subdivisions as shown in Table-1.

Table-1. Classification of food flavors (Fisher and Scott, 1997).

Flavor Class	Subdivision	Example
Fruit flavors	Citrus (Terpene)	Grapefruit, orange
	Non-Citrus (Non-Terpene)	Apple, raspberry, banana
Vegetable flavors	Fresh	Lettuce, celery
	Dried	Tomato leather, tobacco
Spice flavors	Aromatic	Cinnamon, peppermint
	Lachrymatory	Onion, garlic
	Hot	Pepper, ginger
Bevergage flavors	Unfermented	Juices, milk
	Fermented	Wine, beer, tea
	Compounded	Soft drinks, cordials
Meat flavors	Mammal	Beef, Lamb, pork
	Fish	Salmon, menhaden
	Fowl	Chicken, turkey
Fat flavors	Vegetable	Olive oil, soybean oil
	Animal	Lard, tallow, butter
Cooked flavors	Broth	Beef bouillon
	Vegetable	Peas, potatos, bouillon
	Fruit	Marmalade, jelly
Empyreumatic flavors	Smoky	Hams, kippers
	Broiled, fried	Processed meats
	Roasted, toasted, baked	Coffee, snack foods, breakfast cereals, bread
Stench flavors	Fermented	Blue cheese
	Oxidized	Spoiled fish

Texture is food quality that can be detected by fingers, tongue, palate, or teeth. Texture can be divided into three main characteristics: 1) Mechanical characteristic, the examples of popular term are soft,

VOL. 9, NO. 9, SEPTEMBER 2014 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

crunchy, tender, etc.; 2) Geometrical characteristic, the examples are coarse, grainy, etc.; and 3) Other characteristics that are related to moisture and fat contents, the examples of popular term such as greasy, creamy, etc. Appearance is a quality that can be detected by sight, such as color and shape. Popular terms of food texture are described in Table-2.

Table-2. Classification of textural characteristics (Szczesniak, 1963).

Mechanical Characteristics		
Primary Parameters	**Secondary Parameters**	**Popular Term**
Hardness	-	Soft >> Firm >> Hard
Cohesiveness	Brittleness	Crumby >> Crunchy >> Brittle
	Chewiness	Tender >> Chewy >> Tough
	Gumminess	Short >> Mealy >> Pasty >> Gummy
Viscosity	-	Thin >> Viscous
Elasticity	-	Plastic >> Elastic
Adhesiveness	-	Sticky >>Tacky >> Gooey
Geometrical Characteristics		
Class		**Examples**
Particle size and shape		Gritty, Grainy, Coarse, etc.
Particle shape and orientation		Fibrous, Cellular, Crystalline, etc.
Other Characteristics		
Primary Parameters	**Secondary Parameters**	**Popular Terms**
Moisture content	-	Dry >> Moist >> Wet >> Watery
Fat content	Oiliness	Oily
	Greasiness	Greasy

Thai food characteristic and food sensory characteristic knowledge can be summarized into a Table for an ontology design as shown in Table-3.

Table-3. Food sensory properties for an ontology design.

Sensory Characteristic	**Sensory Property**		
Taste	1. Sweet	4. Bitter	7. Capsaicin
	2. Sour	5. Umami	8. Hot
	3. Salty	6. Astringent	
Flavor	1. Citrus-Fruit	9. Fermented-Beverage	17. Vegetable-Cooked
	2. Non-Citrus-Fruit	10. Compounded-Beverage	18. Fruit-Cooked
	3. Fresh-Vegetable	11. Mammal-Meat	19. Smoky-Empyreumatic
	4. Dried-Vegetable	12. Fish-Meat	20. Broiled, fried Empyreumatic
	5. Aromatic-Spice	13. Fowl-Meat	21. Roasted, toasted, baked-Empyreumatic
	6. Lachrymatory-Spice	14. Vegetable-Fat	22. Fermented-Stench
	7. Hot-Spice	15. Animal-Fat	23. Oxidized-Stench
	8. Unfermented-Beverage	16. Broth-Cooked	
Texture	1. Brittleness	3. Gumminess	5. Oiliness
	2. Chewiness	4. Creaminess	6. Viscosity

