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Expert System Software Framework for Nutritional Analysis and Diet-Related Disease

Akuma C. Fortune[a*], Etemi J. Garba[a], Martin E. Teman[a] and Ogbonna J. Uchenna[b]

[a]*Department of Computer Science, Faculty of Physical Science, Modibo Adama University, Yola,*

[b]*Department of Computer Science, Alex Ekwueme Federal University, Ndufu-alike Ikwo, Ebonyi State*

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ABSTRACT

Nigeria faces a serious health crisis with diet-related diseases, which calls for creative ways to improve nutritional results and public knowledge. In addressing the challenges, this study introduces an Expert System Software Framework for Nutritional Analysis and Diet-Related Diseases, leveraging advanced technologies to address healthcare and nutrition challenges. Developed through rigorous research, the framework offers dynamic capabilities, personalized recommendations, and a user-friendly interface. Key features include customized algorithms, blockchain authentication for security, dynamic scheduling, and robust administrative tools. It fills critical gaps by providing insights into nutritional contents and health impacts of foods, supporting informed decision-making and proactive management of diet-related disorders. The performance evaluation demonstrates a high accuracy rate of 91.7%, ensuring reliability in dietary recommendations. Future directions include integrating wearable technology and AI to provide real-time health data for personalized dietary recommendations. This framework sets a new standard in nutritional analysis and disease management, contributing to advancements in healthcare and nutrition. Its recommendations for sustained engagement, collaboration with medical professionals, and global expansion aim to improve user outcomes and quality of life beyond the Nigerian setting.

1. Introduction

The methods by which the human body's organelles, cells, tissues, systems, and functions employ the materials they need from food to maintain a structurally sound and functional balance are taken into account when discussing human nutrition. It can be difficult to obtain accurate health information, including analyses of food and nutrition and diseases linked to diet, in developing economies like Nigeria, where the population is more than 200 million. This is due to a limited number of industry-based experts, such as dieticians and nutritionists, who can cater to the growing demand of the population. Additionally, the cost of hiring these experts in Nigeria is often prohibitively expensive (Sasu, 2024).

The complexity of the relationship between nutrition and health and well-being makes it difficult for individuals to make informed decisions about their diet (Al-Thuhli *et al*., 2013; Mchiza 2022). According to the World Health Organization report (WHO, 2022), non-communicable diseases (NCDs) are responsible for 41 million deaths annually, accounting for 74% of all global deaths. Among these deaths, 17 million occur before the age of 70, with 86% of premature NCD deaths happening in low- and middle-income countries. Furthermore, 77% of all NCD deaths occur in low- and middle-income countries (Roy *et al.,* 2022).

Malnutrition can have serious health consequences, including the development of metabolic and diet-related diseases. According to Adeloye *et al.*, (2021), there is a significant incidence of overweight and obesity in Nigeria, with an estimated 12 million people over the age of 15 who are obese and 20.9 million over the age of 15 who are overweight in 2020. Nigerians are vulnerable because they lack a mechanism to determine the precise nutrients in their food and which foods in their community can be used to prevent or treat diseases linked to nutrition. To address these issues, this research aims to develop an affordable health expert system software framework that can provide access to nutritional information and diet-related diseases.

* Corresponding author. Tel.: +234 906 878 6588
E-mail address:chijiukafortune@mau.edu.ng (Akuma C. F.)

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Expert systems for nutritional analysis and diet-related diseases can play an important role in helping individuals make informed decisions about their diet especially in Nigeria. With active internet users of 164 million people as at Q1 of 2024 (Okamgba, 2024), the system will help individuals in Nigeria to avoid the pitfalls of nutrient over- or under-supply, prevent the development of diet-related metabolic diseases and help in the management of diet-related diseases using local foods.

2. Literature Review

Several studies have aimed to develop expert system frameworks for precise and personalized nutritional analysis. Notably, Ünal and Çilgin (2022) developed an expert system with two main components. The first is a Prolog-based inference engine that uses rules from various nutritional values and BMI to make informed recommendations. The second is a web-based interface for practitioners to manage patient processes and generate personalized nutrition plans. This system allows patients to specify calorie reductions and offers alternative meal choices, combining the Prolog inference engine's power with a user-friendly web interface for effective nutrition planning and management. A Diet and Nutrition Expert System (DANES), for meal management and nutrition counseling, was created by Gupta *et al*., (2017). In order to provide individualized diet recommendations, including BMI and calorie targets, DANES gathers user data such as age, weight, height, and medical history. It takes into account dietary limits due to medical problems, such as warning diabetics not to eat items high in sugar. DANES customizes recommendations according to dietary preferences (vegetarian, eggetarian, and non-vegetarian) and age, gender, and use of decision tables. The system comes with a tracker to record daily activity and food intake, which generates reports to track improvement. The diet plan is modified in response to user feedback, guaranteeing ongoing advancements in dietary control.

