A Qualitative Analysis of the Machine Learning Methods in Food Adultery: A Focus on Milk Adulteration Detection

V. Surya, Assistant Professor, Department of Computer Science and Engineering, SRM Institute of Science and Technology, Chennai. E-mail: suryav@srmist.edu.in

A. Senthilselvi, Associate Professor, Department of Computer Science and Engineering, SRM Institute of Science and Technology, Chennai. E-mail: senthila3@srmist.edu.in

Abstract--- Food adultery is the process where the quality is compromised by adding certain chemicals or other substitutions which when consumed causes health hazards. The process includes not only the purposeful addition of additives but also the contamination occurring in growing stage, storage and when distributed. Adulteration has become a big business. We belong to a land where our ancestors taught that "food is medicine". Milk is one of the important foods consumed irrespective of age that ranges from infants till old people. On the contrast, in recent business era, milk is getting adulterated in more complicated ways that bypass the normal tests and hence there is a huge demand for a cutting-edge technology for detecting the same. Application of Artificial Intelligence has emerged in many diverse fields not limiting to identification of food adulteration. This paper gives a gist of most important and significant researches that are carried on in the detection of adulterated food, particularly milk using the techniques of machine learning. A special attention is kept on the Machine Learning techniques that are designed specifically to detect the milk adulteration.

Keywords--- Adulteration, Artificial Intelligence, Machine Learning, Contamination.

I. Introduction

Food is the basic need for humans. In this world of technology, humans are not able to get an organic and non-adulterant food. Adulteration is the process of adding a harmful substance to the authentic products which causes dangerous diseases to the human being. People should be aware of the adulterations done in regular food products. Adulteration is processed in dairy products, pepper, turmeric, meat, rice, flour, chili powder, nutmeg and other products. To improve business and to get more profit, adulteration has been carried out worldwide. High toxins, banned additives, chemicals and preservatives are added to good quality of food products, which results in death for human. Adulteration is done to increase the quantity and expiry date of the product which can even cause death to human on regular consumption. Government need to create awareness by conducting awareness programs starting from schools, colleges and public places etc. Stringent actions to be taken on the people and industries that carry out such malpractices. Authentic foods should be healthier natural and 100% harmless to the future generation at least.

Adulteration is a growing food safety concern worldwide. It is the act of degrading food quality by incidental or intentional means through the addition of chemicals, extraneous matter, etc. In a country like India where there is a huge population to feed and there is lack of monitoring of what reaches the consumer, the act of adulteration isn't quite surprising. Items of daily consumption like grains and milk, etc are found to be adulterated much to our disregard. Food adulteration is done for the selfish interest of food vendors for monetary gains and not only compromises on the health of the consumer but also results in wastage of food which are discarded if found adulterated. The country which faces a gap in the supply and demand goes several steps back again due to this. Quite unknowingly, most of the times, the food vendors indulge into such malpractices with callous disregard to the health interests of the consumer by all possible means. Food safety is an aim to bring safe and nutritious food to the plate of the consumer. Hence the prime objective of food is not sufficed due to the menace created by food adulteration.

The adulteration of milk and other dairy products have grabbed the attention globally after the identification of melamine particles in milk in Chinese products in the year 2018 [1]. The practice of milk adultery is a very old scenario. The milk scandal that has been reported in the year 1850 made nearly 8000 infants to lose their lives in the city of New York. Milk is one of the chief and most used food item and has nutrients required for all ages of human. It is also a rich source of many essential minerals and proteins. Milk is subjected to adultery easily across the globe. The prime reasons behind this is the gap between supply and demand and high business motives. This also occurs

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due to the affordability of the customers to buy and lack of efficient mechanisms to detect the same [2]. Although the motive is economic, the impact the adultery costs lives [3]. The situation is unmanageable in most of the underdeveloped and developing countries owing to the lack of efficient mechanisms and proper laws to enforce strict action against the culprits. Adulteration of milk can be identified either using qualitative or quantitative mechanisms. The former uses various chemical reactions for the purpose and the latter identifies the nature of the adulterants. Milk adulteration detecting methods needs a swift from old manual methods to a highly accurate machine-based techniques [4].

