REVISTAMATÉRIA V.29 N.3
ISSN 1517-7076 articles e20240347, 2024

Evaluation and categorization of raw cassava log quality for structural applications

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ABSTRACT

Cassava used in various processing industries needs new tools and technology to ensure it's the final quality Cassava product based on the component exists in the raw root to make the final product competitive. Modifying industry currently uses the traditional wet chemical method for ingredient identification as per Indian Standard assessment system developed in 1978. It was expensive, take prolonged testing time, need skilful worker involvement and chance of toxic byproduct formation. This paper focuses on the pre-determined raw material quality feeding for suitable starch industry through raw Cassava categorization based on its active constituent presence to meet the final quality of modified Cassava starch by integrating Fourier Transform Infra-Red spectroscopy (FTIR) with Partial Least Square (PLS) algorithm. The classification of raw cassava logs based on its ingredient concentration (ash and moisture) implemented through Support Vector Machine algorithm according to the industrial standard requirements needed by the third party users for guaranteed final quality product from raw materials observation.

Keywords: Fourier Transform Infrared Red (FT-IR); Support Vector Machine (SVM); Partial Least Squares (PLS); Root Mean Square Error of Prediction (RMSEP); Relative Percent Difference (RPD).

1. INTRODUCTION

The inherent properties of native cassava starch, such as insolubility in cold water, susceptibility to thermal degradation, high adhesiveness, poor shear-stress resistance, and the presence of linamarase-releasing cyanide compounds, render it unsuitable for direct use [1]. The cyanide content in cassava poses a significant health risk for both humans and animals, necessitating careful processing to mitigate its effects. However, with the burgeoning global population, there is a growing demand for cassava starch, driving its utilization through various modification techniques, including physical, chemical, enzymatic, and genetic approaches [2].

In many developing countries, cassava serves as a vital source of nutrition, thriving in marginal soils and serving as both a subsistence food and a raw material for starch production [3]. The starch industry in countries like India is still in its nascent stage of development, despite the wide-ranging applications of starch across industries such as paper, textiles, pharmaceuticals, food processing, beverages, and animal feed [4].

Moreover, the cultivation of cassava as a drought-tolerant crop holds promise for regions facing water scarcity, offering a sustainable solution for food security and economic growth. As efforts to improve cassava processing techniques continue, there is a need to assess the quality of raw cassava logs systematically to ensure their suitability for various applications, including structural uses in civil engineering projects [5]. This necessitates comprehensive evaluations and classifications based on parameters such as purity, moisture content, starch content, and cyanide levels, thereby facilitating informed decision-making in the utilization of cassava resources [6].

Cassava root extracts serve a multitude of purposes across diverse industries, ranging from paper and textiles to pharmaceuticals and cosmetics. In the paper industry, they are utilized for achieving uniform

Corresponding Author: Madhan Mohan Murukesan Received on 13/06/2024 Accepted on 30/07/2024

DOI: https://doi.org/10.1590/1517-7076-RMAT-2024-0347

coatings, while in textiles, they enhance cloth stiffness [7]. Additionally, these extracts play a pivotal role in the manufacturing of glucose, dextrin, and syrups, as well as serving as filler materials for tablets in the pharmaceutical sector. Moreover, they find application as powders in cosmetics, additives in food products like noodles, vermicelli, and ice cream, and even as glue in adhesive and rubber industries [8].

In India, the starch industry is poised for significant growth in the coming years, driven by escalating demand from various sectors due to population growth. Notably, Tamil Nadu contributes a substantial portion, around 80%, of the national requirement for sago production, both in food and non-food sectors, through efficient cassava processing facilitated by numerous small-scale starch industrial units [9]. As India's demographic landscape undergoes changes, there is an increasing need for quality improvements in the final products to meet international standards, particularly in the modified food starch industry [10]. This entails adopting advanced processing techniques and stringent quality control measures to ensure that Indian starch products can compete on a global scale. Such enhancements will not only bolster the country's starch industry but also position it as a key player in the global market for starch-based products [11].