A SWI-Prolog-based expert system for nutrition supplementary recommendations was created by Chia-Heng Liou and Che-Chern Lin (2020), and it was presented at the 34th Annual Conference of the Japanese Society for Artificial Intelligence. The system offers individualized dietary recommendations based on user-inputted symptoms using a rule-based methodology with three rules and more than 2000 facts. It suggests particular foods and vegetables in order to correct nutrient deficiencies. Java-based graphical user interfaces (GUIs) improve user engagement by letting users choose between a man, woman, pregnant woman, or nursing woman role; they may also describe symptoms and get personalized dietary advice. Three knowledge structures are part of the system's framework: nutrition to foods, nutrition to symptoms, and nutrition to dose. Three steps are followed by users: choosing a job, describing symptoms, and seeing suggestion outcomes.

The approach is all-inclusive for treating nutritional deficiencies, encompassing a broad spectrum of vitamins, minerals, and nutrition components. Because Java GUIs are integrated, it becomes more aesthetically pleasing and easier to use, which makes it a useful tool for encouraging a healthy lifestyle. Using a case-based methodology, (Ma'aruf and Garba, 2012) created the Expert Diet Prescription System (EDPS). A database of previous instances, complete with disease names, descriptions, symptoms, and recommended diets, is kept on file by the system. This database can be queried by users using names of ailments or symptoms. Three access levels are available to the system: administrator, doctor, and patient. With information gathered from specialists, the database covers seven illnesses: diabetes, cancer, cholera, measles, malaria, goiter, and enlarged heart disease. For design, programs like Code Charge Studio, PHP, MySQL, and WAMP server were utilized. The EDPS promotes food and fruits as substitute treatments in an effort to lessen drug dependency and negative side effects.

In order to enhance health outcomes and lessen overcrowding in healthcare facilities, the researchers advise putting the system into place in homes, restaurants, and hospitals. It does this by providing individualized nutrition prescriptions that encourage a healthy lifestyle without having negative side effects. Several significant challenges to professional nutritional analysis and diet-related disorders are revealed by a review of current systems. These systems are limited in their usefulness because they mainly concentrate on meal preparation and suggestions based on user input of BMI and calories, ignoring particular illnesses or health conditions like diabetes, cardiovascular disorders, or food allergies. Furthermore, they fail to take into consideration the uniqueness of the Nigerian setting, particularly with regard to the foods that are consumed locally and their function in the management of disorders related to diet. The limited variety of food choices, which limits possibilities for certain dietary restrictions, is another problem. Moreover, these systems do not offer information on the nutrient (micro and macro) components of the food items and do not explain the reasons behind the use of specific food items, such as their glycemic index.

A timely and helpful approach would be to create an expert system that mostly uses foods that are consumed locally, explains the rationale behind dietary recommendations, and encourages healthy living.

3. Materials and Methods

To achieve the aim of creating an expert system framework for nutritional analysis and diet-related diseases, a combination of powerful tools was harnessed to facilitate the various aspects of the project. These tools include:

Datasets: Numerous datasets on the nutrient compositions of food items and diet-related diseases were used. Prominent among them are data from Baiwa *et al.* (2018) on Nutritional Food Composition Analysis of some traditional foods in Jigawa, Nigeria, and Morakinyo *et al*. (2015) on the Mineral Composition of commonly consumed local foods in Nigeria.

Figma and Protopie: The development of the system's functionality and user interface was greatly aided by the use of these superb modeling, simulation, and product design tools. Their dynamic capabilities and user-friendly interfaces helped in creating an efficient and user-friendly user interface and user experience for the proposed system.

React Native: React Native was used in the front end/user interface development process. React Native, which is well-known for its efficiency and cross-platform compatibility, made it possible to create a fluid and responsive user experience on a variety of devices (Paul & Nalwaya, 2019).