Food Safety policies and tools has been generated and started adopting it in all over the world. On adopting the available tools, still many challenges been arising on various aspects such as accuracy of contamination prediction. The issue of food adulteration is a contemporary mechanism and it is as old as the food production techniques themselves.

Owing to the less accuracy and time complexity involved in the conventional methods of identifying the milk adultery, the modern scientific development is needed and since there are large variety and complex information available on this , many data mining technique in terms of supervised [5] and unsupervised model have been employed.

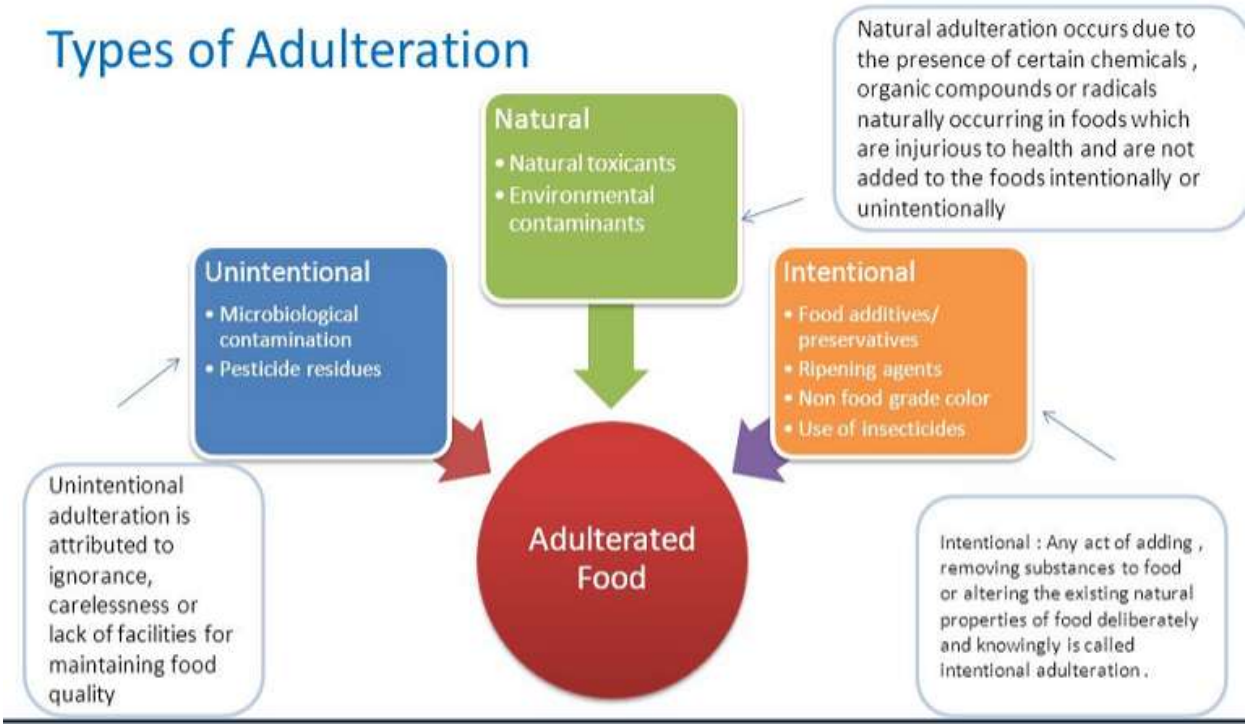

Fig. 1.1: Types of Food Adulterations

Those models focus on the microbiological or toxic chemical hazards. The ultimate goal to the study is to examine the data mining technique employed for food adulteration and contamination.

The remaining sections of the paper are organized as follows: Section 2 gives the preliminaries on the types of machine learning and section 3 gives the best research works carried out on each of them with the methods, advantages and the area for improvisation. Section 4 gives a comparative study on the results obtained through the methods adopted in the literature and the conclusion and future directions are projected in section5.Fig 1.1. shows the various types of food adulteration and its hazardous.

