# A Review on Multilingual Food Recommendation Systems for Critical Medical Conditions in Pregnancy Care*

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**Abstract**

AMedical conditions require proper attention as some of them especially those occurring in women that are expecting pregnancy require proper care. Although pregnancy exposes them to several critical health conditions, most of these conditions were actually in existence before pregnancy with their causes traced back to poor nutrition resulting from food intake. However, there have been a good number of food recommendation systems in existence with few of them being context-aware. This work is aimed at performing a critical review of the food recommender systems that considers medical conditions and design the food ontology for critical medical conditions that adopts the pathology test results of patients in caring for the existing medical conditions such as pregnancy. Focus of the framework is on deploying a multilingual ontology-based approach in addition to other required approaches for recommendations. This work also introduces the addition of uncooked food in the food ontology for recommendations. The proposed food ontology for critical medical conditions considers the required nutrients based on the combination of several factors including the pathology test results, location/language, medical conditions and user preferences. The use of this food ontology framework for food recommender is reliable due to the additional factors.

**Keywords**

Critical Health conditions, Ontology-based Representations, Nutrition, Pathological test

## 1. Introduction

Recommender systems work behind the scenes on many of the world's most popular websites. The preceding few decades have shown a tremendous rise in web services like AMAZON, FACEBOOK & INSTAGRAM, YOUTUBE, GOOGLE, ETC. Other examples of recommender systems at work include movies on Netflix, songs on Spotify and profiles on Tinder. And with the rise of such sites, recommender systems are getting much more important than before. Several

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recommendation systems use algorithms including the collaborative filtering, content-based and hybrid approaches. Context-Aware Recommendation (CAR) is a recent approach said to generate better recommendations based on the specific contextual situation of the user. CARs use several approaches to incorporate contextual information for the users in the recommendation process and then use such approaches for different applications. The representation of these knowledge for context-aware recommendations is very necessary. Hence, the choice of ontologies as representation tools for semantic web reasoning of the proposed food recommender system.

Ontology is best known for defining the concepts and relationships used to describe and represent an area of concern with the specific role of facilitating data organization and integration in the semantic web [1]. Ontologies are suitably considered here due to its crucial role in enabling automatic knowledge processing, sharing, and reuse among various applications. The use of ontologies and other AI techniques are reported by many potential research studies [2, 3, 4].

Another application domain with high demand for context-based recommendation is the food and health domain with a particular task of providing care for expectant mother and the unborn baby (pregnancy) regarding what should be eaten. Making decisions about what to eat, when to eat and even the proportion of food intake has become major problem in our everyday lives, particularly the expectant mothers, due to a wide variety of ingredients, cultures, personal tastes and individual medical conditions has made choosing the right food at the right time to be as a very difficult task. Today, many diseases that were previously thought as hereditary are now seen to be connected to biological dys-function related to nutrition.

Already existing food recommender systems mostly focused on meals (cooked food) and users' preferences without considering uncooked food and pathology test of users for accurate breakdown of the nutritional state of the user. Among many factors for healthy living, right food consumption is one of the major factors, specifically, for people suffering from critical health ailments such as over-weight, under-weight, heart disease, cancer, diabetes, allergies, obesity, which may significantly lead to many other complications in pregnancy such as birth defects, premature birth, miscarriage, stillbirth and infertility. Complications in pregnancy can be life threatening (critical), most common, minor, rare, early and chronic. Although, certain medical conditions may complicate a pregnancy, with proper care, most women can enjoy a healthy pregnancy even with her health challenges. Various studies portray that inappropriate and insufficient intake of food are the major reasons of various health issues and diseases (WHO/UNISEF, 2001).

Most of the critical health conditions occur due to the excess and deficiency of food element. Some of the key elements of food include carbohydrate, calcium, iron, protein and vitamins and the consumption of balanced diet can normalize some of the medical conditions. Addressing the problem of selecting what and how to eat can promote healthy living and decrease usage of unhealthy food ingredients or compounds such as oxidants. Healthy eating is possible only when you ensure that your body is getting the right food elements in the right quantity that it requires. Therefore, it is essential to know about the food nutrition to be sure of what is consumed into the body. These food elements categorically include carbonaceous (starch, sugar, fats), nitrogenous(albumen) and inorganic substances (minerals).