VOL. 9, NO. 9, SEPTEMBER 2014 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Table-3 contains three sensory characteristics which are used for knowledge inference in the proposed ontology. Taste sensory characteristic includes astringent, capsaicin and hot since they are general words that are frequently used for describing food taste in Thai ingredient by Thai cookery book. Flavor sensory characteristic covers all subdivisions from Fisher and Scott (1997).

Texture sensory characteristic in this work applies the mechanical characteristic from Szczesniak (1963) by excluding some characteristics because this work has attention on texture for mastication. Cohesiveness is a coverage property to clarify the ingredient texture which is frequently seen for ingredient explanation on the ingredient cook book. Viscosity texture is needed because this property is an advantage to tell which ingredient is solid or liquid. In other words, if an ingredient has a non-viscosity value, the ingredient is not a liquid ingredient. Creamy and oily are words which use to describe taste properties in Thai food but both words are sensory properties to describe fat containing. Thus, this work appends creaminess (creamy) as a texture property as same as oiliness (oily). Geometrical characteristics are not excluded in the texture sensory characteristic because this characteristic may be transformed by cutting or assembly process. Moisture content is also excluded because it has too technical meanings and is rarely seen on ingredient explanation by cookery books.

KNOWLEDGE CAPTURE BY ONTOLOGY

Main concepts in the ontology design are Ingredient, Dish and Thai Ingredient Group. A subclass of Ingredient class is an ingredient category based on the Cook'sBook of Ingredient. Instances in "Ingredient" class are the basic components of ontology. For examples, the instances in Ingredient class are Lime Juice, Green Mango, Green Apple, etc. Subclasses of Dish class are Thai dish types such as Dipping, Fried, Grilled, Roasted, Salad, Side-dish, Soup, Steamed, and Stir-fried. Instances in "Dish" class are Tom Yum Kung, Nam Prik Kapi, etc. Instances in "Thai Ingredient Group" class are ingredients which are inferred from rule bases. This research considers sensory property as the datatype property of Ingredient class in the ontology. Since ingredient has different level of flavor and taste as see in ingredient explanation such as "Kale has slightly bitter", "Hyssop has strong aroma flavor" then the words "Strong and Slightly" are also using to describe flavor and taste level. The sensory property will take an advantage for comparison by "Built-in" interoperation of SWRL (W3C, 2004). An example of ingredients and their sensory properties is shown in Table-4.

Table-4. Examples of ingredients and their sensory properties.

Ingredient	**Sensory Property**		
	has flavor	***has taste***	***has texture***
Kaffir lime juice	strong citrus fruit	strong sour	thin liquid
Lime juice	strong citrus fruit	strong sour	thin liquid
Green Apple	strong non-citrus fruit	strong sour, slightly sweet	crunchy, chewy
Green Mango	slightly non-citrus fruit	strong sour, slightly sweet	crunchy, chewy

Moreover, the relations between dishes and ingredients are needed because the same ingredient may have different using purposes and sensory property requirements in different dishes. In other words, an ingredient might be able to substitute another ingredient in one dish, but it could not substitute the former ingredient in other dishes. For example, Green Mango can substitute Lime Juice in a dish "Nam Prik Kapi", but Green Mango cannot substitute Lime Juice in a dish "Tom Yum Kung", because the dish "Tom Yum Kung" is soup which requires sour seasoning from a liquid soluble ingredient.

The sensory property requirements of ingredients comprise three levels which are all demands, some demands, and no demand. The requirement levels will be used for a sensory property comparison of ingredients. The "all demands" level means all sensory properties in the same sensory characteristic of a rare ingredient must be equivalent to another substituted ingredient. The "some demands" level means at least one sensory property of the rare ingredient must be equivalent to the substituted ingredient. The "no demand" level means the sensory property ignored for ingredient substitution. An example of sensory property requirements is illustrated in Table-5.

