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A review on material analysis of food safety based on fluorescence spectrum combined with artificial neural network technology

Trias MAHMUDIONO[1], Raed Obaid SALEH[2], Gunawan WIDJAJA[3,4], Tzu-Chia CHEN[5*], Ghulam YASIN[6], Lakshmi THANGAVELU[7], Usama Salim ALTIMARI[8], Supat Chupradit[9], Mustafa Mohammed KADHIM[10,11,12], Haydar Abdulameer MARHOON[13,14]

Abstract

Aiming at the problem that it is difficult to achieve rapid and accurate detection of pesticide residues, the artificial neural network method is used to separate the mixed fluorescence spectra in the measurement of acetamiprid pesticide residues, and a fluorescence spectrum that can quickly detect the pesticide residues of acetamiprid on solid surfaces is designed. According to the back-propagation algorithm, the three-layer artificial neural network principle is used to detect the acetamiprid residue in the mixed system of acetamiprid and filter paper with severely overlapping fluorescence spectra. In the range of 340nm~400nm, using the fluorescence intensity values at 20 characteristic wavelengths as the characteristic network parameters, after network training and testing, the recovery rates of acetamiprid concentrations of 40mg/kg and 90mg/kg are 102% and 97%, respectively. The relative standard deviations of the determination results were 1.4% and 1.9%, respectively. The experimental results show that the BP neural network-assisted fluorescence spectroscopy method for the determination of acetamiprid pesticide residues on filter paper has the characteristics of fast network training, short detection period, and high measurement accuracy.

Keywords: pesticide; food safety; artificial neural network; fluorescence spectra.

Practical Application: In this paper, it was aimed to review the material analysis of food safety based on fluorescence spectrum combined with artificial neural network technology.

1 Introduction

The most important quality feature is to ensure the health of the food. The goal of government agencies and food industries (FIs) is to produce healthy and safe food and provide adequate and desirable food security in the community (Thomas et al., 2019; Truman et al., 2020; Xiong et al., 2019; Molajou et al., 2021a). The issue of healthy food production is overshadowed by quality control and quality assurance. Therefore, food production requires a hygienic design of equipment and factory and requires management commitment to the two categories of safety and quality. Currently, food safety and security issues are related to microbial risk assessment and the design of food safety objectives. These two are the duties of government agencies, which ultimately determine the allowable number of pathogens in food, which itself affects food safety and health, and hygiene of food (Augustin & Guillier, 2018; Dogan et al., 2019; Tesson et al., 2020). Food risk management in global trade includes risk assessment, setting food safety goals, achievable food safety goals, setting microbiological criteria, and determining food acceptance practices at the point of entry. Hazard analysis at the critical control point (HACCP) is a logical and uniform control system to prevent problems. In conclusion, it can be said that the correct application of increasing knowledge in the field of food microbiology can significantly contribute to food safety and health and therefore play an essential role in the overall quality of human life and comprehensive food security in society.

The Hazard Analysis Critical Control Point (HACCP) is a new international food standard that is currently being implemented worldwide on food quality and hygiene (Bauman,

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[1] Department of Nutrition, Faculty of Public Health, Universitas Airlangga, Surabaya, Indonesia
[2] Department of Pharmacy, Al-Maarif University College, Al-Anbar, Iraq
[3] Postgraduate Study, Universitas Krisnadwipayana, Bekasi, Indonesia
[4] Faculty of Public Health, Universitas Indonesia, Depok, Indonesia
[5] Department of Industrial Engineering and Management, Ming Chi University of Technology, New Taipei City, Taiwan
[6] Department of Botany, Bahauddin Zakariya University, Multan, Pakistan
[7] Saveetha Institute of Medical and Technical Science, Saveetha University, Chennai, India
[8] Al-Nisour University College, Baghdad, Iraq
[9] Department of Occupational Therapy, Faculty of Associated Medical Sciences, Chiang Mai University, Chiang Mai, Thailand
[10] Department of Dentistry, Kut University College, Kut, Wasit, Iraq
[11] College of Technical engineering, The Islamic University, Najaf, Iraq
[12] Department of Pharmacy, Osol Aldeen University College, Baghdad, Iraq
[13] Information and Communication Technology Research Group, Scientific Research Center, Al-Ayen University, Thi-Qar, Iraq
[14] College of Computer Sciences and Information Technology, University of Kerbala, Karbala, Iraq
*Corresponding author: tzuchiachen1689@gmail.com