The requirement of food changes over time, with respect to the stage of life that we are in, for example while a child requires food to grow and develop, adults need it more for the energy

required to function daily. In addition to that, food is also required so as to repair the various parts of the body that are worn away, or those that have to be discarded due to wear and tear caused by critical health conditions. Therefore, we need to continuously replenish our body with a variety of elements present in food and drink. Pathology test is the major mode of examination that offers the status of these key elements.
To get appropriate food intake to improve overall well-being, smart food recommender systems will offer prevalent recommendation for healthier food choices [5, 6]. This work is aimed at carrying out a critical review of food recommendation systems that consider medical conditions and giving the design of a context aware food recommender framework for medical conditions and pregnancy care. Its focus is on providing an ontology-based model for classification and recommendation of food (cooked and uncooked) for users with critical health conditions in the right proportion for consumption. This work will bring an improvement to the challenge of an existing system by directly recommending right food (cooked and uncooked), nutritional elements and the proportion of food consumption especially for critical health conditions based on user's pathological reports
The rest of the paper is organized as follows. Section 2 presents the critical review on related works while the methodologies and the data collection adopted for the design of the system are described in section 3. Section 4 presents a detailed food ontology to include the uncooked brand of food with the required proportion of the nutritional elements for pregnant women with medical conditions.

## 2. Related Literature about Recommendation Algorithms

### 2.1. Recommendation Algorithms

The major and most common algorithms used in recommendation systems are discussed as follows. Collaborative filtering is basically an algorithm used in the recommendation system that basically makes the use of similarities between the items and users in order to provide the right recommendations. This means this type of algorithm can provide a recommendation to user A depending on the interest of a similar user B. What makes collaborative filtering different is the fact the past user-item interaction is enough for the predictions to be made for similar users.
Content-based recommendation, on the other hand, solely depends on the choice of the users themselves, and the recommendations are made based on the items or products the users like based on their previous feedback or actions. The content-based recommendations shown in Figure 3 are less problematic for the new users as the items can be described by their characteristics or content, and thus relevant recommendations can be made for the new entities.
The hybrid approach of recommendations combines collaborative and content-based recommendations. In a system, first the content recommender takes place as no user data is present, then after using the system the user preferences with similar users are established. These kinds of approaches are said to have provided better and accurate recommendations. Netflix uses a hybrid approach of recommendations because it compares the watching habits of similar users and also offer movies that share the characteristics with all those films which the user has rated high.

The earliest recommendation system, called Tapestry filters, use information by collaborative filtering system. Collaborative recommendation system is the most famous and commonly used one. The system analyses the preferences from the set of users within the system. It finds out the set of users with similar characteristics and takes this relevance as evidence to induct the potential preferences of the users. Besides recommending the interested information to the users, this research is expected to recommend the information that may arouse the users' potential demands based on users' culture and pathology test.

Various studies portray that inappropriate and insufficient intake of food are the major reasons of various health issues and diseases. A study conducted by World Health Organization (WHO) estimate that about 30% of the total population of the world is suffering from various diseases, 60% deaths each year in children are related to malnutrition and about 9% of heart attack deaths. Moreover, many children are suffering from Vitamin-A deficiency, 200 billion people are suffering from iron deficiency (anemia) and a lot of people are suffering from iodine deficiency (WHO/UNISEF, 2001).

Several works proposed different recommendation systems related to food. These systems can be categorized as:

(a) food recommendation systems [7, 8]

(b) menu recommendations [9]

(c) diet plan recommendations[10]

(d) health recommendations for different diseases like diabetes and cardiovascular [11, 12]

(e) recipe recommendations [13, 14]

The above mentioned systems provide recommendations to either some specific disease or balance the diet without considering information about any disease or nutrition deficiency in the body. For instance, in[7] a food recommendation system is proposed for diabetic patients that used K-mean clustering and Self-Organizing Map for clustering analysis of food. The system recommends various foods for diabetic patients without considering the disease level that may fluctuate frequently in different situations of the patient and the food recommendations may also vary accordingly.

Similarly, the authors in [8], do not consider the nutrition factors that have significant importance for a balanced diet recommendation. Tags and latent factor are used for android-based food recommender system [8]. The system recommends personalized recipe to the user based on tags and ratings provided in user preferences. The proposed system used latent feature vectors and matrix factorization in their algorithm. Prediction accuracy is achieved by use of tags which closely match the recommendations with users' preferences. However, the authors do not consider the nutrition factors in order to balance the diet of the user according to his needs.