II. Preliminaries

2.1 Machine Learning

Machine Learning is the buzzword in the current digital era. The important reason behind this is the increase in data accumulation and a parallel increase in computational powers and hardware capacities. ML is almost used

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everywhere from automation till producing intelligent decisions in almost every domain [6].The ML methods have hit the floor in such a way that the users itself would have already using the devices without their understanding. ML techniques are the one which enables the system to learn from the Data and improve their performance themselves without being given explicit programming. ML is a category of algorithms which allows the application software to be more accurate in the process of outcome prediction without additional programming [7]. The basic intend of ML methods is to constitute algorithms which can get data as input and uses various statistical methods for predicting the output as and when new data are accumulated [26].

2.2 Types

Machine Learning algorithms are more generally classified as Supervised, Un-Supervised and re-inforcement learning [8]. In case of supervised methods, the system is given the data along with the labels which indicate that all the data are tagged correctly with the label. The motive is to make the mapping function appropriate such that when we have X as the input data, the output Y can be predicted. The important methods of supervised learning are i. Classification where the output variable is of any of the category such as "color", "shape" or simple YES or NO and the other methods being the regression models.

As the un-supervised learning is considered, the Artificial Intelligent systems here are presented with data that are not labelled and which are not categorized and the algorithms act upon the data without training. The output here is dependent on the algorithms which are pre-coded. Using un-supervised learning is a kind of testing the AI systems. The unsupervised learning are normally classified as i. clustering where the intention is to discover under which group a particular entity falls and ii.Association where the intention is to identify the rules which describes the large part of data such that "customer who bought X are likely to buy Y also" .

A reinforcement learning method is where the agent interacts with the environment for learning purpose. The agents here get the rewards if performing correctly and penalties if malfunctions. The agent here learns without the influence of the human for maximum rewards and minimum penalty [9]. This is also considered as a dynamic programming which trains the algorithms to use a system of rewards and penalties.

The commonly used methods are i. Q-Learning which is considered to be an off shore policy learning where the algorithm which seeks for identifying the best fit action to be performed if the current state is given. It is termed off shore because the systems' actions are outside the present policy such that random actions. ii. Deep learning where the ML techniques use multiple level of layers for progress through high level features from the input. For instance, in the image processing domain, the low level may identify edges and high levels identify the core concepts that are relevant to the humans such as digits or as letters. The figure 2.1 gives a generalized view on the classification of ML techniques.

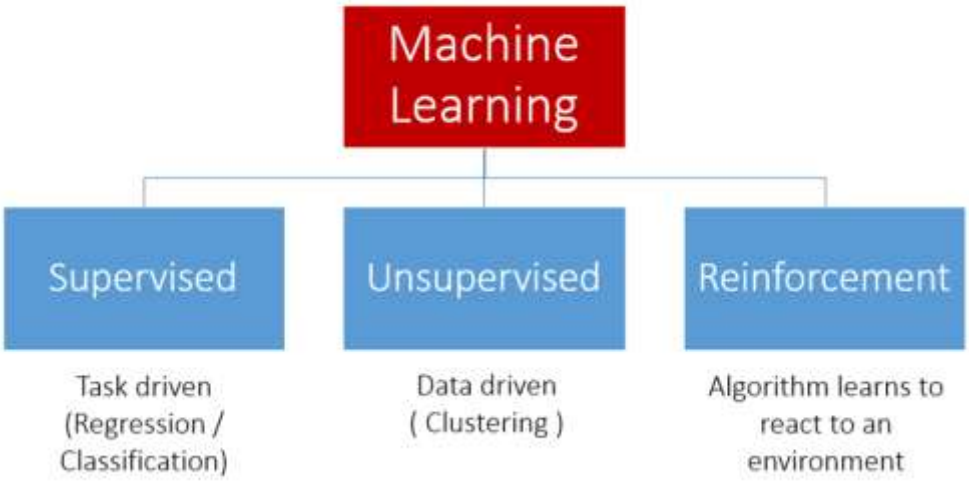

Fig. 2.1: Generic Classification of ML Methods

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III. Studies on Ml Methods in Food Adulteration