2018; Chen et al., 2019; Guzewich, 2018; Kuo & Hsiao, 2020; Putri et al., 2019; Zeb et al., 2020). HACCP certification is defined in the discussion of international food standards. Obtaining this certificate is necessary to continue operating in the food production and processing industry so that now the major exporters of products such as saffron, pasta, and the country's fisheries industry for commercial transactions with other countries have obtained this certificate. What is certain is that implementing this law among countries is to pay attention to personal health and ensure food security and public health. The purpose of the HACCP certification is to closely monitor the hygienic production of a food item from the beginning of the production chain to the end. So that, in the end, a healthy product, free of pathogenic microbes and with the desired quality, reaches the consumer. For this purpose, the influence of biological, physical, and chemical factors that may affect the production process should be avoided. For this purpose, seven principles have been set by observing which the manufacturer succeeds in obtaining this international certificate, which is mentioned in the next section (Cano et al., 2018; Dara, 2019). The establishment of HACCP, in addition to increasing safety and food security, has other significant benefits. The application of this system facilitates the possibility of monitoring and inspection of government agencies and leads to the growth of international trade as a result of increasing food safety assurance and food security for consumers.

1.1 The seven principles of the HACCP program

In order to be HACCP certified, it is essential to follow the seven principles set by the World Health Organization. Depending on the conditions and facilities, the manufacturer will be able to obtain this certificate by changing the production system, closely monitoring the performance of subsidiary units, and harmonizing the production program with international standards. In order to achieve proper food security in the discussion of food, it is very important to observe these principles, and not to use them is critical (Cano et al., 2018; Dara, 2019). These principles are as follows:

- *Risk Determination Analysis:* This principle is the analysis of hazards that may affect the final product at the production stage. Therefore, various hazards should be identified in the first step, including biological, physical, and chemical hazards;
- *Identify critical control points:* Identifying crisis control points is the next step. This means that after recognizing the potential risks, it is necessary to identify the ways through which the risks are likely to enter the production cycle and take the necessary measures to prevent their entry;
- *Determining the critical limit and limits:* Determining the limits of the crisis, i.e., the limit beyond which causes a crisis. For example, some microorganisms that are naturally present in the environment may be at risk if their levels exceed a certain level. Some microorganisms have a very low crisis level;
- *Determining monitoring methods:* Supervision Managers of production departments should have accurate and continuous control and monitoring in the work process to ensure compliance with the limits of the crisis;
- *Carrying out corrective operations:* Following the monitoring performed, it is possible to observe weaknesses in some stages that indicate that the existing conditions do not comply with the set critical limits. In this case, the necessary measures should be taken to identify the cause and then correct the weaknesses;
- *Determining methods for verifying the effectiveness of the HACCP system:* All work steps must be accurately recorded and records kept in an archive. Registering and maintaining documents in later stages helps to identify weaknesses and eliminate them;
- *Document the above principles and their application:* This step is to perform various tests to evaluate the performance of the system, which auditors of different companies usually do.

Implementing these principles requires careful planning, time and money, consultation with experienced experts, and proper management. Otherwise, the unit in question will not be able to implement all the principles. After the establishment of the mentioned programs, experts and auditors in private companies affiliated with the World Trade Organization visit the unit to evaluate the system and evaluate the correctness of the performance by performing the necessary tests. After these steps, the HACCP certificate is issued to the relevant unit.

1.2 HACCP and food security

There are various sources that reduce the quality of food and agricultural products needed by consumers, which the use of the HACCP system plays a very effective role in organizing production, increasing safety, and providing comprehensive sustainable food security. There are many factors underlying the provision of food security in the society, which, if used in the mentioned system, due to its wide range, is important in establishing this important (Balan et al., 2020; Singh et al., 2018). Food safety policy, optimal operations and production, proper management, commitment and involvement of senior management in food safety, proper policy implementation, training of workers involved in the production, comprehensive health control, and many other important parameters are determining factors. In order to implement national and international standards for microbiological, chemical, and physical hazards in food, it is necessary to believe in the principle that there is always a risk factor for contamination of raw materials. Preventing the growth of microorganisms by applying special and safe conditions and using isolated equipment to produce food products plays a key role in this regard (Granato et al., 2020; Stavropoulou & Bezirtzoglou, 2019). Legal authorities and government agencies have a responsibility to protect society from unhealthy foods, so they must be able to assess the dangers of food and develop ways to control it. Risk assessment in the HACCP system is the scientific part of a system known as risk analysis. This assessment should provide an estimate of the likelihood and severity of adverse effects resulting from human exposure to food hazards, known as risk assessment.

