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A Review: Peanut Fatty Acids Determination Using Hyper Spectroscopy Imaging and Its Significance on Food Quality and Safety

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Abstract
This paper is a review of determination of peanut fatty acids by using Hyper Spectral Imaging (HSI) methods as a non-destructive food quality and safety monitoring. The key spectral areas are the visual and near-infrared wavelengths. Few have been published on determination of peanut fatty acids by using HSI as an efficient and effective method for evaluating the quality and safety of oil. Providentially, the use of HSI has been observed to have positive effects on determination of food quality and safety (Smith B. 2012). It has gained a wide recognition as a non-destructive, fast, quality and safety analysis, and assessment method for a wide range of food products. Literature shows that, HSI is not commonly and widely used therefore this paper aspires to emphasize the use of HSI on improving the quality and safety of peanut oil and its products based on the determination of peanut fatty acids. The authors predicted that even in its current imperfect on the affordability, maintenance and complexity on finding solutions or model approaches to their food quality problems from optics, imaging, and spectroscopy, yet HSI is the best method than other current existing methods, and can give an idea of how to better meet market and consumer needs on high food quality and safety for their better healthy.
Key words: Hyper spectral imaging, Peanut (Arachis hypogaea), oil, Oleic and linoleic fatty acid, Food quality, food safety,

1.0 Introduction

Peanut (Arachis hypogaea) belong in the legume or "bean" family (Fabaceae). It is known by many other local names such as earthnuts, ground nuts, goober peas, monkey nuts, pygmy nuts and pig nuts (Seijo et al., 2007). Peanut seeds contain 44-56% oil and 22-30% protein on a dry seed basis. In addition, they are a good source of minerals (phosphorus, calcium, magnesium and potassium) and vitamins (E, K and B groups), (Hassan F. and Ahmed M., 2012). According to Xue, et al, (2012), peanut also contain polyphenols, phytosterols, active polysaccharides, phospholipids, dietary fiber and other bioactive ingredients. Fatty acids are important diet for healthy living. They have several functions in the body including helping in transportation of oxygen in the bloodstream, aiding cell membrane development and function (necessary for strong organs and tissue), keeping the skin healthy, preventing early aging, and more importantly, preventing cholesterol build up in the arteries (Dennis et al, 2003). The composition of fatty acids in peanut oil varies both in quality and in relative proportion (Onemli F. 2012). These variations may be caused by the nutritional quality of the seed which is strongly influenced by production location, cultivar and season particularly soil moisture and temperature during crop growth and seed maturation (Hassan F. and Ahmed M., 2012). It is important to know the content of peanut fatty acids for the better quality and safety of its product and this will be successfully through using efficient method such as hyper spectral imaging.

1.1 Composition of peanut oil

Peanut oil like other vegetable oil is determined on the ester which is made up of straight chain higher fatty acids and glycerine. The fatty acids include the unsaturated; palmitic acid and stearic acid, mono unsaturated fatty acids; such as oleic acid, and polyunsaturated fatty acids such as linoleic acid, linolenic acid; docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) (Xue, et al, 2012). Peanut oil is characterized by 45.2% oleic acid (18:1) and 32.4% linoleic acid (18:2), palmitic (C16:0), and a trace amount of linolenic fatty acid (C18:3), (Carrin M.E. and Carelli A.A., 2010; Mondragón M. G.et al, 2009). It also contains some stearic acid, arachidic acid, arachidonic acid, behenic acid, lignoceric acid and other fatty acids (Anneken et al, 2006).

1.2 Importance of oleic and linoleic fatty acid to oil quality and safety

At present, the fatty acid composition of peanuts has become increasingly important with the realization that the compositions of Oleic and Linoleic fatty acids have a large and important bearing on the stability, nutritional quality, and flavor of peanut oil and its derived products (Chamberlin K.D, 2014; Onemli F, 2012). The choice of the fatty acid (FA) is a crucial step in obtaining good results, in particular with short-chain and conjugated FA (Juanéda P., 2007). Measuring and reporting of the fatty acid content of food is an important step that allows consumers the opportunity to establish a healthy dietary strategy (Buchanan M.D., 2011). In view of the fact that, the two leading fatty acids in peanut oil are Oleic and Linoleic fatty acids (Onemli F. 2012), high oleic to linoleic acid ratio characteristic could confer a significant health advantage to the consumer and has the potential to greatly enhance the marketability of peanuts (Hassan F. and Ahmed M., 2012).