Table-5 shows a dish "Tom Yum Kung" requires all sensory properties in the taste and texture characteristics from an ingredient "Lime juice", while "Nam Prik Kapi" requires only some sensory properties in the taste characteristic from the Lime Juice. Therefore, the ingredient "Green Mango" cannot substitute "Lime Juice" in the dish "Tom Yum Kung" because texture properties of both ingredients are not all the same. On the other hand, "Green Mango" can substitute "Lime Juice" in the dish "Nam Prik Kapi" because texture properties of Lime Juice do not need in this dish and also some taste properties of both ingredients is equivalent.

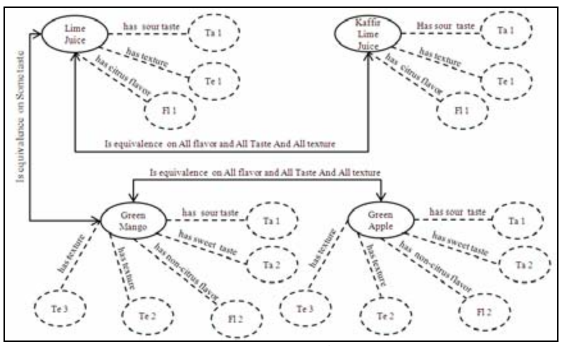
VOL. 9, NO. 9, SEPTEMBER 2014 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Table-5. Examples of sensory property requirement in each ingredient of different dishes.

Dish	Ingredient		Sensory Requirement		
	Name	**Using Purpose**	**Flavor**	**Taste**	**Texture**
Tom Yum Kung	Lime Juice	Seasoning	no demand	all demands	all demands
Nam Prik Kapi	Lime Juice	Seasoning	no demand	some demands	no demand

In Figure-1, an example of ingredient sensory property comparison is presented. However, the ingredient substitution must consider the different sensory requirement of each ingredient in each dish as discussed above.



Ta 1 = Strong Sour
Ta 2 = Slightly Sweet
Te 1 = Thin Liquid
Te 2 = Crunchy
Te 3 = Chewy
Fl 1= Strong Citrus Fruit
Fl 2 = Slightly Non-Citrus fruit

Figure-1. Examples of ingredient sensory comparison.

This research considers creating another class, except Dish and Ingredient classes to keep those inferred ingredients. The new class called "Thai Ingredient Group" aims to keep ingredients inferred by the sensory equivalence based on sensory property requirements of each ingredient in each dish. This class has 4 subclasses based on using purposes of Thai ingredients

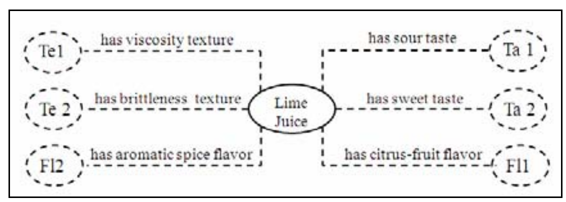
KNOWLEDGE INFERENCE BY SWRL

Semantic Web Rule Language (SWRL) is a rule language of the Semantic Web which contains antecedent (body) and consequent (head). Meaning is "whenever the conditions specified in the antecedent hold, the conditions specified in the consequent must also hold" (W3C, 2004). This article does not describe more details about SWRL but it will show how it applies the SWRL in this research.

The SWRL is applied in this research for ingredient substitution. A set of rule bases has divided into 7 main groups for different purposes as follows: 1) Rule bases to dispose sensory properties of ingredients, 2) Rule bases to infer the similarity of ingredient shapes after their shape transformation, 3) Rule bases to infer proper ingredients by considering a cooking-and-assembly method, 4) Rule base to infer using purposes of ingredients, 5) Rule bases to infer equivalence relations among sensory properties of ingredients, 6) Rule bases to infer sensory requirements of each ingredient in each dish, and 7) Rule bases to infer rare ingredient substitution based on the sensory property requirements. More details of these rule sets are described below.