Python: Python was utilized for developing the backbone of the system's intelligence, known as the inference engine. This core component is responsible for generating recommendations. Python's versatility and extensive libraries made it a prime choice for crafting an efficient and adaptable inference engine.

MySQLi: To store and manage the knowledge base, MySQLi was employed to create and handle the database. MySQLi's robust capabilities in data management and retrieval will ensure the efficient organization and accessibility of the information required for the system's decision-making process.

Visual Studio Code (VSCode): The Expert System Software Framework for Nutritional Analysis and Diet-Related Diseases was constructed with great ease using this robust and flexible open-source code editor from Microsoft. It offers a large library of extensions, supports a large number of programming languages and frameworks, and has built-in facilities for collaboration, version control, and debugging. Because of these features, Visual Studio Code is a great option for quickly and effectively writing, testing, and maintaining the code required for creating and deploying the expert system framework.

By using these technologies, the system was developed in a complete and all-encompassing manner, guaranteeing an easy-to-use interface, wise decision-making, and efficient data management all the way through the project.

3.1 System architecture

The development of an expert system software framework for nutritional analysis and diet-related diseases is the aim of this project. To do so, a number of procedures were followed to achieve the multiple useful modules that work together to form the entire system. As shown in Figure 1, the Data Sets Acquisition phase of the system architecture is where different datasets on nutritional compositions and diseases linked to diet are gathered. Data sets preprocessing is applied to these datasets in order to clean, normalize, and get them ready for additional analysis.

The datasets are then utilized to construct rules and train the system on illness correlations and nutritional analysis in Data Sets Training and Rules Definition. This results in Model Training, wherein the system gains the ability to produce suggestions by using the rules and processed data as a basis. Following training, the system is put through a Model Evaluation process to see how accurate and useful its recommendations are. After then, the model can be updated in light of fresh information or enhanced algorithms, and it can be saved for later use and reference.

The system then moves on to the recommendation phase, where it makes use of the saved and trained model to offer individualized health and nutritional advice based on user inputs and the availability of food in the area. This linear process guarantees a methodical approach to creating and deploying a successful expert system for diet-related disease management and nutritional analysis.

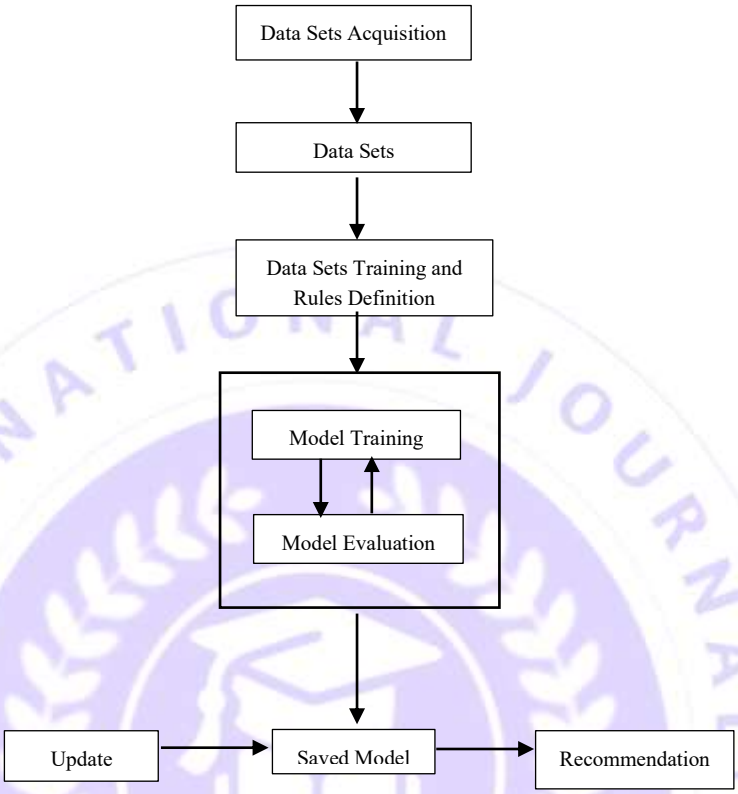

Figure 1: System Architecture

4. Results and Discussions

The study created a sophisticated Expert System Software Framework for Diet-Related Diseases and Nutritional Analysis, utilizing cutting-edge technologies like blockchain authentication to improve security and provide users more control. This method, which is shown in Figure 2, ensures transparent and strong protection, which overcomes the limits of traditional authentication. Taking into account any user difficulties, the framework has a carefully thought-out user interface for usability and accessibility.