Risk assessment is an estimate of the probability of consuming a risk factor. This is done by using the information available in the field of alcohol consumption, i.e., the amount of consumption of a particular food by different people, and taking into account changes due to factors such as age, economic and social conditions, religion, etc. The number of microbial hazards present in food at the time of consumption should be estimated, information that can be obtained from the inspection and application of predictive models that show the growth and survival status of organisms in the conditions of possible storage and processing before consumption (Baksh et al., 2018; Gerba, 2019; Saint-Jacques et al., 2018; Suter, 2020).

In summary, the HACCP standard applies to all stages of the food chain (such as raw material preparation, food preparation, processing, production, packaging, storage, and transportation). HACCP is integrated with other quality management system standards. Within this framework, quality management system (ISO 9001), good production practices (GMP), good laboratory methods (GMP), good health practices (GHP), occupational health and safety (OHSAS), and environmental management system (ISO) 14001) Systems. The concept of risk in the HACCP system includes physical, chemical, and biological factors that are at risk of harm to human health. Food safety means that foods that are prepared and consumed in accordance with the intended purposes do not harm human health. When food is harmful to human health due to physical, chemical, or biological factors in it, it is called food safety hazards. Major risks to food security include:

- Microbiological hazards are conditions in which the food consumed disrupts the digestive system of consumers;
- Physical dangers are the occurrence of foreign substances in the food consumed;
- Chemical hazards occur when consuming food with detergents, diesel oil, or foreign odors.

Occupations are required to conduct risk analysis studies to determine the following situations:

- What hazards should be controlled?
- What level of control should be in place to ensure food safety?
- What control measures should be taken?

Depending on the type of business activity, the type of food, and the method of preparation, any food safety hazards that may arise must be identified and recorded. When defining hazards according to the HACCP standard, the following should be considered:

- Steps before and after each process;
- Equipment, utilities, services, and environmental factors used in the processes;
- Previous and next links on the food chain.

2 Material and Methods

Fluorescence is a property of luminescence that occurs in gaseous, liquid, or solid chemical systems. Fluorescence is caused by the absorption of photons in the ground state and reaching the excited state (Bu et al., 2013; Liang et al., 2013). Unlike phosphorescence, in this case, the electron spin is still paired with the ground-state electron. When the excited molecule returns to its ground state, it emits photons with lower energy and longer wavelengths. The most obvious example of fluorescence is when the absorbed radiation is in the ultraviolet range and is invisible to humans while the emitted light is in the visible spectrum. In this case, if the fluorescent material is exposed to a UV lamp, it will get a very clear color. Unlike phosphorescent materials, fluorescent materials lose their luminosity as soon as the radiation source is stopped. Fluorescence has many practical applications in mineralogy, "gemology," medicine, fluorescence spectroscopy, identification of biological molecules, and so on. Daily applications of fluorescence include its use in fluorescent and LED lamps. These lamps use a fluorescent coating that converts short wavelengths of ultraviolet or blue light into longer wavelengths of yellow to have the same color and effect as incandescent bulbs. This property is also found in nature (Ishizawa et al., 2009; Themelis et al., 2009).

Fluorescence is associated with the release of energy (see Equations 1 and 2). As can be seen in Figure 1, this phenomenon occurs when an electron from a molecule, atom, or nanostructure returns to its ground state and releases a photon from an excited "single state" (Lodahl et al., 2015).

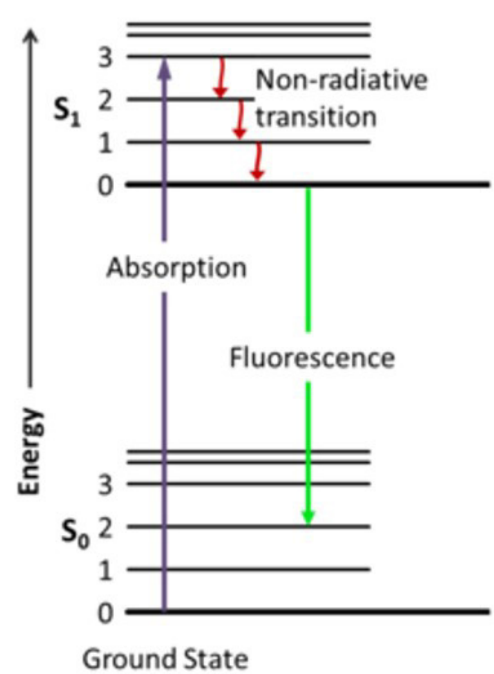

Figure 1. Jablonski diagram.

