Food Research 5 (4) : 382 - 385 (August 2021)
Journal homepage: http://www.myfoodresearch.com

FOOD RESEARCH

FULL PAPER

Identification of Thai coconut sugar (*Cocos nucifera* L.) and prediction moisture content in Thai coconut sugar using FT-NIR spectroscopy

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Article history:
Received: 14 May 2021
Received in revised form: 6 June 2021
Accepted: 10 August 2021
Available Online: 28 August 2021

Keywords:
Thai coconut sugar,
Coconut sugar,
FT-NIR spectroscopy,
FT-NIR absorption Spectra

DOI:
https://doi.org/10.26656/fr.2017.5(4).260

Abstract

Coconut sugar is a local sugar from the blossoms of a coconut tree. It has been considered a healthy sugar due to its low glycemic index. There is an attempt to add other sugar to it to lower the cost. Thus, this research aimed to identify Thai coconut sugar and to establish models for predicting the moisture content of coconut sugar by using FT-NIR spectroscopy. Thai coconut sugar samples were purchased from local grocery stores in four provinces, online, and the community market. Their moisture contents were varied and equilibrated for 24 hrs prior to the measurements of moisture and FT-NIR spectra. The results showed that FT-NIR spectra of Thai coconut sugar differ from sucrose, glucose and fructose at the absorbance spectrum of 5379-5011 cm^{-1}. FT-NIR spectroscopy of 54 known moisture samples of Thai coconut sugar was used to obtain a model to predict moisture content. The predicted equation, using the PLS technique with the Spectrum Quant program, was found to give a standard error of prediction (SEP) 0.077% (less than 0.10%), indicating a non-destructive method of accurately and precisely predicting moisture levels in the coconut sugar. The results obtained suggested that FT-NIR spectroscopy has the potential to be used as a tool to identify Thai coconut sugar accurately. It can rapidly predict the moisture content in the sample which will be useful in quality control standards.

1. Introduction

Thai coconut sugar, traditionally used as a sweetener, is produced from the blossoms of a coconut tree (*Cocos nucifera* L.). The coconut tree is widely grown in Thailand and is the source of sweetener called "coconut sugar". The traditional method of coconut sugar production in Samut Songkharm Province, Thailand, begins by collecting juice from blossoms. The juice collectors climb up the coconut trees, usually in the afternoon, and cut off the blossoms. The escaping sap is collected in bamboo tubes overnight and collected the next morning. The sap is filtered through a filter cloth and poured into a large pan. The content is then heated to evaporate the water with constant stirring until it thickens into a sticky brown, sugary substance. The sticky brown sugar is then poured into a container to cool down. Coconut (*Cocos nucifera* L.) sugar has a glycemic index (GI) value of 35 (Trinidad *et al*., 2010), while the sugar from sugarcane (*Saccharum officinarum* L.), sucrose (table sugar), and glucose have GI values of 58-82 (Saputro *et al*., 2007), 65 (Atkinson *et al*., 2008), and 103 (Atkinson *et al*., 2008), respectively. The GI value of coconut sugar suggests a healthier sugar than these alternatives. The universal method for analyzing the glycemic index (GI) of food is using an *in vivo* experiment involving sample collection from healthy volunteers – a difficult and highly costly method of analysis. Therefore, the purpose of this study is to demonstrate a convenient, quick and accurate method of classification of coconut sugar from sugarcane sugar and glucose. From the study, it was found that the Fourier transform near-infrared spectroscopy (FT-NIR) has the advantages of being non-destructive, fast analysis without the need for sample pretreatment. FT-NIR has been used to analyze sugars in fruit juices (Rodriguez-Saona *et al.*, 2001), glucose and fructose in lotus root powder (Nui *et al.*, 2012) and predict the quality characteristics of apple purees (Weijie *et al.*, 2020). Lapcharoensuk and Nakawajana (2018) used FT-NIR spectroscopy for the identification of syrup type, with the results showing FT-NIR spectroscopy has the potential to be used for syrup type identification. Omar (2013) reported that NIR spectral absorbance linearization and

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gradient shift has higher accuracy and precision for the measurement of water-sucrose solution. The partial least squares regression (PLSR) is a multivariate regression technique used in spectroscopic data analysis of agricultural products, such as predicting calcium in wine (Véstia *et al*., 2019), classifying maple syrup type (Lapcharoensuk and Nakawajana, 2018) and apple puree quality (Weijie *et al.*, 2020), and quantifying dilution in fresh coconut water (Richardson *et al*., 2019).

Coconut sugar is a well-known natural product in Samut Songkharm province, Thailand, which has been inherited for over 100 years. However, the substance has high hygroscopicity which often leads to an undesirable product. Therefore, this study was conducted with the objective to 1) study the absorption spectra of coconut sugar compared to the spectra of sucrose, glucose, and fructose, and 2) evaluate the moisture content of coconut sugar using FT-NIR spectroscopy.