Users are empowered to customize recommendations to their own health needs and preferences with the use of user preference customization, which includes Diet Goals, Sensitivity to Ingredients, and Allergies to Foods as shown in Figure 3. With its global search capabilities and customized meal recommendations, Figure 4 the Home Page acts as a primary center for proactive health management tools and extensive nutritional information, enabling well-informed decision-making. The Repository module as shown in Figure 5 improves users' knowledge and health-related decision-making by serving as an extensive database of Nigerian foods and diet-related diseases. While Figure 6, the Diet-Related illness Details Module provides essential information on illness management and prevention, the Food Details Module, shown in Figure 7 delivers detailed insights on nutritional content and glycemic index to assist informed food choices. In order to promote proactive health management, users can schedule activities while aligning dietary demands with the use of the Activity Planner Module in Figure 8. Lastly, by enabling regular updates to the knowledge base, the Admin Module as shown in Figure 9 guarantees the system's dynamic evolution and keeps the framework adaptable to shifting dietary patterns and health discoveries.

All things considered, the Expert System Software Framework is a major step forward in tackling the difficulties associated with nutritional analysis and diet-related illnesses. Through tailored recommendations and all-inclusive

health management tools, it improves user empowerment, health outcomes, and quality of life by fusing cutting-edge technologies and user-centric design concepts.

The Figures 2 to 9 represent the results and working of the framework.