Arousal: $S_0 + h\nu_{ex} \rightarrow S_1$ (1)

Fluorescence radiation: $S_1 \rightarrow S_0 + h\nu_{em} + heat$ (2)

Fluorescent bands have a wavelength longer than the resonance line. This shift to a longer wavelength is called a "Stokes Shift." Aroused states have a short lifespan of about 1E-8 seconds. Molecular structure and chemical environment affect the property of light. In fact, these two factors determine the intensity of radiation.

The image above shows the Jablonski energy diagram in fluorescence. The purple arrow indicates the absorption of light. The green arrow also indicates "Vibrational Relaxation." This type of comfort is not in the form of radiation because the excitation energy is propagated in the form of vibration or heat, and no photons are emitted.

The quality, safety, and accuracy of food are very important. The ability to accurately detect these is an important consideration in the FI. One way to measure food quality is to use fluorescence spectroscopy. According to Medical News, fluorescence spectroscopy is one of the safest methods that can detect in the shortest time and with high accuracy (Coleman et al., 2005; Hanlon et al., 2000; Millet et al., 2003). In this method, a light beam (mostly ultraviolet) is used to excite the electron, which in turn emits light. This light is then directed to the filter, and after detection, molecular changes and their location can be detected and measured. The fluorescence excitation spectrum makes this measurement. For a given fluorophore, the wavelengths of the excitation and the radiation of the image are reflected. The spectral density or peak of the fluorophore wavelength depends on variables such as concentration intensity, interaction with other molecules, pH, and temperature. Many organic molecules, such as amino acids and fluorescent proteins, and chlorophylls, emit light and are detected by spectroscopy. There are two types of spectroscopy tools; Fluorometer filter, which uses one filter to separate the sub-lights, and the other spectrophotometer, which uses a single diffraction gauge. The sources of secondary light used are LEDs, lamps, and lasers (Karoui & Blecker, 2011; Lakowicz, 2013; Mayer et al., 1999).

Quality assessment is one of the most important aspects of the FI. The nutritional value, chemical and physical properties of food are examples that should be measured in the FI. The quality of perishable foods such as meat, eggs, dairy, and fish is very important because of their importance in the diet. Also, storage methods and additives in non-perishable and long-lasting foods such as canned foods, pickles, and food can be studied in this area. Fluorescence spectroscopy is also used as a diagnostic tool in many other industries such as the chemical and pharmaceutical industries, mining, and water and wastewater.

Today, using Learning Machine due to many advantages such as simplicity, high speed, high accuracy in predicting various processes, no need for complex equipment and tools, and the availability of many applications in various sciences and fields such as statistics, mathematics, physics, chemistry, biochemistry, materials engineering, medical engineering, pharmacy, etc. Therefore, in the present era, the study and study of various methods and algorithms of machine learning is very important (Mayer et al., 1999; Sun & Scanlon, 2019; Wang et al., 2014; Wuest et al., 2016). As a subset of artificial intelligence, machine learning algorithms create mathematical models based on sample data or instructional data for unpredictable prediction or decision making. One of the most interesting topics that can be focused on with artificial intelligence is predicting and estimating future events. Machine learning provides machines with the ability to learn independently. In other words, the machine can learn from experiences, observations, and patterns that it analyzes based on a set of data. Nowadays, machine learning has many applications in decomposition chemistry and from modeling data from various decomposition methods such as spectroscopy, fluorescence, voltammetry, emission spectroscopy, solid-phase microextraction, liquid swan, gas swarm, infrared spectroscopy, etc. for modeling, forecasting, and data classification is used. Machine learning is also widely used in the synthesis, optimization of parameters, and control of the properties of polymers. Built models are very accurate.