2. Material and methods

2.1 Material

Fifty samples of 100% coconut sugar, made and distributed in Thailand, were purchased from local groceries in four provinces (Bangkok, Nakorn Pathom, Samut Sakorn, and Samut Songkhram), online, and from a community market in Samut Songkhram. All samples were stored at room temperature (25±2°C) in a plastic box.

2.2 Moisture content determination

The moisture content of all coconut sugar samples (from 6 different sources) were varied from approximately 1.4 to 6.5% by dropping distilled water into the samples and let them equilibrate for 24 hrs at room temperature. The moisture content was determined using infrared moisture analyzer model FD-660 (Kett Electric Laboratory, Japan). Five grams of sample were placed on a sample dish (ϕ 110 mm.) and measured with the FD-660 in "auto" mode. Measurements were done in 3 replicates.

2.3 FT-NIR spectra acquisition and processing

Prior to FT-NIR spectral data collection, four grams samples were packed in PE bags (size 2×3 inch^2) (Figure 1). The absorbance spectra of the samples were measured using the Frontier FT-NIR Spectrometer (PerkinElmer, model NIRA, Massachusetts, USA). Each sample spectrum was collected by using reflectance mode, in a scanning range of 4000-10000 cm^{-1}, and accumulating 60 scans. The FT-NIR spectra of each type were recorded with 3 replicates. The reference spectrum for absorbance measurement was collected through the PE bag. Since the principal carbohydrates of coconut sugar are sucrose, glucose, and fructose (Wrage *et al.*, 2019), the original spectra of coconut sugar were compared with the spectra of sucrose, glucose, and fructose (Univar Ajax Finechem, Australia).

Figure 1. The sample for FT-NIR measurement.

For the prediction model, the 54 samples were measured using infrared moisture analyzer model FD-660 (Kett Electric Laboratory, Japan) and used to create the model. The FT-NIR spectra of absorbance for moisture content of coconut sugar were exported to the PerkinElmer Spectrum Quant software (Version 10.6.0.893). The program for predicting moisture content was QuantPlus PLS1 (the partial least square regression technique). The process was obtained from spectra data after the application of spectral pre-processing techniques to reduce external interferences. Pre-processing techniques were applied to achieve maximum accuracy and reliability for the prediction model. The PLS regression was computed up to 10 components, and the optimum number of components was selected to minimize the prediction error. These components were used for the prediction model instead of the original spectra (Wold *et al.,* 2001).

3. Results and discussion

3.1 FT-NIR spectra of Thai coconut sugar

The FT-NIR absorption spectra of 54 coconut samples are shown in Figure 2. The FT-NIR absorption spectra of all coconut sugar samples were unique and differed from the FT-NIR absorption spectra of sucrose, glucose, and fructose, which was consistent with that of Lapcharoensuk and Nakawajana (2018). They reported that FT-NIR has a good potential in classifying syrup from different sources. The shape of the FT-NIR absorption spectra of all coconut sugar samples was similar to the spectra of sucrose, except the scanning range of 5379-5011 cm^{-1}, which was consistent with the sugar content in coconut sap. In coconut sap, sucrose content was found to be the highest (6.91%), while glucose content and fructose contents were 2.53% and 3.48%, respectively (Asghar *et al*., 2020). At the wavenumber 6900 cm^{-1} (1450 nm.) and 5160 cm^{-1} (1940 nm) was the absorption range of water (1940 nm, Combination OH stretching ± OH bending) (Osborne

eISSN: 2550-2166

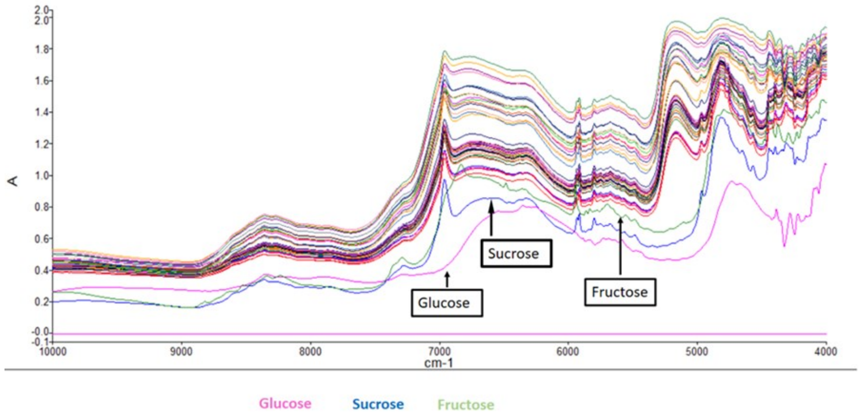


Figure 2. The FT-NIR absorption spectra of all coconut sugar samples, sucrose, glucose and fructose at wavelength 4000-10000 cm^{-1}.

and Fearn, 1986). The FT-NIR absorption spectra indicate that the chemical structure of coconut sugar has more water-like bonds than the spectra of sucrose, glucose, and fructose. The different evidence of FT-NIR absorption spectra of each sugar is distinguished. Thus, it is possible to identify coconut sugar by using FT-NIR spectroscopy for quick identification from other sugars with different GI values.