The various modification techniques for cassava starches through physical, chemical and enzymatic treatment. Modified starches offer functional benefits to food such as bakeries, snacks and beverages. Modified starch of Cassava used for consistency improvement, nutritional values along with high temperature firmness [12]. A cross-linking four different reagents with various acid to manufacture four modified starch grades. The modified starches exhibited better functional properties of ash and moisture content, pH, content and viscosity ranges for the combination of acid and base variations in the native starch [13]. The calibration model under Near Infra-red region to evaluate the ingredients of Cassava root using PLS model. The Support Vector Machine binary resourceful Multiclass Tree technique to attain high categorization effectiveness for multiclass issues. The modified tropical starches by oxidation and acid treatment to evaluate amylose content of the starch using principal component analysis in mid-infrared spectroscopy. Categorize starch for production of various goods based on the nature of chemical modification process through Support vector machine [14]. The classified cassava starch thin layers according to their characteristic behavior and relate multivariate calibration with permeability determination use infrared spectroscopy with principal component analysis and PLS [15]. The characteristics of Octenyl Succinic Anhydride (OSA) starch obtained on grains and vegetables with respect to the parameters Consistency, Volume, and Temperature and ratio variations. Study shows that the characteristics of modified starch not only depend on the ratio variations of OSA but also on the origin place of the raw material [16].

Analyzed the vibration characteristics of starch sample property through FTIR and Raman methods for detection the fat, casein content level. It is revealed that FTIR detection better than Raman spectroscopy using Principal component analysis (PCA) [17]. The electrolyzed starch employed for dents and many other applications with morphological structural changes under various parameters. The micronization of Cassava and changes in the property of cassava against Temperature Viscosity and Settling time [18]. The design of an instrument to evaluate the quality of raw Cassava from various parameters like moisture, pH and color. Applied Support Vector Machines technique for repeated detection in young-old gait types from their respective gait-patterns. FTIR employed for faster and specific technique for concurrent determination of various components present in organic products [19]. It is reported that the FTIR spectroscopy is a credible nondestructive quality investigation tool to identify the ingredients added in food materials. The cassava starch ingredient determination using FT-IR spectroscopy with a calibration model built using PLS. Analysed the usage of Pregelatinized Cassava Starch Phthalate as a capsule shell substance. Cassava coating found to be highly soluble in the alkaline intermediate than in acidic standard. The chemometric algorithms using partial least squares method in Near Infrared regions for fruit maturity estimation [20].

The global quest for sustainable alternatives to conventional plastics, derived predominantly from synthetic polymers, has driven extensive research into harnessing natural polymers like cassava starch for biodegradable plastic production. Unlike their synthetic counterparts, which pose severe environmental challenges due to their non-biodegradable nature, bioplastics derived from natural sources offer a promising solution to mitigate plastic pollution [21]. To optimize the properties of cassava starch for bioplastic applications, researchers have explored various modification techniques. These include treatments involving water with anhydrides and variations in base ratios, as reported in recent studies. These modifications aim to enhance the compatibility and performance of cassava starch when used in conjunction with synthetic polymers, ensuring the resulting bioplastic meets desired mechanical, thermal, and biodegradability criteria [22]. However, despite significant advancements in cassava starch modification and bioplastic formulation over the past decade, challenges persist in ensuring the consistent quality of raw materials for diverse industrial applications. Achieving the desired properties and performance characteristics of cassava starch for specific end-uses according to various industry-standard requirements remains a complex and ongoing endeavor that demands further attention and research [23].

In response to these challenges, innovative methodologies have emerged for assessing the quality of cassava starch tailored to specific industrial needs. Techniques such as specific gravity correlation, color analysis employing the ID3 algorithm, advanced image processing methods, and Near-Infrared Spectroscopy (NIRS) are employed to comprehensively evaluate cassava starch quality for various industrial applications [24]. These advanced analytical tools enable precise characterization and quality assurance, facilitating the selection of cassava starch variants that best align with the requirements of different industries, from packaging to biomedical applications [25]. By continuing to refine processing methods and leveraging sophisticated analytical techniques, the development of high-quality cassava-based biodegradable plastics can be accelerated, contributing to a more sustainable future for the plastics industry and the environment [26–28].