Set 1: Rule bases to dispose sensory properties of ingredients:

The proposed model designs sensory properties of ingredients as the datatype property of Ingredient class in the food ontology. A value of sensory property is a string consisting of popular terms such as Strong-Sour, Slightly-Sour, Strong-Aromatic-Spice, Crunchy, and Tender. This work constructs a comparison method using Close World Assumption, and then each ingredient needs to be filled-in all datatype properties to calculate the equivalence relations among ingredient properties. For example, "Lime Juice has strong-sour taste but has not sweet taste, and Lime Juice has strong-citrus-fruit flavor but has not aromatic-spice flavor, and Lime Juice has thin liquid texture but has not brittleness texture", therefore relations between Lime Juice and its properties are shown as Figure-2.



Ta 1 = Strong-Sour
Ta 2 = Non-Sweet
Fl 1 = Strong-Citrus-Fruit
Fl 2 = Non-AromaticSpice
Te 1 = Thin-Liquid
Te 2 = Non-Brittleness

Figure-2. Examples of ingredients and its datatype properties.

Rule bases to dispose the sensory properties of each ingredient will benefit the proposed model to compare some sensory properties among ingredients. For example, if two ingredients have the same "hasTaste" property, they have at least one equivalence relation. It implies that both ingredients have some taste properties that are equivalent. An example rule of sensory disposition is shown below.

Set 1_Example Rule: Ingredient(?a) □ hasTaste-Sour(?a, ?taste) □ swrlb:notEqual(?taste, "Non-Sour") → hasTaste(?a, "Sour")

VOL. 9, NO. 9, SEPTEMBER 2014 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Set 1 Example rule means that “If sour taste value of ingredient (? a) does not equal to Non-Sour, then infer that ingredient (? a) has taste sour”

Set 2: Rule bases to infer the similarity of ingredient shapes after transformation:

Since the ingredient shape can be transformed by a cutting or assembly process and a variety of ingredient shapes has an effect on ingredient selection for cooking dishes, the facts can imply that ingredients with the same transformable shape has an opportunity to be substituted by each other. An example rule of inferring the similarity of ingredient shapes after transformation is shown below.

Set 2_Example Rule: Ingredient(?a) hasOriginalShape(?a, ?shapea) hasAdaptableShape(?b, ?shapeb) swrlb:equal(?shapea, ?shapeb) → isSameShapeAs (?a, ?b)

Set 3: Rule bases to infer proper ingredients for each dish by considering a cooking-and-assembly method:

Each ingredient has different ways to cook and assemble. This rule set acts as a matching process between a cooking-and-assembly method of dish and the proper cooking-and-assembly method of ingredient which is recommended by a cookery book in order to infer proper ingredients for the dish. For example, “Lime Juice” can be used in soup and “Tom Yum Kung” is a kind of soup. This means that “Lime Juice” is a proper ingredient for “Tom Yum Kung”. An example rule of proper cooking method inference is shown below.

Set 3_Example Rule: Ingredient(?a) hasIngredientMethod(?a, ?m) Dish(?dish) hasDishMethod(?dish, ?m) → hasProperIngredientByCookingAndAssemblyMethod(?dish, ?a)

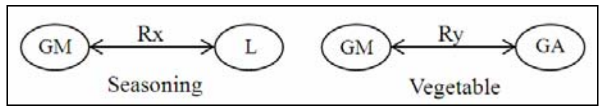
Set 4: Rule bases to infer using purposes of ingredients:

An ingredient can stay in two classes since each ingredient has more than one using purpose. For instance, Lemongrass can be consumed as seasoning for smell enhancer, and Lemongrass can be consumed as vegetable for a nutrition value. This rule set acts as categorizer to classify each ingredient into a using purpose group. The condition to infer the using purpose group is concerned on the sensory property requirements of ingredients. For example, if an ingredient has strong-sour taste, the ingredient is available to be a seasoning. An example rule of inferring the using purposes of ingredients is shown below.