Content based food recommender system [13] is proposed which recommend food recipes according to the preferences already given by the user. The preferred recipes of the user are fragmented into ingredients which are assigned ratings according to the stored users' preferences. The recipes with the matching ingredient are recommended. The authors do not consider the nutrition factors and the balance in the diet. Moreover, chances of identical recommendation are also present because the preference of the user may not change on daily basis.

In [15], knowledge based dietary nutrition recommendation system is proposed for obesity. The recommendations include dietary nutrition and diet menus for individuals using collaborative

filtering technique. An application for mobile users is also developed in order to recommend the dietary and menus to the users. Similarly, a food recommender system is proposed in [16] for patients in care facilities. The application is designed for caregivers in the care facilities in order to offer the food according to the patient preferences.

Majority of these recommendation systems extract users' preferences from different sources like users' ratings [17, 5], recipe choices [18, 19] and browsing history[1] [20] ,[21, 22] . For instance, in [19] a recipe recommendation system is proposed using social navigation system. The social navigation system extracts users' choices of recipes and in return recommends the recipes. Similarly, in[22], a recipe recommendation system is proposed that is capable of learning similarity measure of recipes using crowd card-sorting. The above-mentioned recommendation systems lack in solving a common problem known as cold start problem. All these systems must wait for the users to enter enough data for the effective recommendations[23].

Some of the commercial applications offer users for a quick survey in order to get users preferences in a short time. For instance, the survey used by [24] is specifically designed to match the lifestyle of the user i.e., healthy, sportsman, pregnant, etc. The survey also attempts to avoid various foods which do not match the user's lifestyle. Similarly, a questionnaire is used by [25] through which a user answers different questions about his/her lifestyle, food preferences, nutrient intake, and habits. The system once extracts all the basic information is then able to recommend different meals for daily and weekly basis.

This work presents an ontology-based multi-lingual food recommendation system that will specifically deal with the pathological tests results. Our system considers diseases related to pathological reports, most common nutrition factors in recommending the food items to the users and the proportion of the food intake. For this purpose, we will use a database of 400 pathological test reports to categorize various diseases that occur due to the changes from the normal ranges of compounds/parameters.

[1] urlhttps://www.nutrinohealth.com/

**Table 1**
Summary of research contributions related to food recommendation system

| Ref | Aims | Data | Method | Key Findings | Critique |
|---|---|---|---|---|---|
| [26] | Food recommendation system to users with a simple scenario | Manual rating of food items | Health and standard food database | TF-IDF (Term Frequency-Inverse Document Frequency) extraction and Similarity between the food items and user profile. | Manual rating is prone to error and reliable information could be ignored |
| [5] | Corresponding ingredients in recipe | Content-Based (CB) algorithm and Recipes prediction and recommendation | Medical conditions or nutrition deficiency not considered | | |
| [27] | summary and highlight of approaches in recent state-of -art system | Recommendation of recipes, meal plans, groceries and menu in 25 recent papers | Simulation using historical | Performance algorithms measurement | Mimic users' profile and feedback for recommendation |
| [28] | Recommend dishes (breakfast, lunch and dinner) for diabetes patients | Food ontology construction from nutrient food dataset | K-Means clustering algorithms and Self Organizing Map (SOM) | Generates a dietetic plan based on accessibility and filtering unsuitable food. | Limited to only one medical conditions |
| [29] | Determine and identify side effects of nutrients in packaged food products on market and recommend based on medical condition | Queuing database from Republic of Turkey Ministry of Food Agriculture and Livestock | Semantic matching (concept matching engine (CME)) Inference mechanism | makes use of semantic rules, | System does not consider recipes for healthy eating habit |
| [20] | Provide dietary assistance to people with medical conditions | Composition of foods integrated dataset (CoFID) - 3,400 food items with 26 entries and 345 pathological test reports | A cloud-based solution using Ant Colony Optimization (ACO) algorithm | Recommends various foods and nutrition to the people based on their pathological test reports as well as manages and updates the heuristic information | No food recommendations breakdown for different timings of the day, such as breakfast, lunch, and dinner and the proportion of food items was not considered |