The Neural Network is the innermost layer of the amazing science of Artificial Intelligence. The science that makes our world today so different from decades ago and technology owe much of its progress to it (Bornstein, 2016; Kardan & Stanley, 2017; Sejnowski, 2020). By simplifying human life in various fields such as medicine, economics, engineering, and so on, neural networks have made many differences from the way of life decades ago. The neural network is the foundation of the science of deep learning, and deep learning itself is the basis of machine learning. Together, these concepts form the science of artificial intelligence (Figure 2). The general goal is to give a set of information to a machine or computer in a way that is understandable to him, and he can use it for human purposes. The neural network concept is like trying to teach a child how to distinguish the shape of a circle from different shapes. We show him several pictures of circles in different sizes and colors. After a while, he learns what a circle is and can distinguish circles from all the images shown to him. This is exactly what we do with neural networks to train a machine; Training the machine will eventually give rise to artificial intelligence.

Neural networks are a collection of neurons that follow unique algorithms (Nourani et al., 2019, 2020; Molajou et al., 2021b). This collection, modeled and inspired by the human brain, is designed and used to identify patterns. In general, it can be said that neural networks include machine learning algorithms, which lead to the classification of input data and the provision of optimal output (Abraham, 2005; Ciaburro & Venkateswaran, 2017). This is why neural networks can be considered as part of the machine learning process (Sharghi et al., 2018, 2019). Neural networks receive data and analyze it in their hidden layers to finally provide an output (Figure 3). This data can be a group of images, sounds, text, etc., that a machine must translate and understand. With the help of neural networks, we classify information; Different information can be grouped based on the similarity of a specific example. They can even provide and categorize the features and data needed to feed another algorithm.

The multilayer perceptron is the simplest model of neural network available, which is called MLP for short. This neural

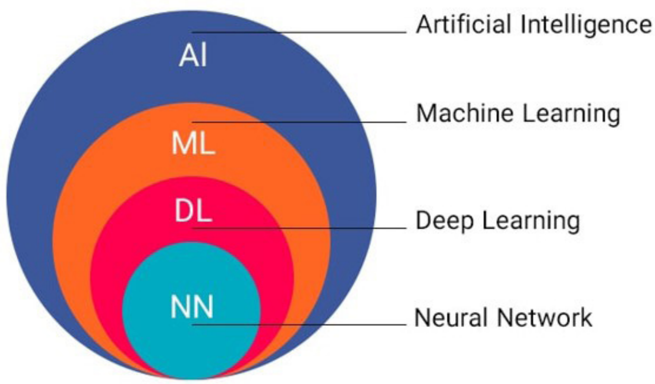

Figure 2. Comparison of artificial intelligence, machine learning, deep learning, and neural network.

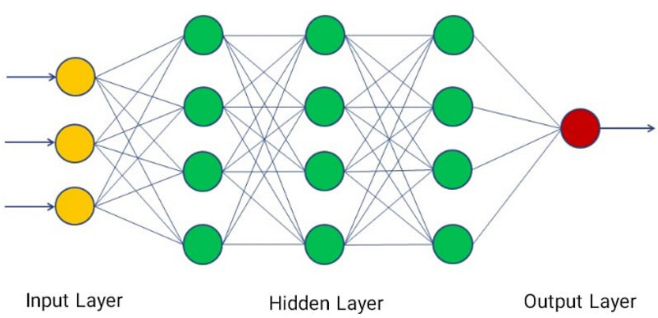

Figure 3. A simple diagram of neural networks.

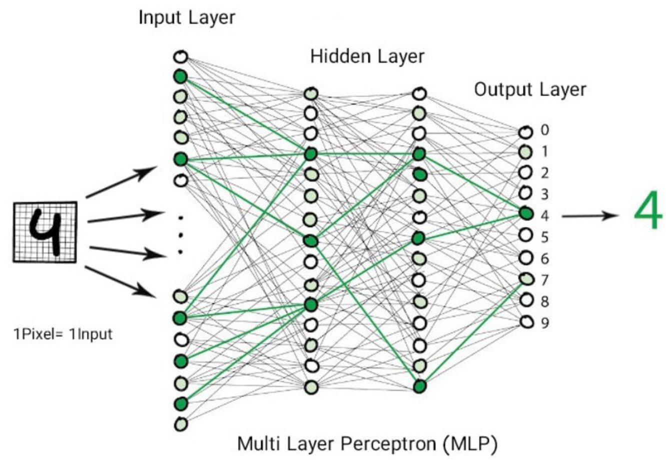

Figure 4. MLP neural network.

network functions like how information is transmitted in the human brain. Because this type of neural network is inspired by the behavior of the layers of the human brain network and the method of signal propagation, it is also called Feed Forward Neural Networks. In this method, each neuron or nerve cell, after receiving data, processes it and transfers it to another cell (Noriega, 2005; Parlos et al., 1994). As mentioned earlier, this process continues until you get the desired result, which leads to an action (Figure 4).