Set 4_Example Rule: Ingredient (?a) hasTaste-Sour (?a, "Strong-Sour") isAvailableToUseAs(?a, "Seasoning") → has Function (?a, "Flavoring") Seasoning(?a)

Set 5: Rule bases to infer equivalence relations among sensory properties of ingredients:

These rules in this set benefit the ingredient substitution model by comparing “All” and “Some” equivalence relations among sensory properties of each ingredient. Relations of this inference comprise 26 relations. The model is designed to determine the equivalence relations of sensory properties of each ingredient based on the using purposes of ingredient. For example, if an ingredient “Green Mango” is stayed in both vegetable and seasoning groups, Green Mango must be determine the equivalence relations in both vegetable and seasoning groups as shown in Figure-3.



GM = Green Mango Rx = Is same some taste as
L = Limejuice Ry = Is same all taste as
GA = Green Apple

Figure-3. Equivalent relations of sensory properties of each ingredient based on its using purposes.

An example rule of inferring equivalence relations of sensory properties of each ingredient is shown below.

Set 5_Example Rule: Vegetable(?a) Vegetable(?b) hasTaste(?a, ?ta) hasTaste(?b, ?tb) swrlb:equal(?ta, ?tb) hasFunction(?a, ?fa) hasFunction(?b, ?fb) swrlb:equal(?fa, ?fb) → isVegetableThatEquivalenceOnSomeTaste(?a, ?b) isSameTasteAs(?a, ?b)

Set 6: Rule bases to infer sensory property requirements of each ingredient in each dish:

This rule sets identifies the sensory and using purpose from ingredients required in each dish. A dish has many ingredients, but each ingredient has one using purpose and various sensory property requirements. Results from this rule set are sensory property requirements of each ingredient in each dish. For example, Tom Yum Kung requires Lime Juice for sour seasoning and all taste and all texture properties from Lime Juice, but flavor properties are not required. This condition can transfer to relations between dish and ingredient as shown in Figure-4.

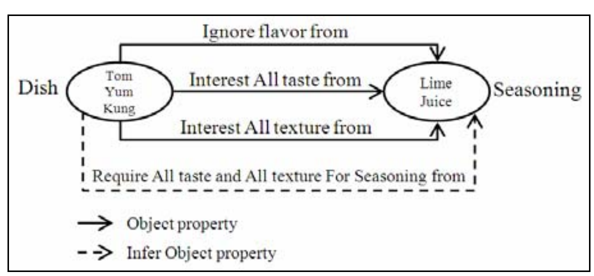


Figure-4. Sensory requirement relations between dish and ingredient.

An example rule of inferring sensory requirements of an ingredient in each dish is shown below.

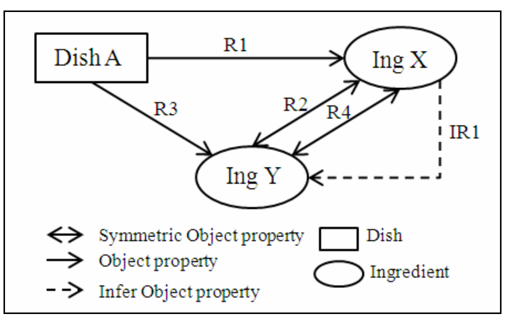
Set 6_Example Rule: Dish (? d) ∧ Seasoning (? a) ∧ IgnoreFlavorFromSeasoningIngredient(?d, ?a) ∧ InterestAllTasteFromSeasoningIngredient(?d, ?a) ∧ InterestAllTextureFromSeasoningIngredient(?d, ?a) → RequireAllTasteAndAllTextureForSeasoningFrom(?d, ?a)

Set 7: Rule bases to infer rare ingredient substitution based on the sensory property requirements:

This rule set infers the final results for rare ingredient substitution. The condition in this set includes the proper ingredients for a dish, ingredient shapes after transformation, equivalence relations among ingredient properties, and sensory property requirements of each ingredient in each dish. The diagram of ingredient substitution is shown in Figure-5.