## 3. Domain Data Collection towards a Context-Aware Food Recommender Framework

Addressing the problem of selecting what and how to eat can promote healthy living and decrease usage of unhealthy food ingredients or compounds such as oxidants. To get appropriate food intake to improve overall well-being, smart food recommender systems will offer prevalent recommendation for healthier food choices [5, 6]. The mode of examination to offer the key element is pathology test.
The following categories of knowledge (concepts and relations) were obtained from literatures and adopted in this work. 1. Nutritional Elements: The key nutritional elements of food such as carbohydrate, calcium, iron, protein and vitamins. 2. Categories of Food Elements: They are classified as carbonaceous (starch, sugar, fats), nitrogenous(albumen) and inorganic substances (minerals). 3. Complications in Pregnancy: Birth defects, Premature death, miscarriage, stillbirth, infertility, Preeclampsia, Preterm Labor, Gestational Diabetes, 4. Classes of Complications in Pregnancy: life threatening (critical), most common, minor, rare, early, chronic 5. Critical medical conditions: over-weight, under-weight, heart disease, cancer, diabetes, allergies, obesity, pregnancy 6. Food: food can be cooked(meal) and uncooked 7. Pathology test: Can be blood tests, urine tests, stools (faeces) and bodily tissues 8. Specialisations in pathology: chemical, haematology, anatomical, Cytopathology, medical microbiology (bacteria, viruses, fungi, parasites), immunopathology, genetic, forensic pathology, general, clinical In addition to that, food is also required so as to repair the various parts of the body that are worn away, or those that have to be discarded due to wear and tear caused by critical health conditions. Therefore, we need to continuously replenish our body with a variety of elements present in food and drink. Healthy eating is possible only when you ensure that your body is getting the right food elements in the right quantity that it requires. Therefore, it is essential to know about the food nutrition to be sure of what you consumed into the body.

## 4. Food Ontology for Critical Medical Conditions

The Meal Recommender System will recommend list of desired meals based on the health condition of the User. The Ontology classifies the meal with concentration on those suitable for patients with critical health conditions in both Veg and Non-Veg classes and at specific times for the meal (Breakfast, Lunch and Dinner). The ontology design is as described in Figure 1.

The presence of the location or language which every patient has and every menu for all meals are based on the location/language introduce the concept of multilinguality in the food recommendation process. The use of the pathology test results for each patients unfolds the nutrition deficiency of these patients, their susceptibility to some critical medical conditions and the need to recommend food based on their nutritional values.
The concepts and relationships used to describe and represent the domain of discourse are shown in the ontology diagram with all the linkages to all necessary domain data/information. The role of ontologies in Semantic Web is to facilitate data organization and integration. The concepts include: patients, pathology test results, critical medical conditions, balanced diet informed by nutrition contained in food. The recommendations will be based on the language/location of