1.3 Common methods used to determine fatty acids

Generally, the methods for food analysis can be classified as chemical or biological analysis (Alander J.T., 2013). Different methods used for quality evaluation and determination of fatty acids in peanut oil mostly are slow and destructive (Nicolaï et l., 2007). Some of the methods include Gas Chromatography (GC), Thin Layer Chromatography (TLC), High performance Liquid Chromatography (HPLC), Capillary Electrophoresis (CE), Real-Time Polymerase Chain Reaction (RT-PCR), Near-Infrared Reflectance Spectroscopy (NIRS), and HSI. The most common method used is GC as it has been used traditionally to determine fatty acids in peanut oil (Chamberlin K.D., 2014). With the exception of NIRS and HSI, other methods are destructive, less efficient and need preparation of samples, (Scotter, 1997). The well-known, Near-Infrared Reflectance spectroscopy (NIRS) offers a potential alternative, because it is fast, non-destructive, involves no sample preparation and provides a safe working environment. Moreover, it is related to overtones and combinations of such chemical bonds as C–H, O–H, and N–H which has influence on many properties of food and enables both quantitative and qualitative analysis (Hein M, 1997). However, analysis of spectral measurements is often not easy and requires expertise. The mathematical and statistical models created might not be general and need to be adjusted to new conditions and products (Alander J.T., 2013).

Hyper Spectral Imaging (HSI) such as Sichuchema-NIR, Specimen QY, Finland, also known as Chemical or Spectroscopic Imaging, is an emerging technique that integrates conventional imaging and spectroscopy to attain both spatial and spectral information from an object (Gowen A.A. et al, 2008). It is the fastest chemical imaging solution, acquiring spectral images in just a few seconds. The primary advantage of hyper spectral imaging system is that the operator needs no prior knowledge of the sample because an entire spectrum is acquired at each point. It can also take advantage of the spatial relationships among the different spectra in a neighborhood, allowing more elaborate spectral-spatial models for a more accurate segmentation and classification of the image (Ghita, 2009). Therefore, the purpose of this paper is to emphasize the use HSI as the advanced technology for determination of peanut fatty acids particularly oleic and linoleic acids and its significance on food quality and safety.

2.0 Hyper spectral imaging

2.1 Detection of fatty acids by Hyper Spectral Imaging

Hyper spectral imaging is the method used to obtain spectrum for each pixel in the image of a scene that is invisible to the human eye for the purpose of finding oobjects, identifying materials, or detecting processes. Sisu CHEMA, like other spectral imaging, collects and processes information from across the electromagnetic spectrum. Like the human eye sees visible light in three bands (red, green, and blue), spectral imaging extend the electromagnetic spectrum beyond visible light (400 and 1700 nanometers (Ghita, 2009)) and divides the spectrum into many more bands. Hyper spectral sensors collect information as a set of 'images', each image represents a spectral band. These 'images' are then combined and form a three-dimensional hyper spectral data cube for processing and analysis (Ghita, 2009).

2.2 Production of hyper spectral images

A line of light reflected from the sample enters the objective lens and is separated into its component wavelengths by diffraction optics contained in the spectrograph; a two dimensional image (spatial dimension - wavelength dimension) is then formed on the camera and saved on the computer. The sample is moved pass through the objective lens on a motorized stage and the process repeated; two dimensional line images acquired at adjacent points on the object are stacked to form a three-dimensional hypercube which may be stored on a PC for further analysis (Gowen, et al., 2007) as shown in figure 1.