An example rule of inferring rare ingredient substitution based on each dish is shown below.

Set 7_ Example rule: Dish (? dish) ∧ RequireAllTasteAndAllTextureForVegetableFrom(?dish, ?a) ∧ IsVegetableThatEquivalenceOnAllTasteAndAllTexture (?a, ?b) ∧ hasProperIngredientByCookingAndAssemblyMethod (?dish, ?b) ∧ isSameShapeAs(?a, ?b) → isSubstitutedForVegetableThatEquivalenceOnAllTasteAndAllTextureBy (?a, ?b)



R1 = Require All taste and All texture for vegetable from
R2 = Is vegetable which is equivalent on All Taste and All texture
R3 = Has a proper ingredient
R4 = Is same shape as
IR1 = Is substituted for vegetable which has All taste and All texture by

Figure-5. The example diagram of ingredient substitution.

RESULTS AND DISCUSSIONS

The preliminary evaluation of the ingredient substitution model applies Semantic Query-Enhanced Web Rule Language (SQWRL) which is an SQL-Like language to retrieve knowledge from ontology (O'Conner and Das, 2009). Suppose that a question, sample data and sensory requirements of each ingredient in each dish are assigned as follows.

Question:

What ingredient can substitute an ingredient "Lime Juice" in a dish "Tom Yum Kung"?

Sample Data:

- Lime Juice has strong sour taste, strong citrus flavor and thin liquid texture.
- Kaffir Lime Juice has strong sour taste, strong citrus flavor and thin liquid texture.
- Green Mango has strong sour and slightly sweet taste, slightly non-citrus flavor, and crunchy and chewy texture.

Sensory Requirements of each Ingredient in each Dish:

Tom Yum Kung uses Lime Juice as seasoning and requires all taste and all texture properties, but it does not require any flavor properties from Lime Juice.

The SQWRL syntax of the question is shown below, while the query result is exposed in Figure-6.

Query for Ingredient Substitution:

RequireAllTasteAndAllTextureForVegetableFrom (?dish, ?a) ∧ isSubstitutedForVegetableThatSameAllTasteAndAllTextureBy (?a, ?b) → sqwrl:select("Substitute", ?a, "in", ?dish, "by", ?b)

SQWRLQueryTab | Rule-Query-Test

[Substitute]	?a	[in]	?dish	[by]	?b
Substitute	LimeJuice	in	TomYumKung	by	LimeJuice
Substitute	LimeJuice	in	TomYumKung	by	KaffirLimeJuice

Figure-6. Final results of rare ingredient substitution.

Following the sensory properties requirements using the SQWRL syntax for retrieval, the query results show that Lime Juice can be substituted by Kaffir Lime Juice in Tom Yum Kung because all taste and all texture properties of both ingredients are equivalent.

CONCLUSIONS

This research proposes a knowledge acquisition model for ingredient substitution in Thai cuisine recipe. The main purpose of this research is to substitute rare ingredients using existing ingredients. The proposed model is applying the concept of domain ontology to design classes, properties of each class, and relations among these classes which are related to ingredient substitution in Thai cuisine recipe. In addition, the model applies the Semantic Web Rule Language (SWRL) for designing and embedding a set of rule bases into the domain ontology. The set of rule based is applied for discovering the existing ingredients that can substitute the rare ingredients.