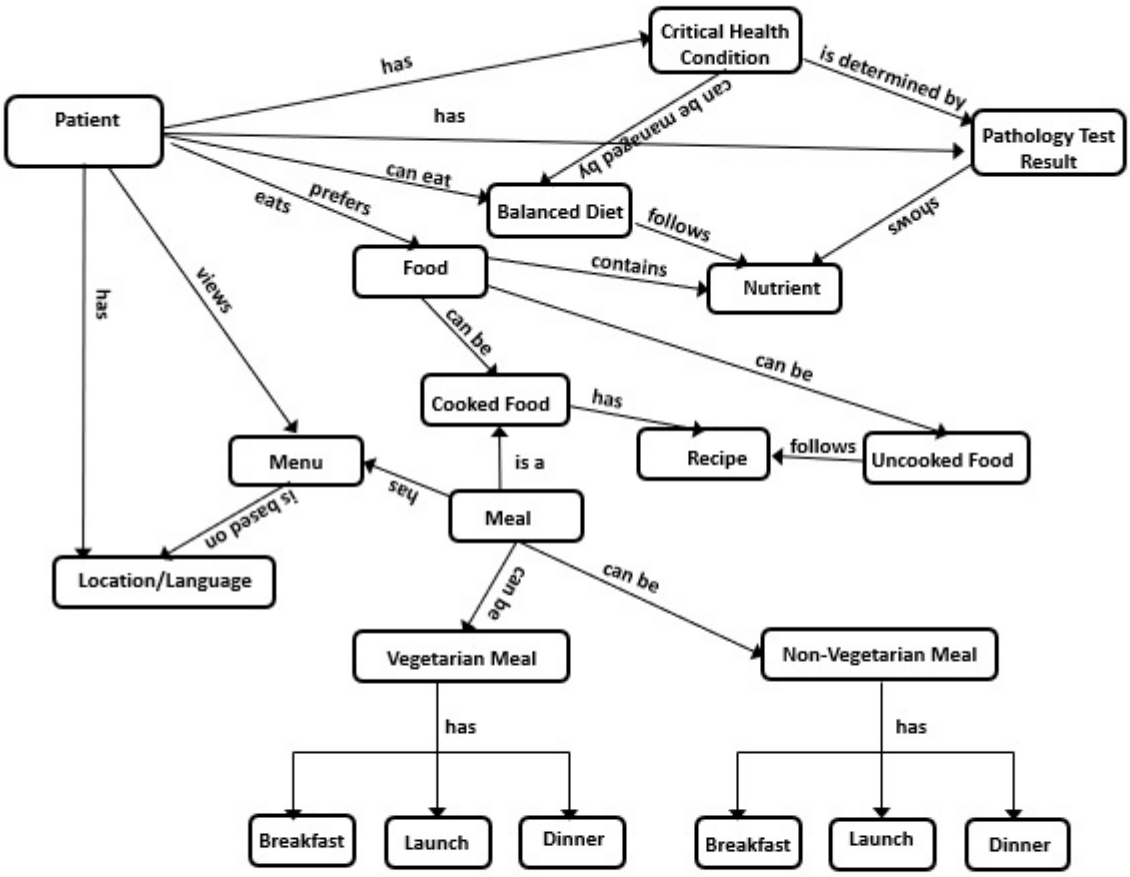


**Figure 1:** Food Ontology for Critical Medical Conditions.

the patient. Other sub-concepts are as contained in the food ontology without the linked data.

## 5. Conclusion

This integrated data (known as Linked Data) can be used for reasoning or simply querying is the main strength of the Semantic Web as it introduces various levels of complexities to the

food ontology. Ontologies can play a crucial role in enabling automatic knowledge processing, sharing, and reuse among applications. Reasoning with the food ontology in multilinguality is therefore an interesting research task that needs to be carried out and doing this requires a context-aware recommender framework.

## References


[1] M. R. Saeed, C. Chelmis, V. K. Prasanna, Automatic integration and querying of semantic rich heterogeneous data: Laying the foundations for semantic web of things, in: Managing the Web of Things, Elsevier, 2017, pp. 251–273.

[2] F. Ortiz-Rodriguez, J. M. Medina-Quintero, S. Tiwari, V. Villanueva, Egodo ontology: Sharing, retrieving, and exchanging legal documentation across e-government, in: Futuristic Trends for Sustainable Development and Sustainable Ecosystems, IGI Global, 2022, pp. 261–276.

[3] F. Ortiz-Rodriguez, S. Tiwari, R. Panchal, J. M. Medina-Quintero, R. Barrera, Mexin: Multidialectal ontology supporting nlp approach to improve government electronic communication with the mexican ethnic groups, in: DG. O 2022: The 23rd Annual International Conference on Digital Government Research, 2022, pp. 461–463.

[4] R. Panchal, P. Swaminarayan, S. Tiwari, F. Ortiz-Rodriguez, Aishe-onto: a semantic model for public higher education universities, in: DG. O2021: The 22nd Annual International Conference on Digital Government Research, 2021, pp. 545–547.

[5] J. Freyne, S. Berkovsky, Intelligent food planning: personalized recipe recommendation, in: Proceedings of the 15th international conference on Intelligent user interfaces, 2010, pp. 321–324.

[6] M. Harvey, B. Ludwig, D. Elsweiler, You are what you eat: Learning user tastes for rating prediction, in: International symposium on string processing and information retrieval, Springer, 2013, pp. 153–164.

[7] M. Phanich, P. Pholkul, S. Phimoltares, Food recommendation system using clustering analysis for diabetic patients, in: 2010 International Conference on Information Science and Applications, IEEE, 2010, pp. 1–8.

[8] M. Ge, M. Elahi, I. Fernaández-Tobías, F. Ricci, D. Massimo, Using tags and latent factors in a food recommender system, in: Proceedings of the 5th International Conference on Digital Health 2015, 2015, pp. 105–112.

[9] M. Runo, Foodroid: a food recommendation app for university canteens, Unpublished semester thesis, Swiss Federal Institute of Theology, Zurich (2011).