Please take into consideration the following properties for the food grade industry: moisture, ash, pH, viscosity, protein, sulfur dioxide, fiber content, acid factor, and solubility, as well as microbiological contents. Additionally, the paper cone, textile, and ceramic industries should consider borax content. Among the various parameter requirements for these industries, ash and moisture content are common features required by third-party users. Therefore, the model is primarily designed for analyzing ash and moisture content. However, in the future, when considering all other parameters listed by third-party users, the SVM technique would provide better classification. Looking ahead, there is a need to focus on standardization efforts and the inclusion of extensive quality parameters for cassava roots to ensure robust quality assurance and classification protocols. Furthermore, enhancing standardizations involves expanding the scope to cover a comprehensive range of cassava quality parameters in future research endeavors.

2. PROPOSED WORK

The block diagram of the proposed work shown in Figure 1 find the ingredients determination from raw material observations using FTIR spectroscope applied with the PLS calibration model. The major components of FT-IR spectroscopy are source, interferometer, sample holder and detector. Cassava root sample pellet form is placed between interferometer and detector using sample holder. The few mg of Cassava sample is exposed under Infrared source in the range from 4000 cm^{-1} to 400 cm^{-1} to obtain interferogram of the spectrum through FT-IR spectroscopy. Based on the absorption of this infrared light source, detector produces interferogram and the resultant is applied Fourier transformation to obtain spectrum. Spectrums are further analyzed to determine

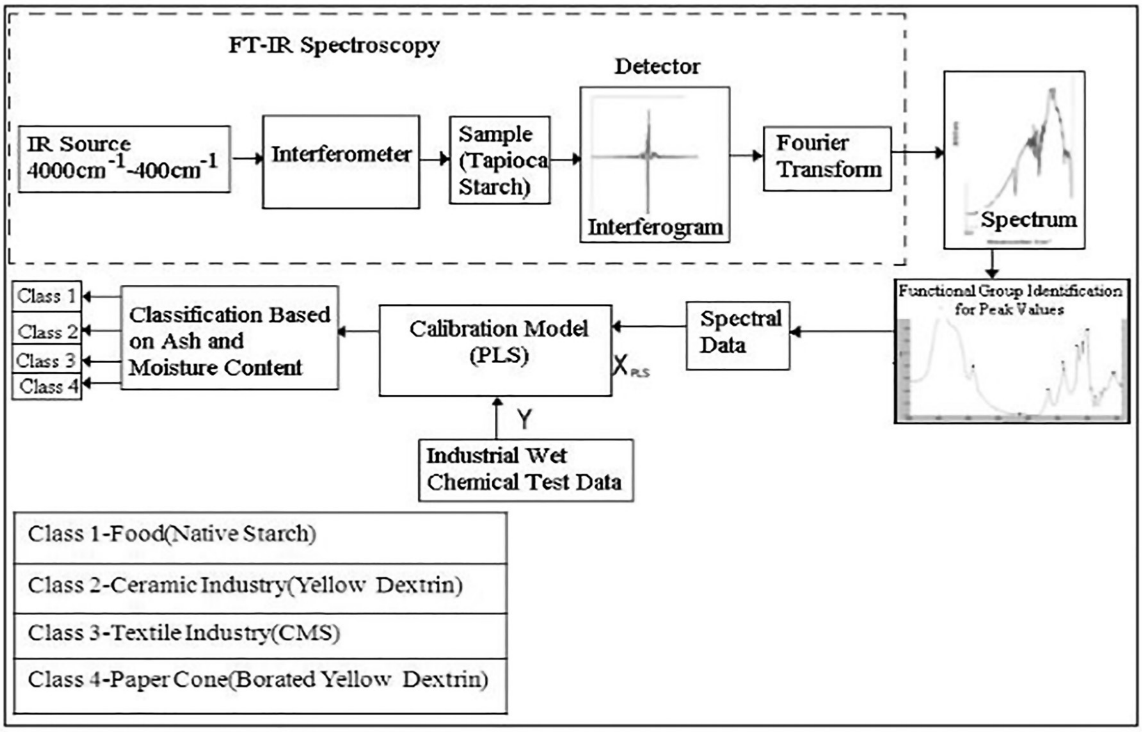


Figure 1: Functional block diagram for quality ensure.

the respective element presence through chemical bond identification with respect to standard FT-IR table. Preliminarily, Cassava classified according to the requirements of different types of starch applications for various industries based on the concentration values of the ingredients of moisture and ash using Support Vector Machines. Figure 1 shows the Functional Block Diagram for Quality Ensure.