The following research work exhibit several issues needed to further perform. The rule inference could support ingredient substitution for a dish of vegetarian food. The development of semantic web by adopting the proposed food ontology facilitates users to access the inference knowledge more conveniently and rapidly. The inference knowledge could help users to substitute rare ingredients using the existing ingredients. Moreover, it helps users save money for buying out-of-season or import food ingredients which have high price and helps support the sustainable economic development because it can reduce enormous ingredient import from aboard for cooking ethnic food.

REFERENCES

Badra F., Bendaoud R., Bentebitel R., Champin P. A., Cojan J., Cordier A., Després S., Daubias S. J., Lieber J., Meilender T., Mille A., Nauer E., Napoli A. and Toussaint Y. 2008. TAAABLE: Text Mining, Ontology Engineering, and Hierarchical Classification for Textual Case-Based Cooking.

Batista F., Paulo J., Mamede N., Vaz P. and Ribeiro R. 2006. Ontology Construction: Cooking Domain.

DeMiguel J., Plaza L. and Diaz-Agudo B. 2008. ColibriCook: A CBR System for Ontology-Based Recipe Retrieval and Adaptation.

Fisher C. and Scott T. R. 1997. Food Flavours: Biology and Chemistry. Cambridge, England: The Royal Society of Chemistry.

Fudholi D. H., Maneerat N., Varakulsiripunth R. 2009. Ontology-based daily menu assistance system. The 6th International Conference on Electrical Engineering/ Electronics, Computer, Telecommunications and Information Technology.

Gruber T. R. 1993. Toward Principles for the Design of Ontologies Used for Knowledge Sharing, the International Workshop on Formal Ontology.

Herrera P. J. and Iglesias P. 2008. JaDaCook: Java Application Developed and Cooked Over Ontological Knowledge.

Kimura M., Kitamura Y., Matsuda M. and Tijerino Y. 2008. English-Japanese Cooking Recipe Translation System Using Ontology.

Kiryakov A. K. and Penev V. V. 2011. Pagane: EDAMAM Food KB. [Online]. Available: http://www.ontotext.com/case/pagane-foodKB

Koenderink N. J. J. P., Hulzebos J. L., Rijgersberg H. and Top J. L. 2005. Food Informatics: Sharing Food Knowledge for Research and Development. Sixth Agricultural Ontology Service Workshop at the joint EFITA/WCCA conference.

Lee C. S., Wang M. H., Li H. C. and Chen W. H. 2008. Intelligent Ontological Agent for Diabetic Food Recommendation. IEEE World Congress on Computational Intelligence.

Nardpinit K. 1999. Thaifood. Bangkok: Semadhama Publishing House.

O'Connor M.J. and Das A. 2009. SQWRL: a Query Language for OWL: Experiences and Directions (OWLED), 6th International Workshop, Chantilly, VA.

Snae C. and Bruckner M. 2008. FOODS: A Food-Oriented Ontology-Driven System. Digital Ecosystems and Technologies, 2nd IEEE International Conference on. pp. 168-176.

Suksom N., Buranarach M., Thein Y.M., Supnithi T. and Netisopakul P. 2010. A Knowledge-based Framework for Development of Personalized Food Recommender System. Proceedings of the 5th International Conference on Knowledge, Information and Creativity Support Systems.

Szczesniak A. S. 1963. Objective Measurements of Food Texture. J. of Food Sci. 28(4).

2010. The Cook's Book of Ingredients. Dorling Kindersley Limited.

Vadivu G. and Hopper S. W. 2010. Semantic Linking and Querying of Natural Food. Chemicals and Diseases.

Villarías L. G. 2004. Ontology-Based Semantic Querying of the Web with Respect to Food Recipes.

Wang M. H., Lee C. S., Hsieh K. L., Hsu C. Y. and Chang C. C. 2009. Intelligent Ontological Multi-Agent for Healthy Diet Planning. Fuzzy Systems, IEEE International Conference, 20-24 Aug.

W3C, SWRL: A Semantic Web Rule Language Combining OWL and RuleML, 2004. [On-line]. Available: http:// www. w3.org/Submission/SWRL/.