3.1 Review of Supervised Learning in Food Adulteration Detection

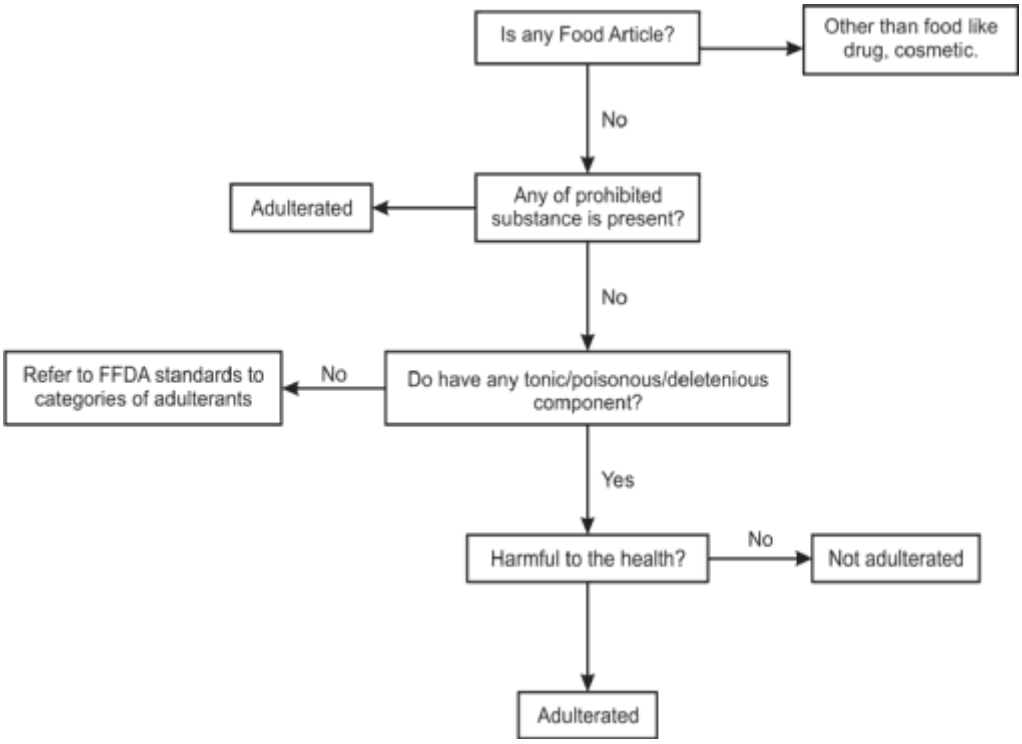

Fig. 2.2: Identification of Adulteration in Food

Wabben et al [10] proved that the concurrent use of both targeted and the un-targeted models which are applied to the FT-IR spectrum in identifying the milk adultery is efficient. By the use of appropriate methods, the detection limits, sensitivity and the specificity are identified. The proposed model used a multivariate linear regression model for the practical implication of the method. The theoretical limitations are also provided for a potential range of adulterants used. The performance metrics used here are the Precision, F score and Recall.

Zhang et al [11] proposed a series of samples of adulterer milk by adding different levels of aqueous dextrin. The improvised Support Vector Machines are used for the purpose of building the classification model for differentiating the milk that were adultered based on the NIR spectrum of various sample sets. Uniformity in the design of tables was made used. The results showed that the milks in which the adultered content is greater than 5 % are well detected by the proposed SVM combined with NIR based spectroscopy with very high validation ratio. The proposed methods outperformed other methods in terms of Specificity, Sensitivity and Correlation values.

Neto et al (2019) introduced the ML algorithms on milk spatial data. The proposed methods was able to find the most common adulteration methods that prevails in the dairy industry. Both classification and linear regression methods were used for the binary and also multiclass means of classification and the experimental results were compared. The proposed classification and regression methods was able to perform better that the FITR device and also the other traditional methods of the diary manufacturing. The performance measures included cosine value and the correlation.

Mahood et al (2017) developed a new Infrared based spectroscopy (NIR) which is combined with that of the multivariate linear regression for identify the level of formalin in cows' milk. The methods such as PCA and partial test regression (PCA) are applied for a statistical investigation of the NIR data, The PLS-NIR methods was used for checking the difference between the pure and adulterated milk. A regression model using PLS was built for quantifying the formalin levels in milk. The proposed method used Entropy, F Score, Precision and recall as the performance measures.