2.1. Wet chemical method

Starch industry carry out Wet Chemical test based on the Indian Standard assessment practice IS4706 developed in 1978. The data taken from SPAC Tapioca Industry, Poonachi, and Erode district employ traditional wet chemical methods to find out the constituents of Cassava starch. As per Indian standard testing procedure for ash, moisture and also other component presence determined using wet chemical methods. Preliminarily, only ash and moisture content are considered for classification since the third party users particularly concentrate on these parameters. Take 5g to 10 g of the final modified starch in a platinum bowl. Set fire to the substance in the bowl with blaze till every part of the starch undergoes carbonization and maintains the ignition temperature in the furnace as 550°C for three hours. Cool the resultant part in desiccators and weigh it. Reiterate the process of ignition in the furnace, cooling and weighing at half hour intervals until the differentiation between the two consecutive weighing is less than one milligram. Take the lowest mass value for determining the quality.

Ash content is determined by $$\text{Ash in }\% = \frac{(M_2 - M) \times 10000}{M_1 (100 - X)}$$

Moisture Content is determined by $$\text{Moisture in }\% = \frac{(M_1 - M_2) \times 100}{10}$$

Where M_1: Mass of the trial before aeration

M_2: Mass of the bowl with ash / Mass of the sample on drying to constant mass;

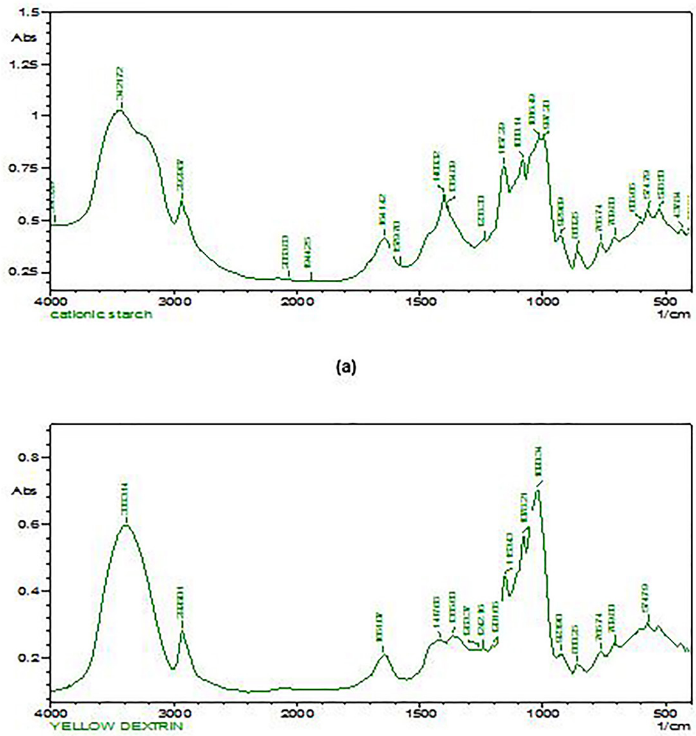
M: Weight of the empty dish;

X: Moisture content;

2.2. FTIR spectrum

A few milligram of the raw starch sample was assorted with 0.5 to 0.6 gram of potassium bromide and exposed to 20 psi pressure in order to make the sample pellet. The sample holder hold the sample between the interferometer and detector of the spectroscope. FTIR (Fourier-transform infrared) spectroscopy focuses on the infrared light range from 4000 cm^{-1} to 400 cm^{-1} wavelength. The sample is passed over the trial 32 times with a resolution of 4 to obtain an interferogram in order to avoid errors. The data obtained from the FTIR spectroscope is available in notepad format and consists of spectral data. This data can be imported into an Excel sheet using the 'data from text' option and selecting the fixed width option. The result is a fourier transformed absorption spectrum recorded in the absorption mode, as shown in Figure 2, to determine the ingredients present in the cassava root and correlate them with their quantities based on peak determination. The peak absorption values of the spectrum are determined using the concept of local maxima, where a local maxima of a function in a search space is a value that is greater than all the values near it. The ingredients of cassava starch are identified by matching the peak absorption values of functional groups with the FTIR standards in the FT-IR spectrum using the local maxima concept, as per standard FTIR spectrum.The respective functional bonds of FTIR standard match with the ingredients present in Cassava is evaluated by calibration model using Partial Least Square algorithm. Figure 2 shows the Spectrum Peak Detection of a) Cationic Starch b) Yellow Dextrin.

