Electro-Optic Properties of Dried Pliek U Powder: Local Ingredients From Aceh

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Abstract. The main aim of this present study is to systematically study the electro-optic properties of dried Pliek U powder based on infrared spectroscopic data. Fast detection of fermentation level stages was also investigated. Diffuse reflectance of infrared spectroscopic data were acquired for all Pliek U powder samples in wavelength range from 1000 to 2500 nm with 0.02 nm increment and 64 co-added scans. Spectra data were enhanced using Savitzky-Golay smoothing and projected onto principal component analysis to detect fermentation levels. The results showed that spectra features of Pliek U powders were highly correlated with several chemical parameters such as moisture content, fiber content, starch and carbohydrates. Moisture content in little portions were associated in wavelength range of 1420 nm and 1950 nm. On the other hand, fiber content can be predicted in wavelength 1700 nm, 1980 nm and 2100 nm. Moreover, starch and carbohydrates were mainly associated in wavelength 2080 nm, 2200 nm and 2340 nm respectively. Fermentation level stages were also can be classified with a total of 98% of explained variance using PCA method. Thus, it may conclude that Pliek U powder’s quality attributes can be determined rapidly based on their electro-optic properties.

1. Introduction

Pliek U is typical powder used as a traditional recipe from Aceh Province, Indonesia. It is made from dried, fermented coconut and can be stored in long period prior to be used. Pliek U is very popular for the people in Aceh due to its used as traditional recipe mixed in main food course. The quality of Pliek U depends on several factors such as fermentation stages, moisture content, drying time and other physical characteristics.

In order to determine and measure quality parameters and fermentation stages of Pliek U powder, several methods have been widely used [1], [2]. Nevertheless, most of those reference methods were based on standard laboratory procedures from which involved chemical materials, destructive in nature, time consuming, laborious, expensive and may cause pollutions [3], [4]. Therefore, it is unsuitable to be applied in farmers and local communities.

In recent decades, many efforts and studies have been performed in searching alternative methods which can be used to determine several quality parameters of foods and agricultural products without involving chemical materials, effective, fast and environmental friendly [5]. These alternative methods mimic the principle works of human sensing devices in which related to the responses of light or optics, sound and vibrations [6], [7]. One of the most promising technique is technology based on electro-optics such as laser, infrared and hyperspectral imaging [5], [8]. Numerous studies have been widely reported on the study of those optical spectroscopy in many field such as in horticulture sectors [9][10][11][12], agriculture products [13], [14], foods authentications [15], soil quality attributes [16][17][18][19], animal feed [20], [21], meat and dairy products [22], [23].

In order to employ this mentioned method, the electro-optic properties of studied samples must be characterized. These properties related to the chemical bonds of structured quality attributes of sample and biological objects. The sample is irradiated with light and goes through sample tissues. The reaction
from the chemical bonds are reflections, absorptions, and transmissions. The amount of responses, called as spectrum, subjected to the variations of chemical structures and depends on tissue heterogeneities. Spectral information provided a signature pattern of each quality attributes such as protein, carbohydrates, fiber content, acidities, pH, starch content and others. These patterns must be revealed in order to predict and determine those quality attributes. Therefore, the main objective of this present study is to systematically investigate the electro-optic properties of dried Pliek U powder based on infrared spectroscopic data. The spectra patterns were generated in infrared region from 1000 to 2500 nm and dried Pliek U powder were fermented in three different stages: 4, 7 and 11 days. Data were analyzed by means of multivariate analysis method

2. Material and Methods

2.1 Electro-optic spectral data
Spectral data of dried powder samples were acquired and recorded in wavelength range from 1000 to 2500 nm with 0.02 nm resolution windows. Samples were scanned 32 times with attenuated optics of 4x. The spectra acquisitions were performed in triplicate and averaged [24]. Electro-optic properties data, in form refelctance spectrum, were saved and stored in two different file formats as .spa and .csv extension files.

2.2 Multivariate analysis
Reflectance spectra data were firstly inspected and subjected onto principal component analysis to detect sample outliers. It was performed by means of PCA in combination with Hotelling $T^2$ ellipse. Data points lies outside the ellipse were marked as outlier and removed.

Moreover, spectral data were derived as 1st derivative using Savitzky-Golay derivative with three cutting edge and second degree of polynomial order. Spectral data were also enhanced and corrected by employing de-trending method.

2.3 Cluster analysis
In order to classify and detect fermentation stages, cluster analysis was conducted by projecting spectral data onto PCA with maximum number of latent variables is 7 LVs. Fermented powder were classified by means of Euclidian distance and hierarchy analysis.

3. Result and discussion

3.1 Spectra features
Reflectance spectra features for dried Pliek U powder samples in wavelength region from 1000 to 2500 nm is presented and described in Figure 1. The reflectance spectrum indicated the availability of organic materials as derived from the chemical bands resulted from interaction between molecular bonds of O-H, C-H-O, C-O, C-H and N-H with the light radiation. These chemical bonds referred to the vibrational energy changes inside the samples and other biological objects.

Two vibration patterns exist in these bonds including stretch vibration and bend vibration. Here, the presence of adequate water absorbance bands was observed at 1480 and 1920 nm due to O-H dirst overtone combination and its second overtone. This also in agreement with some literatures mentioned that absorption bands at around 1400 nm and 1900 nm were previously assigned to water absorption [9], [25]. Moreover, the absorption bands in the range of 1980 – 2150 nm, 2220 - 2310 nm, are suggested to be related to C-H-O structures; around 1620 – 1750 were associated with N-H structures, while absorption bands at around 1220, 1850 and 2190 nm are associated with acidities and organic materials.
Figure 1. Reflectance spectrum of dried *Plek* U powder samples at wavelength range from 1000 to 2500 nm.

Dried *Plek* U powder samples were irradiated with near infrared radiation and the reaction (reflection, absorption or transmission) is captured. While the radiation penetrates the object, its spectral characteristics changes through wavelength dependent scattering and absorption process. The contribution of each reaction depends on the chemical composition, cell structure and physical properties of the powder samples. Beside overtone, vibrational changes of molecular bonds were also occurred as bending, stretching and twisting from which electro-optic properties are defined accordingly. Derivative and enhanced spectra data were performed to eliminate noises and spectra features are shown in Figure 2.
Figure 2. First derivative (D1) reflectance spectrum of dried Pliek U powder samples at wavelength range from 1000 to 2500 nm.

Based on obtained result, each organic molecule, contained bonds of C-H, O-H, C-O, C-C and N-H, appears feasible to apply the optical methods to predict chemical quality parameters of Pliek U powder samples. Important wavelengths of infrared spectra for desired quality attributes predictions can be identified by inspecting regression coefficients of the respective multivariate calibration methods such as principal component regression (PCR). Dried Pliek U quality parameters are mainly constructed with chemical bonds of N-H, C-H-O and O-H from which we believe that the electro-optic properties based on IR spectral data can be used to predict feed quality parameters such as protein, carbohydrates, starch, fiber, ash and fat content.

3.2 Cluster analysis
Further analysis was performed to detect and classify samples based on fermentation level stages. Classification was made by projecting spectral data into PCA analysis and we expect that electro-optic properties combined with PCA and cluster analysis can classify and differentiate Pliek U powder samples based on fermentation stages (0, 4, 7, 10, and 28) days. Classification result was presented in Figure 3.

Prior to PCA classification, D1 spectra correction and de-trending (DT) enhancement methods were applied to all spectra data in order to enhance and correct reflectance spectrum. DT is used to compensate for additive and multiplicative effects in the spectral data, which are induced by physical effects, such as the non-uniform scattering throughout the spectrum. The degree of scattering is dependent on the wavelength of the radiation, the particle size and the refractive index. This method attempts to remove the effects of scattering by linearizing each spectrum to an optimum spectrum of the sample, which is normally corresponds to the average spectrum.

As shown in Figure 3, the first principal component accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible. Our obtained results are as follows: PC1 = 91%, and PC 2 = 7% from which we may argue that most of spectra data of feed samples can be discriminated using the first component (PC1) while remaining components, PC 2 contributed 1%. Furthermore, judging from the classification result, all different fermentation stages can be classify precisely using reflectance spectra data with the support of PCA-NIPALS algorithm.
Derived cluster models were then tested to detect fermentation level stages of several unknown samples. Initial test was performed to detect two sample groups fermented for 7 days and un-fermented as 0 days. Detection results is presented in Figure 4 as shown bellows.

![Figure 4](image_url)

**Figure 4.** Detection of fermentation stages of unknown samples using derived model.

The cluster analysis and PCA employ a mathematical procedure that transforms data into a new set of non-correlated variables, called principal components. The first principal component accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible. PCA is used as a tool for screening, extracting, compressing and discriminating samples based on their similarities or dissimilarities of multivariate data.

The primary information that can be obtained and generated from the electro-optic properties of studied samples with light radiation is its physical, optical and chemical characteristics. Agricultural materials have shown to have identifiable C-H, N-H, and O-H absorption bands in the infrared region whereas each have a specific vibrational frequency and it is different between one object and the others.

4. Conclusion
The electro-optic properties of dried *Pliek U* powder samples with different fermentation stages were investigated. Based on the obtained results, moisture content in little portions were associated in wavelength range of 1420 nm and 1950 nm. On the other hand, fiber content can be predicted in wavelength 1700 nm, 1980 nm and 2100 nm. Moreover, starch and carbohydrates were mainly associated in wavelength 2080 nm, 2200 nm and 2340 nm respectively. Fermentation level stages were also can be classified with a total of 98% of explained variance using PCA method. Thus, it may conclude that *Pliek U* powder’s quality attributes can be determined rapidly based on their electro-optic properties.

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