Rebechi et al (2016) Made a research to test for accuracy in the fatty acid for the detection of adulterants which replaced milk fat with that of animal fat and also proposed a regression model for the evaluation of these kind of

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adulterants. On every adulterant, the Multiple Linear model of regression (MLR) was implied by choosing a model and later it was validated. The matrix between the calibrations and validation are constructed by implementing a genuine mechanism to differentiate between pure and adultered milk. The proposed models were able to find the milk adulteration at levels which are greater than 10%. The proposed method was better in-terms of Specificity, Sensitivity and Entropy when compared to that of other techniques.

Table 3.1: Shows the Tabular Description of the Most Important Researches Carried Out Using Supervised ML Methods for Milk Adulteration Detection

Table 3.1: Review on Supervised Methods

Author(s)	Method	Advantages	Metrics
Wabben et al	FT-IR Spectra	Identification of Potential Adulterants	F score, Precision, Recall
Zhang et al	Improved v-support vector machines	Accuracy increase to 5%	Specificity and Sensitivity, Correlation
Neto et al	Principle component analysis (PCA)	Outperforms traditional FITR	Cosine similarity and correlation
Mahood et al	Partial least discriminant analysis	Identifies Formalin Adulterant	Entropy, F Score, Precision and recall
Rebechi et al	Multiple Linear Regression	Accuracy increase over 10%	Specificity, Sensitivity, Entropy

3.2 Review of Supervised Learning in Food Adulteration Detection

Roney et al (2015) investigated on the effect of Raman Microscopy and the ANN as a practical means of assessing the fluid milk by the addition of whey to it. The Quantitative findings of adulteration was done through the feed-forward ANN. various configurations of the Neural Networks were made and are evaluated based on their co-efficient. The proposed model observed that the data from both training and validation had a high value for Recall such as 99.9% which proved that the combined method of ANN and the Raman spectroscopy is very fast, simple and efficient method for the identification of quality milk from getting adulterated by whey. The model outperformed others in terms of Root mean square and Average area under curve.

Jiang et al (2019) made an attempt for developing an integrated mechanism that used least-square SVMs with NMR technique for the identification of the level of adulteration in milk powder. It is proved that the proposed model can better identify the adulterated milk. The experimental results prove that the proposed SVM-NMR can yield a very high and dense clusters with accuracy more than 98%. The proposed method used F Score, Precision and recall as their performance metrics.

Hsieh et al (2011) implemented the LS-SVM method for the calibration and also a prediction model to identify the adulteration is the cows' milk. The Grid based search technique was made used for arriving at a better value for Network parameters. The graph from results show that the adulteration ratio of above 10% is very well distinguished form the one which are pure. The proposed method uses F score, Precision and Recall as their performance metrics.

Kuswandi et al (2015) made use of the couple of datasets which was recorded using the FTIR means of Spectroscopy using the total attenuated reflection (ATR) based on spectrum data. The chemical analysis was made using the various modelling methods such as LDA, SMCA and SVM on the data. At last, the optimum results of the models into the data set on the analysis of milk adulteration was selected and the best fit model was compared with the famous ELISA method. The proposed method seemed more efficient than that of ELISA model in-terms of Specificity and Sensitivity and Correlation

Leonardi et al (2015) discussed on the ML method which aims for the definition in-order to assess the authenticity of some high valued milk powders. It was also demonstrated that the classification's effectiveness is very high in the proposed model in-terms of the ability to exploit features on the chemical profile of milk that are obtained from bio-chemical methods. The proposed method found to be more efficient when applied in real-time data and with synthetic data generated form a Bayesian generative model. Table 3.2 shows the gist of researches carried out using un-supervised learning for milk adultery identification with the metrics used.