The calibration model for constituent determination present in the native starch sample was built using Partial Least Square (PLS) algorithm between the obtained FTIR spectral data and the experimental industrial real-time data obtained from wet chemical test method of the same sample at SPAC tapioca Industry limited, Poonachi, Erode, Tamil Nadu, India. The calibration model is used to predict the concentration value of the ingredients using the training data, the concentration of new test samples was determined. Here XPLS is the input data for PLS modeling, where each row represents spectrum data of cassava and Y vector represents the experimental values of the concentration obtained from the SPAC industries through wet chemical methods. By partial least squares analysis using MATLAB, the wave numbers corresponding to peak absorption values were used to develop the calibration model.



(b)

Figure 2: Spectrum peak detection of (a) cationic starch (b) yellow dextrin.

2.3. FTIR spectrum calibration model

The calibration model build with the respective peak wave length absorption values of raw cassava spectral data and the experimental data values of wet chemical test employed in ingredient determination of modified starch. Wet chemical Test values for quality assurance obtained from the SPAC Tapioca industry, Poonachi, Erode used for validation of Partial Least Square technique. Calibration model designed using set of training data obtained for same samples of cassava tested with absorption values and experimental wet tests. Concentration of new test samples is evaluated using following equation

$$YPLS = T*P' + E \text{ and } X = U*Q' + F$$

Training Inputs

YPLS: Spectrum data matrix; X: Wet Chemical data matrix;

U and T: Column of X and Y matrix with largest square of sum.

E and F: Irrelevant variability in YPLS and X

Training Outputs

$$W = YPLS'*T;\ Q = X'*U;\ B = T'*U/\ (U\ '*U) \text{ and } P = YPLS'*U/\ (U'*T);$$

P: Y load matrix; W: Y Weight Matrix; Q: X load matrix; B: Regression Coefficient Matrix;

Testing: Using the PLS model, for new (testing input Y1), X1 = (Y1*Q)*B*P';

2.4. Support vector machine (SVM) classifications

Support Vector Machine is a modern mechanism wisdom tool performs categorization under organized algorithm. It creates an N-dimensional hyper plane for optimum separation of the data under various groups. It performance on unnoticed data is easier to train with low converge time. The kernel function categorize the data to facilitate the obscure space vector dimensional representation. Here the Support Vector Classifiers resolve the linearly constrained convex quadratic programming problem using Radial Basis Function (RBF) kernel functions with hyper plane to classify the given data for maximal marginal classifier with optimal co efficient (α) to maximize the function. $S(\alpha) = 1/2 \sum_{i,j} b_i b_j z_i z_j k(y_i, y_j) - \sum_{i=1}^{m} b_i$,

Under the constraints $0 \leq b_i \leq a$, Where a is a regularization parameter.

Hyper plane: $y(x) = \sum_{i=1}^{m} b_i z_i k(x, x_i) + d$, Where d the bias expression, obviously the z related to non-null coefficients and their respective patterns are called Support vectors (SVs). The used RBF Guassian kernel is: $k(y_i, y_j) = \exp\left(-\gamma \|(y_i - y_j)\|^2\right), \gamma > 0$.

3. RESULTS AND DISCUSSIONS

Each industry has different third party requirements with various properties of cassava. The moisture and ash content are common for many of the cassava processing industries. Table 1 shows the cassava classification range of moisture and ash concentrations requirement made by the different types of Application industries. Figure 3 illustrate the FT-IR input spectrum of cassava roots applied for classification, PLS for correlating ingredient presence and SVM classification for application industries. The raw cassava spectral data act as input for the calibration model able to predicts

Table 1: Classification range for various industrial applications.