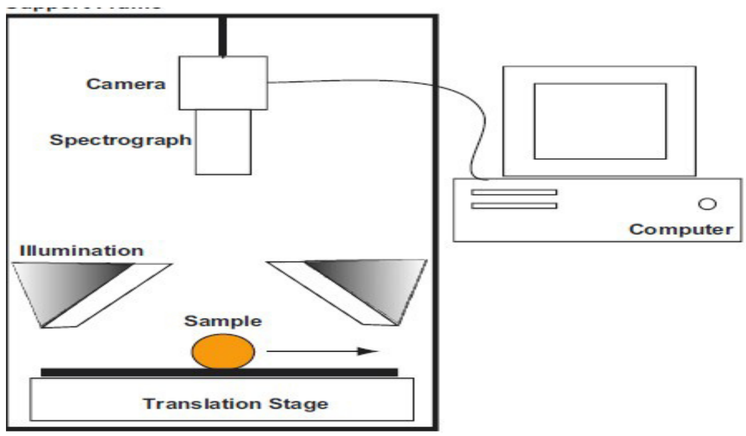

Figure1: Production and storage of hyper spectral image (Gowen, et al., 2007)

2.3 Analysis of hyper spectral images

There are numerous techniques which are used to analyze hyper spectral data, all of which aim to reduce the dimensionality of the data while retaining important spectral information with the power to classify important areas of a scene (Gowen et al., 2007). Typical steps in analyzing hyper spectral images include reflectance calibration, pre-processing, classification and application. Reflectance calibration accounts for the background spectral response of the instrument and the 'dark' camera response.

2.3.1 Reflectance

For reflectance measurements, the background is obtained by collecting a hyper spectral image from a uniform, high reflectance standard or white ceramic and the dark response is acquired by turning off the light source, completely covering the lens with its cap and recording the camera response (Gowen et al., 2007). The corrected reflectance value (R) is then calculated using the following formula: R ¼ (sample - dark) / (background – dark) (Gowen et al., 2007).

2.3.2 Pre processing

Pre-processing is normally performed to remove non-chemical biases from the spectral information (e.g., scattering effects due to surface in homogeneities) and prepare the data for further processing. A number of spectral preprocessing techniques exist, including polynomial baseline correction, Savitzkye Golay derivative conversion, mean centering, and unit variance normalization. Other operations usually carried out at the pre-processing stage include thresholding and masking to remove redundant background information from the hyper spectral image. Pre- processing must be handled with care to avoid the spectral and spatial variability (Amigo et al., 2013).

2.3.3 Classification

Hyper spectral image classification enables the identification of regions with similar spectral characteristics. Due to the large size of hyper spectral images (which can exceed 50 MB, depending on image resolution, spectral resolution and pixel binning) complex multivariate analytical tools, such as principal component analysis (PCA), partial least squares (PLS), linear discriminant analysis (LDA), Fishers discriminant analysis (FDA), multi-linear regression (MLR) and artificial neural networks (ANN), are usually employed for classification image processing (Gowen et al., 2007).

2.3.4 Application

Application step involve image processing to convert the contrast developed by the classification steps into a picture depicting component distribution. Grey scale or color mapping with intensity scaling is commonly used to display compositional contrast between pixels in an image. Image fusion, in which two or more images at different wavebands are combined to form a new image, is frequently implemented to provide even greater contrast between distinct regions of a sample (Pohl, 1998). Images may be combined using algorithms based on straightforward mathematical operations such as addition, subtraction, multiplication and division. One example is the band ratio method, in which an image at one wavelength is divided by that at another wavelength (Liu et al., 2007; Park et al., 2006). The distinction between hyper- and multi-spectral images is sometimes based on an arbitrary "number of bands" or on the type of measurement, depending on what is appropriate to the purpose. It deals with imaging narrow spectral bands over a continuous spectral range, and produces the spectra of all pixels in the scene. So a sensor with only 20 bands can also be hyper spectral when it covers the range from 500 to 700 nm with 20 bands each 10 nm wide. It is noted that a sensor with 20 discrete bands covering the Visible Infrared Spectroscopy (VIS), Near Infrared Reflectance(NIR), Short Wavelength Infrared (SWIR), Medium Wavelength Infrared (MWIR) and Long Wavelength Infrared (LWIR) is be considered as multispectral (Ghita, 2009). The hyper spectral image allows for the visualization of biochemical constituents of a sample, separated into particular areas of the image, since regions of a sample with similar spectral properties have similar chemical composition.

2.4 Hyper spectral image acquisition compared to other imaging

HSI has proven to be an outstanding tool for analysis of agricultural and food products. Its fast measurement, with little or no tedious sample preparation, good adaptability and simultaneous determination of different attributes makes superior to other imaging methods (Nicolaï et al., 2007) as shown in table 1.