3 Results and Discussion

Over the past decade, due to the non-mixed, fast and sensitive nature of fluorescence in the FI, it has been used in spectroscopy programs to analyze food quality, due to the full use of chemical tools and improvements in simplification equipment technical and optical aspects. It is obvious that the food quality is one of the vital aspects of the FI. Food The cerebral, physical and chemical aspects of food must be measured and understood by calculating the quality that helps consumers choose an online store. The quality of perishable foods (fish, dairy, eggs, meat, etc.) is especially important for the FI. This food is considered part of the nutrients for a healthy diet, and it provides essential oils an vital minerals and vitamins that help the brain and body function healthily (Motta et al., 2014).

Fresh food has a limit and is affected by restriction chains and storage processes, which means that careful analysis results in freshness, safety, and profitability. Microbes can also eat spoiled food, causing harmful diseases such as Salmonella and Listeria. Additives and storage methods for perishable foods and long shelf life (e.g., canned, pickled, and dried foods) can also be evaluated for quality using assay techniques. The use of fluorescence in the FI has helped to improve the overall standard of food. Studies have also helped to improve food storage practices and reduce harmful chemical and microbial fraud. Can fluorescence spectroscopy be used to analyze food raw materials? A healthy diet and food safety that our consumption helps our overall standard of living. The FI needs a wide range of analytical techniques to ensure this. Fluorescence spectroscopy is only one part of this toolkit, as it is another feature of the industry. Moving into the future, fluorescence spectroscopy will undoubtedly play an important role in this regard. Using new and complementary technologies such as neural networks, fluorescence spectroscopy has continued to play an important role in ensuring the highest standard of high-quality food, which is another aspect of fluorescence in the FI.

The classification module consists of modules:

- Neural network training;
- Classifications using a neural network;
- Data.

As a means of classification, the neural network was chosen as the most common and due to a large number of available models for the classification of signals, images, etc.

As mentioned above, we will use a neural network as a means of spectrum classification. The main problem with using neural networks is the relatively low speed since tasks related to neural networks are usually resource-intensive. After all, the choice is optimal neural network model is usually associated with a large number of experiments, the results of which allow us to judge the quality of a particular model. Especially time-consuming requires a neural network learning process, the need to accelerate, which is very high. Given these problems, the most optimal type for design is an MLP (multilayer perceptron)