TYPE OF INDUSTRY	MOISTURE%	ASH%	CLASS
Food industry (Native starch)	12 - 13	0 - 0.2	1
Ceramic industry (Yellow dextrin)	6 - 10	0.7 - 1.0	2
Textile industry (Carboxy methyl starch)	10 - 12	16 - 20	3
Paper cone (Borated yellow dextrin)	8 - 10	3 - 5	4
Paper (Cationic starch)	8 - 13	0 - 1	5
Gum (Corrugation powder)	8 - 13	3 - 5	6

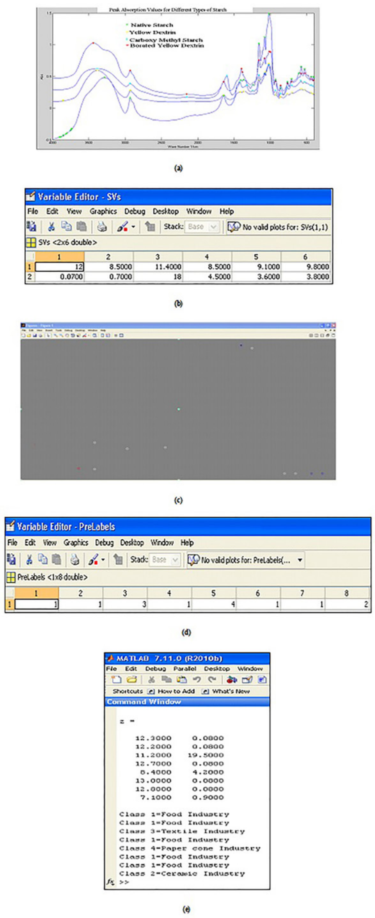


Figure 3: Results of classification (a) cassava spectrum (b) input for SVM classifier (c) output of SVM classifier (c) classification (1-food industry, 2-ceramic industry, 3-textile industry, 4-paper cone).

Table 2: Model valuation.

CONSTITUENT	RMSEP = $\sqrt{\sum_{i=1}^{n} \frac{(y_i - \hat{y}_i)^2}{n}}$	BIAS $\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)$	STANDARD DEVIATION (SD)	STANDARD ERROR OF PREDICTION (SEP)	RELATIVE PERCENT DIFFERENCE RPD = (SD/SEP)
Moisture	0.36	0.17	0.36	0.04	9
Ash	0.003	0.00	0.04	0.01	4

the moisture and ash concentrations through correlating the peak absorption value with the respective wave number of standard FT-IR table using local maxima. The RMSEP and RPD are related to the determination capability of the calibration model built shown in Table 2. The lower value of RMSEP and higher value of RPD of predicted model shows good determination capability of the system. The SVM predicted classes of cassava classification match with the starch preparation for various industries like Native starch property for Food Industry, Yellow dextrin property matching for Ceramic Industry, Carboxy Methyl Starch property matching for Textile Industry and Borated Yellow Dextrin property matching for Paper Cone applications. The obtained confusion matrix is an identity matrix ensures the classification success rate 100% accuracy using SVM. Figure 3 shows the Results of Classification a) Cassava Spectrum b) Input for SVM Classifier c) Output of SVM classifier c) Classification (1-Food Industry, 2-Ceramic Industry, 3-Textile Industry, 4-Paper Cone).

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4. CONCLUSION

The calibration model developed for ingredient identification of cassava, employing the Partial Least Squares (PLS) technique, demonstrated remarkable accuracy in calculations while minimizing processing time and avoiding chemical residue production. An initial endeavor was undertaken to classify raw cassava feedstock for diverse applications, aimed at meeting the stringent requirements of various industrial standards. This classification was primarily based on assessing the ash and moisture content within cassava roots, utilizing a Support Vector Machine (SVM) model.

Moving forward, there is a pressing need to focus on standardization efforts and the incorporation of extensive quality parameters for cassava roots to ensure robust quality assurance and classification protocols. Enhancing standardizations entails broadening the scope to encompass a comprehensive range of cassava quality parameters in future research endeavors. By expanding the array of quality parameters considered, such as starch content, fiber composition, and chemical constituents, the accuracy and reliability of classification models can be significantly bolstered. This will not only facilitate precise identification and classification of cassava for various industrial applications but also contribute to optimizing resource utilization and enhancing overall product quality within the cassava processing industry.

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