Figure 2. User authentication module user interface

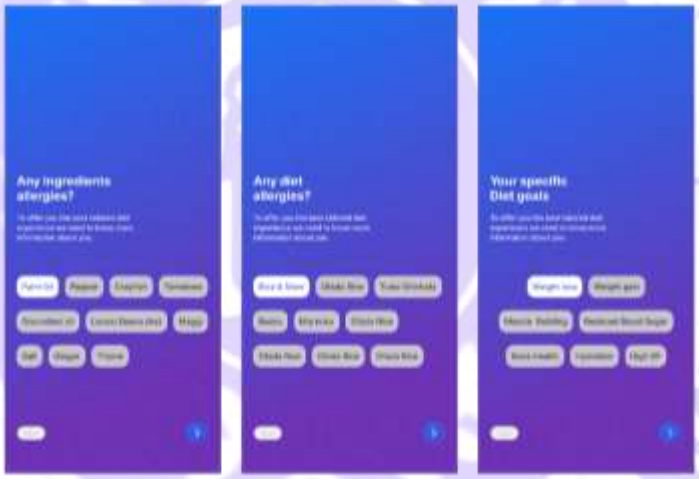

Figure 3 Preference Module User interface

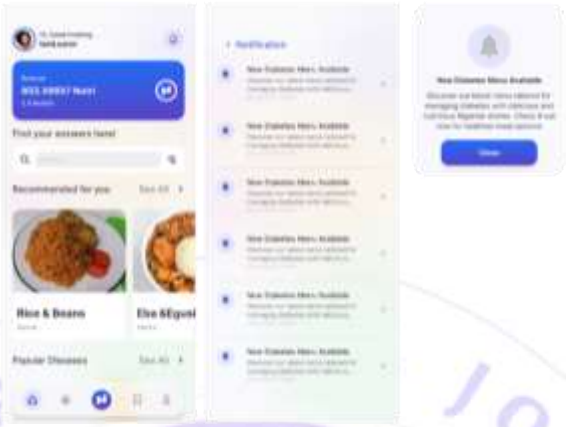

Figure 4 Home page and notification User interface

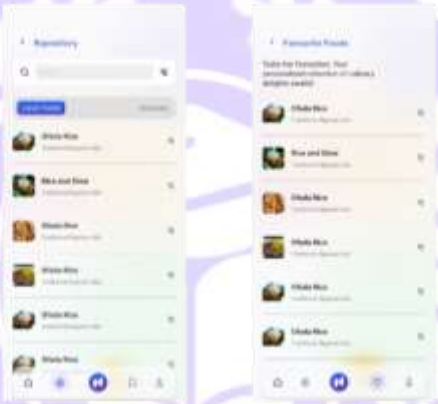

Figure 5 Repository Module User interface

Figure 6. Food Details Module user interface

Figure 7. Diet-related diseases module user interface

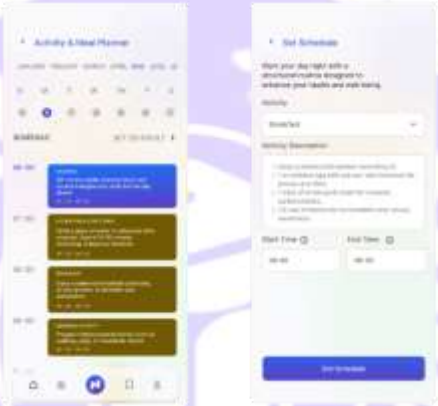

Figure 8. Activity Scheduler module user interface

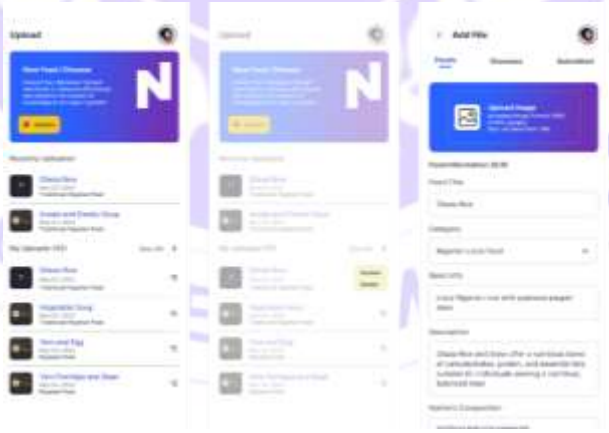

Figure 9. Admin module user interface

4.1 Performance evaluation

An extensive performance review determined how well the system worked to accomplish the goals of the study. A survey was administered to twenty-five beta testers at random to assess the system's accuracy in delivering verified nutritional analysis and diet suggestions. The system's recommendations matched expert advice (true positives), there

were discrepancies (false positives), and any pertinent meals were missed (false negatives). Other important questions were whether testers cross-verified recommended meals with expert sources (such as nutritionists and dietitians). The purpose of these questions was to thoroughly verify the accuracy and dependability of the system.

Table 1 Performance Evaluation survey responses

S/N	Question	Yes				No
1	Have you cross-checked the recommended meals with expert-validated sources (e.g., nutritionists, dietitians)?	23				2
		Not at all satisfied / Strongly disagree	**Somewhat dissatisfied / Disagree**	**Neutral / Neither satisfied nor dissatisfied**	**Somewhat satisfied / Agree**	**Very satisfied / Strongly agree**
2	Were there instances where the app's recommendations matched expert advice (True positives)	0	1	2	9	13
		Not at all satisfied / Strongly disagree	**Somewhat dissatisfied / Disagree**	**Neutral / Neither satisfied nor dissatisfied**	**Somewhat satisfied / Agree**	**Very satisfied / Strongly agree**
3	Were there instances where the app's recommendations differed from expert advice (False positives)	1	1	3	10	10
4	Were there any false negatives (missed relevant meals)?	1	1	3	9	11

From the above the table, the precision rate, error rate and the F1 score for the system were computed as follows

Precision Rate:

Precision rate =True Positives (TP) / True Positives (TP) + False Positives (FP)

True positives are represented by those who agreed or strongly agreed with question 2 in section 2 (22 out of 25 testers). False positives are represented by those who disagreed or strongly disagreed with question 3 in section 2 (2 out of 25 testers).

Precision = 22 / (22 + 2) = 22 / 24 = 0.917 (or 91.7%)

Error Rate:

Error Rate = (False Positives + False Negatives) / Total Testers

False negatives are represented by those who disagreed or strongly disagreed with question 4 in section 2 (2 out of 25 testers).

Error Rate = (2 + 2) / 25 = 4 / 25 = 0.16 (or 16%)

F1 Score Calculation:

F1 Score = 2 * (Precision * Recall) / (Precision + Recall)

Recall = True Positives / (True Positives + False Negatives)

Recall = 22 / (22 + 2) = 22 / 24 = 0.917 (or 91.7%)

F1 Score = 2 * (0.917 * 0.917) / (0.917 + 0.917) = 2 * 0.841 / 1.834 = 0.917 (or 91.7%)

These responses show that the expert system framework has a high precision rate, a low error rate, and a high F1 score, indicating a very good performance in providing accurate recommendations.