Table1. Comparison of RGB imaging, NIR spectroscopy (NIRS), multispectral imaging (MSI) and hyper spectral imaging (HSI

Feature	RGB imaging	NIRS	MSI	HSI
Spatial information	√	Limited	√	√
Spectral information	√	√	Limited	√
Multi-constituent information	Limited	√	Limited	√
Sensitive to minor components	√	Limited	Limited	√

Source: (Gowen, 2007)

2.5 The composition of peanut oleic and linoleic fatty acids and its role in the quality of oil

It is the composition of fatty acid which plays an important role in the quality and safety of oil because of their relationship to the shelf life, nutrition, and flavor of peanut oil and other derived products. As depicted in the table 2 below, there are thirteen fatty acids present in peanut oil. The composition of the two leading peanut fatty acids (oleic and linoleic) are with average of 37.7% and 34.21 % respectively (USDA, 2012). According to Berry S.K. (1982), by Gas Chromatography method revealed the occurrence of palmitic (12.22 to13.30%), stearic (3.17 to 3.67%), oleic (37.94 to 41.90%) linoleic (34.59 to 37.51%), arachidic (1.63 to 1.85%) eicosaenoic (0.99 to 1.22%), behenic (3.24 to 4.36%), and lignoceric (1.08 to 1.44%) as the major fatty acids in peanut oil. In addition, Chamberlin K.D. (2014) revealed that the two fatty acids, oleic and linoleic acid comprise over 80% of the oil content in peanut, and these fatty acids have a strong effect on the stability of the oil and its products.

Table 2. Fatty acid composition in crude and refined peanut oil

Fatty acid	Crude composition (%)	Refined Composition (%)
Caprylic acid (C8:0)	0.013346	0.003208
Capric acid (C10:0)	0.008544	0.005542
Lauric acid (C12:0)	0.275816	0.116076
Myristic acid (C14:0)	0.115270	0.1061
Palmitic acid (C16:0)	8.2280	11.7378
Palmitoleic acid (C16:0)	0.1073	0.1296
Stearic acid (C18:0)	2.4581	2.0606
Oleic acid (C18:1)	58.6871	57.6784
Linoleic acid (18:2)	21.7656	21.5413
Linolenic acid (C18:3)	0.3446	0.2810
Arachidic acid (C20:0)	1.8313	1.4804
Behenic acid (C22:0)	3.8852	2.36610

Source: Aluyor, (2009)

2.6 Summary

Fast computers, sensitive detectors, and large data storage capacities as that of HSI are needed for analyzing hyper spectral data. All of these factors greatly increase the cost of acquiring and processing hyper spectral data (Schurmer, 2003). One of the barrier the researchers have to face is finding ways to program hyper spectral dependency to sort through data on their own and transmit only the most important images, as both transmission and storage of that much data could prove difficult and costly (Schurmer, 2003). The full potential use of a relatively new analytical technique of hyper spectral imaging has not yet been recognized, so emphasis is needed. In the past it was unfeasible to obtain information in all four-dimensions of a hypercube using other methods (refer Table 1).

3.0 RESULTS

3.1 Significances of HSI in food quality and safety

The use of HSI in food science and technology has recently been widely studied and developed, resulting in many successful applications and comprehensive assessment in the food industry for quality and safety evaluation and inspection (Win D.T., 2005). The primary use of the imaging system is to conduct food safety and quality research. Statistical combination of measurements by several sensors as applied in HSI will increase the likelihood of predicting overall quality and safety. This is because; sensor testing and calibration of HSI must include a wide range of conditions important in minimizing the limitations (Abbort J.A, 1998). For instance, Singh, Jayas, Paliwal, & White, 2010a demonstrated the use of HSI in seed color classification, seed kernel purity determination, identification of sound or stained grains, and detection of midge-damaged in wheat kernels. Whereby six image features and ten histogram features were extracted from the most significant wavelengths determined according to the PCA analysis on hyper spectral images, and were then used to develop statistical discriminant classifiers (linear, quadratic, and Mahalanobis) or a back propagation. Therefore, it is vital to emphasize the use of non-invasive, efficient and quick testing method for monitoring food quality and safety.