3.2 The FT-NIR spectra model for predicting moisture content in coconut sugar

The spectra obtained in the entire spectral range correspond to wavenumbers of 10,000– 4000 cm^{-1} for the non-destructive moisture content analysis of Thai coconut sugar. The FT-NIR spectra model for predicting moisture content in coconut sugar was based on PLS regression with pre-processing as shown in Table 1.

Table 1. The steps of created the prediction model

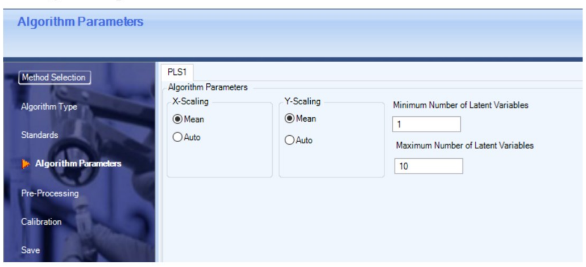
No.	Steps
1	Select Algorithm type "PLS1"
2.	Add standard
3.	3.1 Algorithm parameters: PLS1
	
	3.2 Pre-Processing
	

Table 1 demonstrates that the FT-NIR spectra model for predicting moisture content in coconut sugar has the best correlation with moisture content in Thai coconut sugar, with SEP 0.077 (less than 1) as shown in Figure 3, Figure 4, and Table 2. The results of this experiment are consistent with that of Sitorus *et al*. (2021), which found that the prediction equation from the FT-NIR spectroscopy can accurately predict the adulteration content in coconut milk.

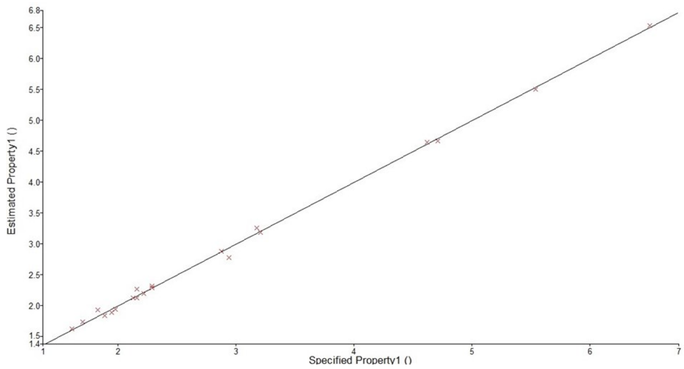


Figure 3. Comparison of the model prediction (estimated property) to the true moisture content (specified property) in coconut sugar.

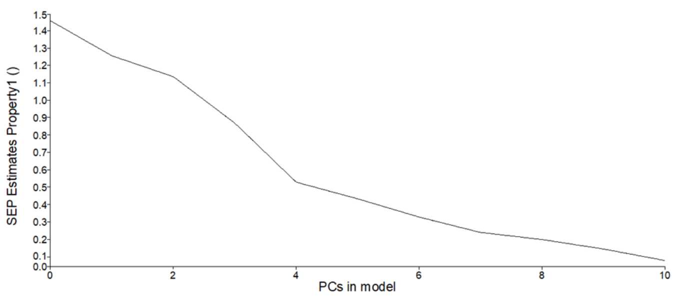


Figure 4. Model-SEP.

Table 2. The regression summary of the prediction model for moisture content (%) in Thai coconut sugar using FT-NIR spectra and PLS1 algorithm.

Parameter	Value
Number of PCs	10
% Variance	99.8642
Std. Error of Estimate (SEE)	0.06895
SEP	0.077

eISSN: 2550-2166

4. Conclusion

The results confirmed FT-NIR spectroscopy can be used to identify the type of Thai coconut sugar, which differ from other sugars such as sucrose, glucose, or fructose. FT-NIR spectroscopy is a non-destructive and rapid method to predict moisture content in coconut sugar. In the future, it should be applied to estimate the shelf life of Thai coconut sugar or to develop the packaging for Thai coconut sugar products.

Acknowledgements

The author would like to thank the Research and Development Institute, Rajamangala University of Technology Krungthep, Bangkok, Thailand for financial support. The author would also like to thank Assoc. Prof. Dr Saiwarun Chaiwanishsiri, from Chulalongkorn University, Bangkok, Thailand, for proofreading this research paper.

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