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Table 3.2: Review on Unsupervised Methods

Author(s)	Method	Advantages	Metrics
Roney et al	Artificial neural network	Simple and efficient	Root mean square and Average area under curve
Jiang et al	Least-squares support vector machine	Accuracy is 98%	F score , Precision , Recall
Hsieh et al	Grid search SVM	Accuracy increases by 10%	Specificity and Sensitivity , Correlation
Kuswandi et al	Fourier Transform Infrared (FTIR)	Better than ELISA method	Cosine similarity and correlation
Leonardi et al	Bayesian network model	Identifies Chemical ingredients in better way	Entropy , F Score, Precision and recall

3.3 Review on Re-inforcement Learning for Food Adulteration

Lei-Hong et al (2019) provided a solution for automatic identification of common beetle species that frequently contaminates the milk products. The approach was based on the convolutional neural network which trained a dataset having 6900 images of various elytra fragments. The proposed methods acquired a accuracy level of 83% when cross validated. It is also to be noted that the performance of the classification is got without the need to design and select the images that are domain specific which depicts the deep learning importance in milk adultery. The proposed methods produced better results in terms of Root mean square and Average area under curve

Al-Sarayreh et al (2018) investigated on the accuracy of hyperspectral imaging for the authentication and to classify fresh samples of milk. These samples are acquired from goat, cow and buffalo milk. A 3-dimensional artificial neural network was proposed for the extraction of spectral features of the milk. A comparison was also made on the proposed methods with that of the existing methods including the least square discrimination methods and SVM methods. The results prove that the 3d-ANN performs better in terms of F score, Precision and Recall than other methods.

Jayanthi et al (2019) introduced a system which used histogram of the gradients along with the SVM classifier for the detection of fungus in milk. The features of the milk species are captured using real-time cameras and are extracted by the Gradients Algorithm. The features are then fed to the ensemble SVM classification algorithm which then compared with the trained and projects the quality of the samples. The proposed method is implemented using the ARM processor. Experimental results prove that the proposed methods produce very good results in terms of Specificity and Sensitivity.

Mahdi et al (2018) evaluated the portable system that is intelligent of identifying the adulteration in the milk using the machine based vision method. The evaluation was done on 13 samples of milk and the mixed ingredients. For the identification of adulteration, the ANNs were deployed and are evaluated using a hidden layer with the count of neurons starting from 1 till 20. The best fit network having the structure 12-6-7 is provided for the prediction of the samples with R as coefficient of correlation and MSE. The proposed methods are found to be effective in terms of Cosine similarity and correlation

Sana Jawaid et al (2017) introduced the SB-ATR based Fourier transformation as a tool to identify the adulteration in milk. This proposed method is specifically used to test the melanin content in milk. The PLS model were incorporated for identifying the correlation of the data spectrum to melanin concentration. Deep neural networks were deployed to classify the pure from impure milk. The proposed technique also tool very little time for the set up and running time. The performance metrics used here are Entropy, F Score, Precision and recall. Table 3.3 shows the gist of researches carried out using re-inforcement learning for milk adultery identification with the metrics used.

Table 3.3: Review on Re-Inforcement Learning

Author(s)	Method	Advantages	Metrics
Lei-Hong et al	Convolutional neural network	Cross Validated accuracy of 84%	Root mean square and Average area under curve
Al-Sarayreh et al	3D convolution neural network (CNN)	spectral-spatial learned features of milk are classified	F score, Precision, Recall
Jayanthi et al	SVM classifier	Real-time capture of fungus growth	Specificity and Sensitivity, Correlation
Mahdi et al (2018)	Artificial Neural Network (ANN)	More samples also yield good results	Cosine similarity and correlation
SanaJawaid et al	Partial least-squares (PLS) model	Very little time complexity	Entropy, F Score, Precision and recall