5. Conclusion

The aim of the research is to create an advanced software framework that integrated state-of-the-art technologies for disorders linked to diet and nutritional analysis. The Expert System Software Framework provides dynamic capabilities, tailored recommendations, and intuitive user interfaces thanks to thorough study and development. Better decisions about diet and healthcare are made possible by this innovation, which improves quality of life and results in better health. By incorporating vast amounts of data on food nutrition and health effects, the framework improves the domains of nutritional analysis and illness therapy while addressing significant shortcomings in existing approaches. Subsequent developments may investigate the integration of wearable technology and artificial intelligence (AI). The framework has the potential to obtain real-time data on users' activity levels, biometrics, and health indicators by utilizing wearables like health trackers. After analyzing this data, AI systems might offer individualized food suggestions, improving health management according to each person's requirements and circumstances. Sustaining user engagement, working with medical professionals, investigating AI integration, and going worldwide are some of the recommendations. This framework promises revolutionary effects on the global healthcare and nutrition industries, setting a new benchmark in proactive health management.

References

Adeloye, D., Ige, J., Ezejimofor, M. C., Owolabi, E. O., Ezeigwe, N., Omoyele, C., Mpazanje, R., Dewan, M. T., Agogo, E., Gadanya, M. A., Alemu, W., Harhay, M. O., Auta, A. & Adebiyi, A. O. (2021). Estimating the prevalence of overweight and obesity in Nigeria in 2020: a systematic review and meta-analysis. *Annals of Medicine*, *53*(1), 495–507. https://doi.org/10.1080/07853890.2021.1897665

Al-Thuhli, B., Al-Gadidi, B. S., Al-Alawi, H. & Al-Busaidi, K. A. (2013). Developing a Nutrition and Diet Expert System Prototype. *ResearchGate*. https://www.researchgate.net/publication/244993766

Baiwa, F. I., Yakubu, A. & Kanya, G. U. (2018). Nutritional food Composition Analysis of some traditional foods in Jigawa, Nigeria. *International Journal of Science and Research (IJSR)*, *7*(11), 676–680. https://doi.org/10.21275/ART20192738

Sasu, D. D. (2024). *Health in Nigeria*. Statista. https://www.statista.com/topics/6575/health-in-nigeria/#topicOverview

Gupta, V., Bhattacharjee, P., Kotian, N. & Vipat, G. (2017). DANES: Diet and nutrition expert system for meal management and nutrition counseling. *International Journal on Recent and Innovation Trends in Computing and Communication*, *5*(12), ISSN: 2321-8169.

Liou, C.-H. & Lin, C.-C. (n.d.). *A SWI-Prolog-based expert system for nutrition supplementary recommendation*. The 34th Annual Conference of the Japanese Society for Artificial Intelligence, 2020, Japan.

Paul, A. & Nalwaya, A. (2019). React Native for mobile development. In *Apress eBooks*. https://doi.org/10.1007/978-1-4842-4454-8

Ma'aruf, L. M. & Garba, M. (n.d.). Design and implementation of an expert diet prescription system. *International Journal of Artificial Intelligence and Expert System (IJAE)*, *3*(4), 126–134.

Mchiza, Z. (2022). Diet Therapy and Public Health. *International Journal of Environmental Research and Public Health*, *19*(14), 8312. https://doi.org/10.3390/ijerph19148312

Morakinyo, A. O., Samuel, T. & Adegoke, O. (2015). Mineral composition of commonly consumed local foods in Nigeria. *The FASEB Journal*, *29*(S1). https://doi.org/10.1096/fasebj.29.1_supplement.736.4

Okamgba, J. (2024). *Internet subscriptions reach 164 million as voice users drop by 3% – NBS*. Punch Newspapers. https://punchng.com/internet-subscriptions-reach-164-million-as-voice-users-drop-by-3-nbs/#google_vignette

Roy, F., Shaji, A., Sherimon, V. & Amri, M. M. S. A. (2022). Stay-healthy: an expert system to suggest a healthy diet. *International Journal of Engineering Science Technologies*, *6*(1), 11–17. https://doi.org/10.29121/ijoest.v6.i1.2022.262

Ünal, C. & Çilgin, C. (2022). Design and implementation of a web-based expert system for personal nutrition planning. International journal of management information systems and computer sciences https://doi.org/10.33461/uybisbbd.1013012

World Health Organization (2022). Noncommunicable diseases. *www.who.int*. https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases