© April 2024 | IJIRT | Volume 10 Issue 11 | ISSN: 2349-6002

Milk Quality Prediction and Yogurt Fermentation Analysis Using Machine Learning

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Abstract— The dairy industry plays a vital role in the global economy, with milk and dairy products being essential for human nutrition. Ensuring the quality of milk and its products is paramount for both consumers and producers. This study presents a novel approach to enhance milk quality prediction and optimize yoghurt fermentation processes using advanced Machine Learning (ML) techniques. An integrated system was developed, incorporating sensors, data processing units, and ML models, enabling automatic adjustments to the fermentation process in response to real-time data inputs. This not only enhanced the quality of the yoghurt but also increased production efficiency and reduced wastage significantly. The findings of this research demonstrate the potential of Machine Learning in revolutionizing the dairy industry. By leveraging predictive analytics and real-time data analysis, this approach ensures higher milk quality and more efficient yoghurt fermentation processes. Implementing these techniques at scale could lead to substantial improvements in dairy product quality, cost-effectiveness, and overall sustainability in the dairy industry.

Index Terms- yogurt; Model-train; consumer preference; autoencoder; support vector Machine.

I. INTRODUCTION

Machine learning (ML) techniques have become a pivotal force in the food industry, particularly in the quest to uphold quality control and food safety standards. One of the significant applications in this domain is the correct differentiation between Milk and yogurt, both essential products in the dairy industry. Achieving this distinction is not just a matter of convenience; it is crucial for safeguarding product quality, preventing contamination, and ensuring authenticity in the dairy sector. To address this challenge and harness the potential of ML, a multi-faceted approach is adopted.[3]

The first step in creating an ML model for distinguishing between Milk and yogurt is the compilation of a comprehensive dataset. This dataset typically includes images, spectroscopic data, or chemical properties of both Milk and yogurt. Gathering a diverse range of data is essential to ensure the model's accuracy in various real-world scenarios. Once collected, this data undergoes rigorous pre-processing. This step involves noise removal, standardization of data formats, and the establishment of data consistency across the entire dataset.

With a clean and well-organized dataset at hand, various ML algorithms come into play. These include support vector machines (SVM), random forests, and deep learning models like Convolutional Neural Networks (CNNs).[2] These algorithms are then trained on the pre-processed dataset to develop a robust model capable of distinguishing between Milk and yogurt with high accuracy.

The motivation behind applying machine learning to predict Milk quality and perfect yogurt fermentation processes is far-reaching. It transcends merely separating the two dairy products. The core aims extend to enhancing the dairy industry's efficiency, ensuring product quality, and driving innovation in an ever-evolving landscape.[7] By using data-driven insights, machine learning opens the doors to more efficient, sustainable, and competitive practices in dairy production.

II. RELATED WORK

Currently, the prediction of Milk yield can help pasture managers coordinate production and transportation planning for a farm on time. The algorithm introduces the genetic algorithm (GA) into the long short-term memory (LSTM) algorithm structure, which considers the time sequence and correlations between the above input variables. The experiment proves that the GA-LSTM algorithm is more correct and stable than the traditional LSTM algorithm in predicting daily Milk yields.[1]

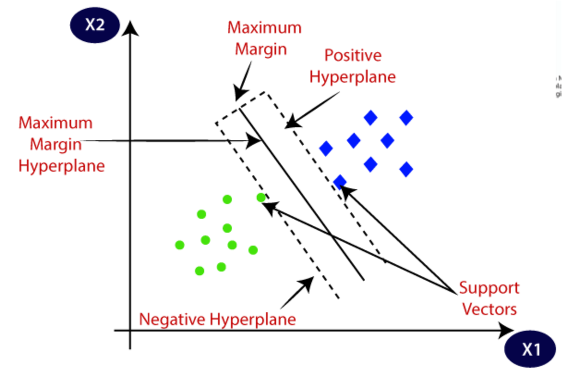
This paper presents the advanced control theory's original utilization to realize a system that controls the fermentation process in batch bioreactors. Proper fermentation control is essential for quality fermentation products and the economical operation of bioreactors. Batch bioreactors are extremely popular due to their simple construction. However, this simplicity presents limitations in implementing control systems that would ensure a controlled fermentation process. Batch bioreactors do not allow the inflow/outflow of substances during operation. Therefore, we have developed a control system based on a stirrer drive instead of material flow.[2]

Milk is a highly perishable product, whose quality degrades while moving downstream in an imperfect cold dairy supply chain. Existing literature adopts a reactive approach for evaluating and preventing Milk with a high microbial index from moving further downstream in a dairy supply chain. In this paper, we argue that such an approach is not the best response if the intention is to maximize Milk life in terms of quality. We propose an initiative-taking approach that checks the metrics of the temperature and the level that are the building blocks of microorganisms in Milk.[3] In this study, a novel deep learning method is proposed that uses an autoencoder to extract product features from the sensory attributes scored by experts, and the sensory features bought are regressed on consumer preferences with support vector machine analysis. Model performance analysis, hedonic contour mapping, and feature clustering were implemented to confirm the overall learning process. The results showed that the deep learning model can vouch for an acceptable level of accuracy, and the hedonic mapping reflected could supply immense help for producers' product design or modification.[5]

III. ALGORITHM

1. Milk Quality Prediction*:*

a. *Support Vector Machines (SVM):* SVM is a popular algorithm for binary classification tasks like distinguishing between Milk and yogurt. It can be used to predict Milk quality based on various parameters.[1]



Support Vector Machines (SVM) is a powerful supervised learning algorithm used for classification and regression tasks. It is also commonly employed in predictive analytics for various domains, including food science and dairy product analysis such as milk quality prediction and yogurt fermentation analysis. Here's how SVM can be applied to these tasks:

1. Milk Quality Prediction:

Feature Selection: For milk quality prediction, you would first need to gather relevant features that can influence milk quality. These could include factors like fat content, protein content, lactose content, somatic cell count, temperature, pH level, etc.

Data Preprocessing: Once you have collected the data, you would preprocess it by handling missing values, scaling features, and encoding categorical variables if any.

Training SVM Model: After preprocessing, you can train an SVM classifier using labelled data where the label could be the quality grade of the milk SVM tries to find the hyperplane that best separates different classes of milk quality in the feature space.

Model Evaluation: Evaluate the trained SVM model using techniques like cross-validation and metrics like accuracy, precision, recall, and F1-score to assess its performance.

2. Yogurt Fermentation Analysis:

Feature Engineering: Similar to milk quality prediction, you need to identify relevant features for yogurt fermentation analysis. These could include initial milk composition, starter culture type, fermentation temperature, fermentation time, pH level during fermentation, etc.

Data Preprocessing: Preprocess the data by handling missing values, scaling features, and encoding categorical variables.

Training SVM Model: Train an SVM regressor or classifier depending on the nature of the analysis you're conducting. If you're predicting the fermentation time or quality of yogurt, you might use regression. If you're classifying the success of fermentation (e.g., whether it's done or not), you would use classification. SVM will find the optimal hyperplane or decision boundary to predict the fermentation outcome based on the given features.

Model Evaluation: Evaluate the SVM model's performance using appropriate regression or classification metrics. For regression tasks, metrics like Mean Absolute Error (MAE), Mean Squared Error (MSE), and R-squared value can be used. For classification tasks, metrics like accuracy, precision, recall, and F1-score are common.

IV. METHODOLGY

Parameters in Quality of Milk & Yoghurt:
Determining the quality of milk involves assessing several factors such as freshness, purity, and nutritional content. Here's a guide on how to evaluate the quality of milk:

Colour and Texture: Fresh milk typically has a creamy white colour and smooth texture. If the milk appears discoloured or has an unusual texture, it may indicate spoilage.

Smell Test: Take a whiff of the milk. Fresh milk should have a clean, slightly sweet smell. If it smells sour, rancid, or off-putting, it's likely spoiled.

Taste: While this might not always be possible before purchase, if you have concerns about the quality of milk, you can taste a small amount. Fresh milk has a mild, slightly sweet taste. Spoiled milk will have a sour or unpleasant taste.

Fat Content: Depending on your preferences, you might want to consider the fat content of the milk. Whole milk contains more fat than skim or low-fat varieties. Make sure the fat content matches your dietary preferences.

Storage Conditions: Milk should be stored properly at the correct temperature (usually around 40°F or 4°C) to maintain its freshness. Check the temperature of the dairy case in the store to ensure proper storage.

The pH value of Milk is one important parameter when checking the **quality of milk**. E.g., the pH value of fresh milk should lie between 6.6 - 6.8. A higher pH value indicates a mastitis infection in the cow and a pH of below 6.5 indicates towards acidification of the sample.[2]

The pH value of Yoghurt is one important parameter when checking the **quality of Yoghurt** is between 4.0 and 4.4 are considered as necessary for flavour and texture in good-quality yogurts. The six yogurt samples tested in this study showed average pH values between 4.0 and 4.4, indicating that these yogurts are good quality.[4]

Yogurt culture is made up of *two bacteria, Streptococcus thermophilus and Lactobacillus delbrueckii subsp. Bulgaricus*

That are responsible for the yogurt's characteristic flavour during fermentation, protein and fat degradation. These bacteria are the only two required by law to be present in yogurt. Other bacterial cultures, such as Lactobacillus acidophilus, Lactobacillus subsp. casei, and Bifido-bacteria, may be added to yogurt as probiotic cultures. Probiotic cultures can improve lactose digestion, gastrointestinal function, and stimulate the immune system. The bacteria are mixed in and a warm temperature of 30–45 °C (86–113 °F) is maintained for 4 to 12 hours to allow fermentation to occur. Higher temperatures work faster but risk a lumpy texture or whey separation.

After getting information we can conclude that pH level, Temperature and colour are main parameters which directly affect on quality of milk so we can develop a model which gives accurate result on predicting the quality of milk so We use a database and trained model accordingly the above trained model is trained with SVM [1] with values of

	precision	recall	f1-score	support
0	0.97	0.84	0.90	166
1	0.86	0.98	0.91	167
accuracy			0.91	333
macro avg	0.91	0.91	0.91	333
weighted avg	0.91	0.91	0.91	333

Classification report for Milk model

After getting information we can conclude that pH level, Temperature and culture of yoghurt are main parameters which directly effect on quality of yoghurt so we can develop a model which gives accurate result on predicting the quality of yoghurt so We use a database and trained model accordingly the above trained model is trained with SVM [1] with values of

Classification Report :

	precision	recall	f1-score	support
0	0.64	0.75	0.69	160
1	0.72	0.61	0.66	173
accuracy			0.68	333
macro avg	0.68	0.68	0.68	333
weighted avg	0.68	0.68	0.67	333

Accuracy : 67.56756756756756
Accuracy: 67.57%

Classification report for Yoghurt model

V. SYSTEM ARCHIETECTURE

System Architecture for Machine Learning-Based Milk & Yogurt Fermentation detection

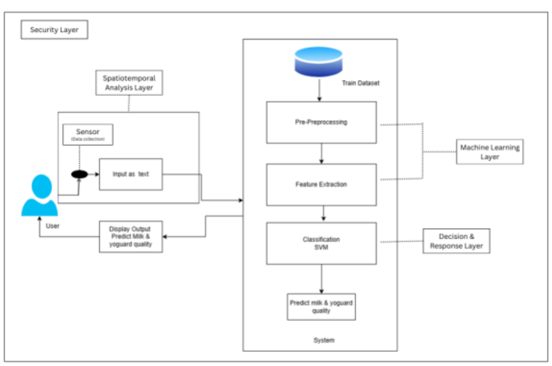


Figure 3: SYSTEM ARCHITECTURE DIAGRAM

Spatiotemporal Analysis Layer: A Spatiotemporal Analysis Layer is employed for structured analysis of Milk and Yogurt data, capturing spatial and temporal dependencies relevant to fermentation trends.[5] It consists of a Temporal Analysis Engine for analyzing time-series data and a Spatial Analysis Engine to examine geographical variations in fermentation prevalence.

Machine Learning Layer: *Training Module:* Uses historical data to train machine learning models like SVM, Decision Trees, and Random Forests. *Detection Module:* Applies trained models to real-time Milk data, detecting Milk and yogurt Fermentation risk factors in individuals. *Prediction Module:* Forecasts future Milk and yogurt Fermentation trends and risk patterns based on historical data and trends.

Decision & Response Layer: The Decision and response Layer assesses model predictions against quality standards and initiates quality control when subpar quality is detected. This involves real-time adjustments in both milk production and yogurt fermentation. The layer issues alerts establishes a feedback loop for continuous model improvement, and optimizes resource allocation. Data visualization aids informed decision-making, while adaptive control ensures product quality. Integration with process control systems automates adjustments, making it the bridge between data analysis and practical implementation, ensuring quality and efficiency.

Security Layer: Encryption: Implement robust data encryption protocols to secure all Milk & Yogurt data, whether in transit or at rest, ensuring the privacy of patient information.[7]. Authentication & Authorization: Employ security measures like multi-factor authentication and role-based access controls to ensure that only authorized personnel, including Milk and yogurt care providers and patients, have access to sensitive Milk and yogurt information within the system.

VI. METRICS /MATHEMATICAL MODEL

Accuracy = (TP + TN) / (TP + TN + FP + FN)
Precision = TP / (TP + FP)
Recall = TP / (TP + FN)
F1-Score = 2 * (Precision * Recall) / (Precision + Recall)
Mean Absolute Error (MAE):
MAE = Σ |Actual - Predicted| / Number of Instances
Mean Squared Error (MSE):
MSE = Σ (Actual - Predicted) ^2 / Number of Instances
Creating a mathematical model for Milk quality prediction and yogurt fermentation analysis using machine learning often involves the use of various algorithms and techniques.[1]

For Milk Quality Prediction:
1. Define a set of input parameters:
   - Fat Content (FC)
   - Protein Content (PC)
   - Bacterial Count (BC)
   - Temperature (T)
   - pH value (pH)
   - Colour of Milk (C)

2. Develop a regression model, such as SVM , to predict Milk Quality (MQ) based on these inputs:
   MQ = f (FC, PC, BC, T, pH, C)

For Yogurt Fermentation Analysis:
1. Define a set of input parameters:
   - Milk Quality (MQ)
   - Fermentation Time (FT)
   - Temperature (T)
   - pH level (pH)
   - Nature of Yoghurt (NY)

2. Utilize various techniques, such as SVM and statistical analysis, to model the fermentation process:
   Yogurt Quality (YQ) = g (MQ, FT, T, pH, NY)

VII. OUTPUT

We carried out some test on trained model of Milk as Well as Yoghurt and results of those are given below:

```
Mean Absolute Error: 0.09309309309309309
Mean Absolute % Error: 365156726543553.75
Mean Squared Error: 0.09309309309309309
Root Mean Squared Error: 0.3051116076013712
R Squared (R²): 0.7922274102385141
```

Figure 4: Values for Milk module

```
Mean Absolute Error: 0.32432432432432434
Mean Absolute % Error: 540972928212672.4
Mean Squared Error: 0.32432432432432434
Root Mean Squared Error: 0.5694947974514994
R Squared (R²): nan
```

Figure 5: Values for Yoghurt module

Based on the confusion matrix of the model, the above results were generated. It shows how many of the samples were predicted correctly,

```
Confusion matrix :

              | Positive Prediction      | Negative Prediction
--------------+-----------------------+---------------------
Positive Class | True Positive (TP) 139    | False Negative (FN) 27
--------------+-----------------------+---------------------
Negative Class | False Positive (FP) 4     | True Negative (TN) 163
```

Figure 6: Values for Milk module

```
Confusion matrix :

              | Positive Prediction      | Negative Prediction
--------------+-----------------------+---------------------
Positive Class | True Positive (TP) 120    | False Negative (FN) 40
--------------+-----------------------+---------------------
Negative Class | False Positive (FP) 68    | True Negative (TN) 105
```

Figure 7: Values for Yoghurt module

Result generated by module is given in terms of quality of milk is good or bad and for yoghurt quality it gives same as well as it will give some ideas about maintained of pH value and IDEAL pH and temperature of milk and yoghurt for good quality fermentation process and it will give such that,

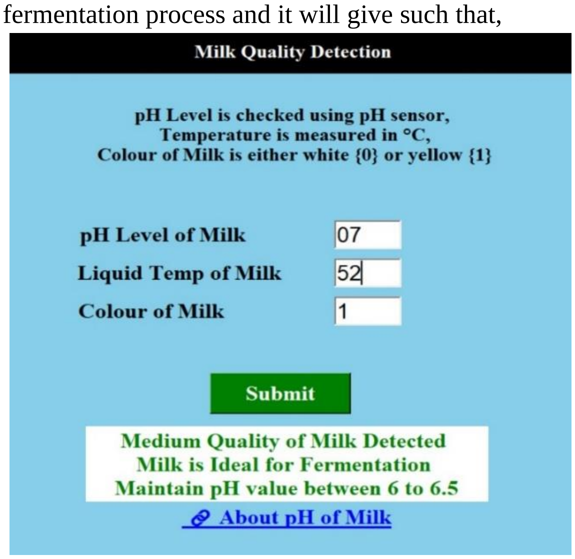


Figure 8: model Result for Milk

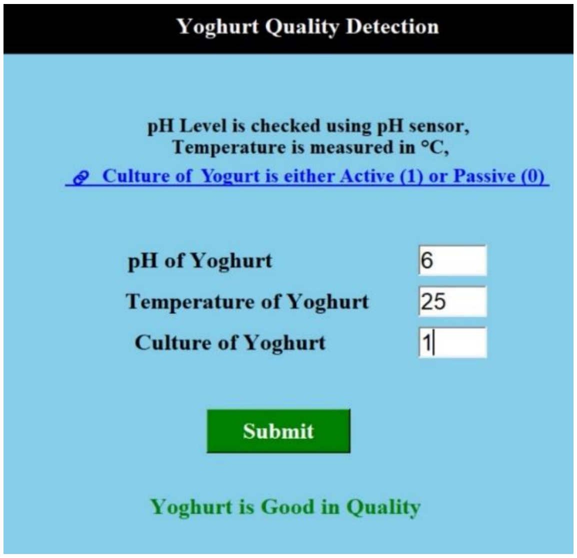


Figure 9: model Result for Yoghurt

CONCLUSION

In conclusion, applying machine learning in the dairy industry, specifically for milk and yogurt quality prediction and fermentation analysis, can enhance efficiency, product quality, and consumer safety. Accurately distinguishing between milk and yogurt is a key challenge that can be tackled with robust machine-learning models. Success in these aims requires a multidisciplinary approach, involving domain ability, data engineering, and advanced machine learning techniques. A diverse dataset, including images, spectroscopic data, and chemical properties, is crucial for correct model training. Data preprocessing is essential for noise removal and data standardization. Various machine learning algorithms, such as support vector machines, random forests, and deep learning models like Convolutional Neural Networks (CNNs), can be used to build these models. These systems can be implemented in real-time, at production lines, dairy farms, or retail settings, ensuring prompt action in cases of mislabelling or contamination, and keeping product authenticity and quality.

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