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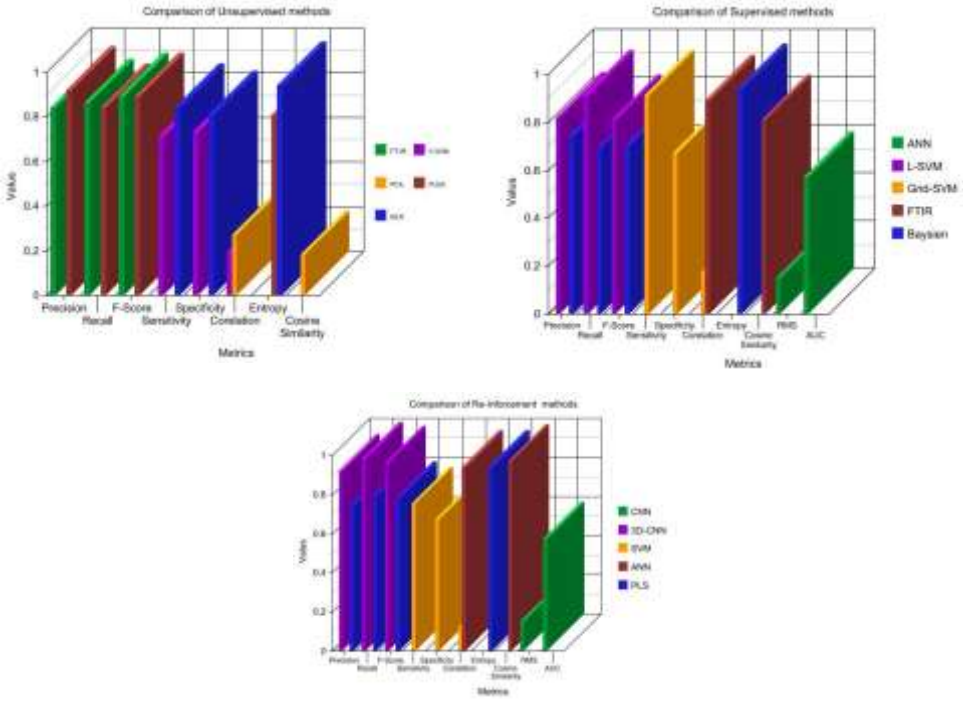
Table 3.4: India's Main Food sub-industry, The Total Adulteration Range in 2004 and 2014

Food Category	Total adulteration range in 2004	Ratio	Total export value in 2014	Ratio	Changes
Meat	706783794	5.15%	1182001960	3.07%	-40.41%
Diary products, Eggs and honey	234214380	1.71%	586072434	1.52%	-10.84%
Vegetables, roots and tubers	2537344845	18.50%	8226338283	21.37%	15.52%
Fruits and Nuts	916373781	6.68%	4318162508	11.22%	67.90%
Grains	740431899	5.40%	445421184	1.16%	-78.57%
Cereal or milk products	652821392	4.76%	1573199047	4.09%	-14.14%
Fruits, Vegetables, products	2578110984	18.80%	7634631424	19.83%	5.51%
Beverage, Wine And Vinegar	742997116	5.42%	1651194331	4.29%	-20.82%

Table 3.4 shows that India's main products for export include 16 meat, fish and aquatic animal products, 07 vegetables, roots and tubers and 20 fruits and vegetables products. The total export value of these three products accounts for 60% of the total export value of India's food industry. The analysis of the changes of each product's exports in 2004 and 2014 proves that the export value of 02 meat, 04 dairy products, eggs and honey, 10 grains, 19 cereal or milk products and 22 beverage, wine and vinegar has declined in 2004 and 2014, with the biggest drop of grains. On the contrary, the adulteration value of 07 vegetables, roots and tubers, 08 fruits and nuts, 09 coffee, tea and spices, 17 sugar and confectionery and 20 fruits and vegetables products has increased, and the rate of 17 sugar and confectionery is the highest.

IV. Comparative Analysis

The graphical representation shows the comparative analysis of the metrics tabulated in each section and which are obtained from the results of various methods. These graphs are self- explanatory and are intended to produce a visual comparative analysis. Figure 4.1 shows the graphical representation of the various results obtained through methods discussed in section 3.



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V. Conclusion

Food adultery is the process where the quality is compromised by adding certain chemicals or other substitutions which when consumed causes health hazards. The process includes not only the purposeful addition of additives but also the contamination occurring in growing stage, storage and when distributed. Milk is the most common food product being adulterated. Although many researches have been carried out in bringing out an accurate method for the detection of adulteration in milk, the usage of Machine Learning in the domain was very limited. This paper gives the gist of such few researches using the Machine Learning methods for the Milk adulteration detection. This gives an insight on the future researches that can be pursued to solve the burning issue of milk adulteration and to save humans from fatal diseases.

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