3.2 Existing issues for consideration on Quality and Safety of food

Nielsen, (2009) reported several issues for considerations on food quality and safety including legal issue, food processing food quality, adulteration and lipid oxidation. Government regulations (legal issue) often demand that the amounts of saturated, unsaturated and polyunsaturated lipids (fatty acids) and the amount of cholesterol should be specified on food labels. In food processing, the manufacture of many foods relies on knowledge of the type of lipids present in order to adjust the processing conditions to their optimum values, e.g. temperature. Moreover, desirable physical characteristics of foods, such as appearance, flavor, taste and texture, depend on the type of fatty acids present. Foods which contain high concentrations of unsaturated fatty acids are particularly susceptible to lipid oxidation, which can lead to the formation of undesirable flavors and aromas, as well as potentially toxic compounds such as cholesterol oxides. By measuring the type of lipids present and comparing them with the profile expected for an unadulterated sample it is possible to detect the adulteration of fats and oils. On these bases, it is important for food scientists to either know or be able to specify the concentration of the different types of fatty acids present in oil Nielsen, (2009). Food process control necessitates real-time monitoring at critical processing points. Fast and precise analytical methods such as HSI are essential to ensure product quality and safety (Gowena et al, 2007).

3.3 Peanut fatty acids and health benefits

Owing to the steadily growing trend towards the intake of a healthy and scientifically balanced diet, the selection of high-quality vegetable oils is constantly rising (Hein M., 1997). Besides physical (seed mass and shape, integrity of seed testa and blanching efficiency) and sensory (seed color, texture, flavor) factors, nutritional (oil, protein contents, fatty acid and amino acid composition) factors are important in the food trade (Hein M., 1997). Besides, WHO (2003) reported that the global burden of chronic diseases is rapidly increase, in 2001 chronic diseases including cardio vascular diseases contributed approximately 60% of the 56.5 million total reported deaths in the world. It has been observed that two important problems in modern lipid chemistry are purity control and the identification of oils and fats (Alander J.T., 2013). Evidence about the impact of lipids in different clinical diseases is still increasing rapidly as the understanding of the role that dietary lipids can play at all ages in preventing diseases related to lifestyle (ISSFAL, 2014). Peanut oil has a role in a healthy balanced diet even though they are energy dense and contain a high proportion of fat (McKelvith B, 2005).Oils that have high oleic acid content and food products containing these oils have been shown to have nutritional benefits (Chamberlin K.D., 2014). Oleic acid has been shown to be associated with a reduction in blood pressure and serum lipoprotein levels. High-oleic peanuts have health benefits over conventional peanuts because the linoleic (polyunsaturated fat) and palmitic (saturated fat) fatty acids have been naturally replaced by the healthier oleic fatty acid (monounsaturated fat) (Chamberlin K.D., 2014). According to Win D.T. (2005), high concentrations of oleic acid can lower cholesterol levels in blood thus, lower the risk of heart problems and block the action of a cancer-causing oncogene, called HER-2/neu, which is found in about 30% of breast cancer patients, also has effect on Type II diabetes. Linoleic acid plays a role in pro-inflammatory reactions, blood clots and allergic reactions.

4.0 Conclusion

HSI are essential for effective food (peanut oil) quality and safety control system as it can sufficient detect the fatty acid contents (quantity and quality) in the seed and its oil, besides selection of peanut seed varieties with high oleic and linoleic fatty acids also need to be considered for the good quality and safety of peanut oil and its product as well.

Food processing industries and food control systems are emphasized to use HSI for ensuring the efficient quality and safety of the product to meet nutritious and health demand of the consumers. This paper is in line with FAO and WHO, (2002) guideline in assuring food quality and safety by widening information on good methods or technique in detecting, evaluating and inspecting and building models on food quality and safety specifically peanut oil and its products.

HSI has recognized as the best in offering the possibility of designing inspection systems for the automatic grading and nutrition determination of food quality and safety products. Several applications outlined in this review show the capability of using HSI for sample classification, and grading, defect and disease detection, distribution visualization of chemical attributes in chemical images, and evaluations of overall quality and safety of food products.

Therefore, it is predicted that real-time for food quality and safety surveillance and control systems with this technique can be expected to meet the requirements of the contemporary food (peanut oil) industrial processing in the near future, hence maintain health of the consumers.

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