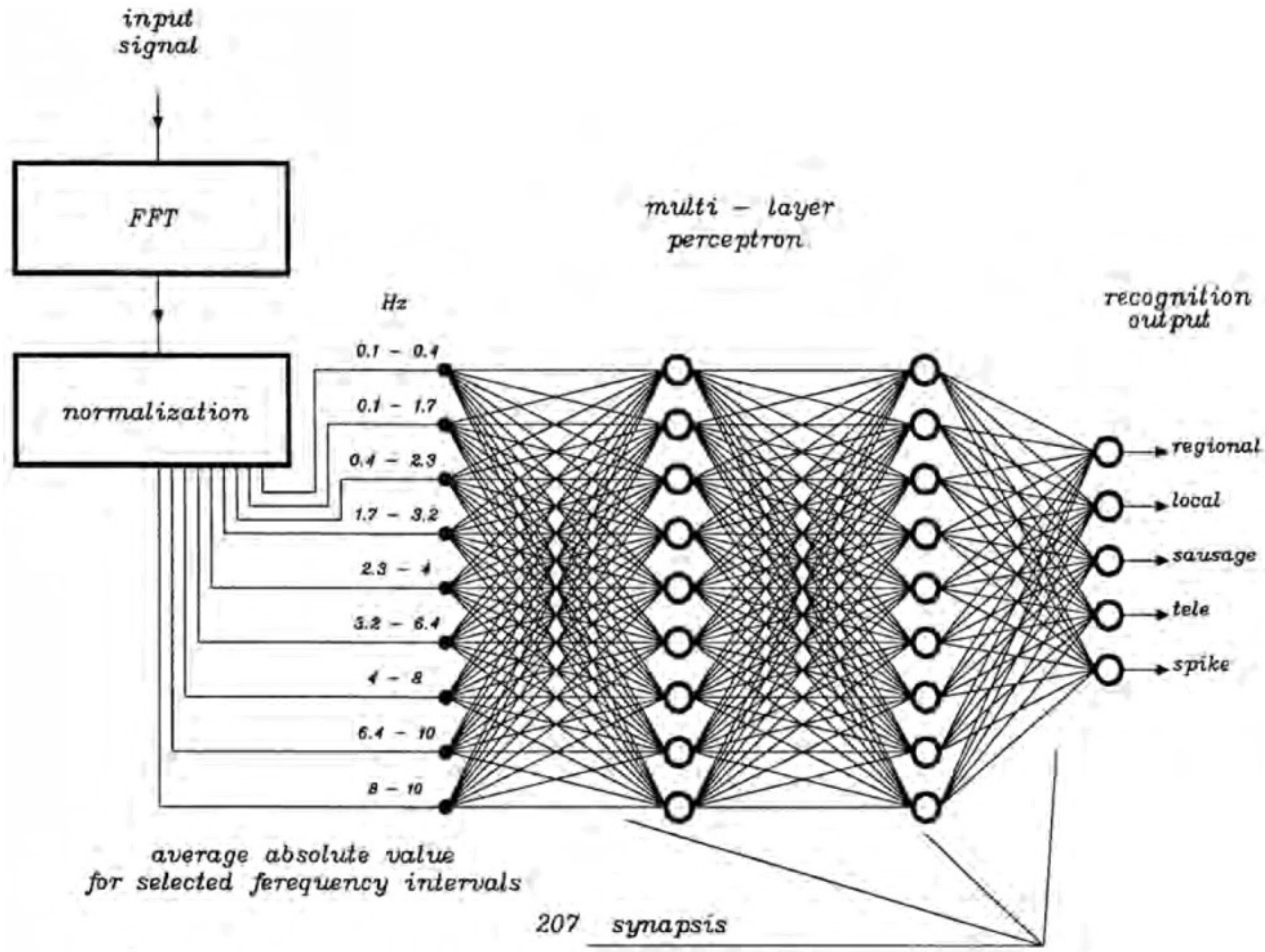

Figure 5. Neural network for classification of seismic events.

because this type of neural network uses the algorithm of inverse propagation of an error, provides two passes on all layers of a network: direct and reverse (e.g., Figure 5). Also, this type has the optimal method of learning - the algorithm of inverse error propagation. The advantages of this method of training are the locality of the method of changes in synaptic weights and thresholds in multilayer perceptron; efficiency of the method of calculation of all partial derivative functions cost according to free parameters (Zeron & Serrano Junior, 2019).

4 Conclusion

Food safety is one of the major challenges of countries in underdeveloped countries and developed and developing countries. To measure food safety, international organizations such as the FAO, the World Bank, the World Labour Organization, and the World Health Organization have provided different definitions that have been completed over time, from one-dimensional perceptions of supply to more comprehensive forms absorption capacity and food distribution. Its health and nutritional effects are enhanced.

Today, different parsing data and algorithms are used to model different problems. The data obtained from analytical methods such as infrared spectroscopy, spectroscopy, fluorescence, voltammetry, plasma emission spectroscopy, solid-phase microextraction, etc., are pre-processed and, after preparation, are modeled by various machine learning algorithms. The models obtained in this way have high accuracy. Modeling has many benefits and saves time and money, high accuracy, high speed, good repeatability. Doing some complex tasks requires huge and very expensive equipment that can be overcome by modeling and simulation.

An artificial neural network (ANN) is a smart information processing system that models the structure and function of the brain using physics. It is appropriate for the detection and analysis of mixed systems with acetamiprid and filter paper and features adaptive learning and automatic simulation functions, as well as excellent fault tolerance and prediction accuracy. The results show that BP neural network-based fluorescence spectrum analysis is effective for measuring complex multicomponent systems by integrating detection methods and results in this study. The ability to use the BP network for quick non-destructive detection of pesticide residues has been demonstrated in practice.

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