[10] C.-J. Su, Y.-A. Chen, C.-W. Chih, Personalized ubiquitous diet plan service based on ontology and web services, International Journal of Information and Education Technology 3 (2013) 522.

[11] A. B. Evert, J. L. Boucher, M. Cypress, S. A. Dunbar, M. J. Franz, E. J. Mayer-Davis, J. J. Neumiller, R. Nwankwo, C. L. Verdi, P. Urbanski, et al., Nutrition therapy recommendations for the management of adults with diabetes, Diabetes care 37 (2014) S120–S143.

[12] M. L. LeFevre, U. P. S. T. Force*, Behavioral counseling to promote a healthful diet and physical activity for cardiovascular disease prevention in adults with cardiovascular risk

factors: Us preventive services task force recommendation statement, Annals of internal medicine 161 (2014) 587–593.
[13] J. Freyne, S. Berkovsky, Evaluating recommender systems for supportive technologies, in: User Modeling and Adaptation for Daily Routines, Springer, 2013, pp. 195–217.
[14] C.-Y. Teng, Y.-R. Lin, L. A. Adamic, Recipe recommendation using ingredient networks, in: Proceedings of the 4th annual ACM web science conference, 2012, pp. 298–307.
[15] H. Jung, K. Chung, Knowledge-based dietary nutrition recommendation for obese management, Information Technology and Management 17 (2016) 29–42.
[16] T. De Pessemier, S. Dooms, L. Martens, A food recommender for patients in a care facility, in: Proceedings of the 7th ACM conference on Recommender systems, 2013, pp. 209–212.
[17] P. Forbes, M. Zhu, Content-boosted matrix factorization for recommender systems: experiments with recipe recommendation, in: Proceedings of the fifth ACM conference on Recommender systems, 2011, pp. 261–264.
[18] G. Geleijnse, P. Nachtigall, P. van Kaam, L. Wijgergangs, A personalized recipe advice system to promote healthful choices, in: Proceedings of the 16th international conference on Intelligent user interfaces, 2011, pp. 437–438.
[19] M. Svensson, K. Höök, R. Cöster, Designing and evaluating kalas: A social navigation system for food recipes, ACM Transactions on Computer-Human Interaction (TOCHI) 12 (2005) 374–400.
[20] F. Rehman, O. Khalid, K. Bilal, S. A. Madani, et al., Diet-right: A smart food recommendation system, KSII Transactions on Internet and Information Systems (TIIS) 11 (2017) 2910–2925.
[21] M. Ueda, S. Asanuma, Y. Miyawaki, S. Nakajima, Recipe recommendation method by considering the users preference and ingredient quantity of target recipe, in: Proceedings of the international multiconference of engineers and computer scientists, volume 1, 2014, pp. 12–14.
[22] Y. Van Pinxteren, G. Geleijnse, P. Kamsteeg, Deriving a recipe similarity measure for recommending healthful meals, in: Proceedings of the 16th international conference on Intelligent user interfaces, 2011, pp. 105–114.
[23] L. Yang, C.-K. Hsieh, H. Yang, J. P. Pollak, N. Dell, S. Belongie, C. Cole, D. Estrin, Yum-me: a personalized nutrient-based meal recommender system, ACM Transactions on Information Systems (TOIS) 36 (2017) 1–31.
[24] K. TONBALAK, D. ONGAN, Yaşlılıkta beslenme durumunu etkileyen engellilik sorunlarına 435–440karşı uygulanan beslenme çözümleri, İzmir Katip Çelebi Üniversitesi Sağlık Bilimleri Fakültesi Dergisi 7 (????).
[25] S. A. Madani, Diet-right: A smart food recommendation system (2017).
[26] M. El-Dosuky, M. Z. Rashad, T. Hamza, A. El-Bassiouny, Food recommendation using ontology and heuristics, in: International conference on advanced machine learning technologies and applications, Springer, 2012, pp. 423–429.
[27] C. Trattner, D. Elsweiler, Food recommender systems: important contributions, challenges and future research directions, arXiv preprint arXiv:1711.02760 (2017).
[28] B. Raj Kumar, K. Latha, Dfrs: Diet food recommendation system for diabetic patients based on ontology, Int J Appl Eng Res 10 (2015) 2765–70.
[29] D. Çelik, Foodwiki: Ontology-driven mobile safe food consumption system, The scientific World journal 2015 (2015).