Journal of Food Engineering 190 (2016) 101–108

Contents lists available at ScienceDirect

Journal of Food Engineering

journal homepage: www.elsevier.com/locate/jfoodeng

Rapid assessment of black tea quality using diffuse reflectance spectroscopy

Niranjan Panigrahi*, Chandra Sekhar Bhol, Bhabani Sankar Das

Agricultural and Food Engineering Department, Indian Institute of Technology Kharagpur, West Bengal, 721302, India

A R T I C L E I N F O

Article history:
Received 26 October 2015
Received in revised form
1 June 2016
Accepted 23 June 2016
Available online 25 June 2016

Keywords:
Total polyphenol
Thearubigin
Theaflavin
Liquor brightness
Total liquor color
Partial-least-squares regression

A B S T R A C T

Tea quality assessment methods generally require elaborate sample preparation steps and often yield in consistent results. Over the last two decades, the diffuse reflectance spectroscopy (DRS) is emerging as a rapid and non-invasive tool for assessing quality parameters of several materials. In this study, we examined the DRS approach by creating a reflectance spectral imaging of 81 black crush, tear and curl (CTC) tea samples and eight tea quality parameters. Spectral models for each parameter were developed using the partial-least-squares regression (PLSR) approach. The ratio of performance deviation (RPD) was used to assess such spectral models. Results showed that moisture content, thearubigin components of TRSI and TRSII, total polyphenol contents and liquor brightness were accurately predicted with RPD values 3.63, 2.32, 2.24, 2.23 and 2.02, respectively. Prediction accuracies were moderate for thearubigin, total liquor color and theaflavin. The variable important projection (VIP) showed the wavelengths around near-infrared and shortwave-infrared regions strongly influence spectral reflectance of black tea.

1. Introduction

Tea is a preferred functional beverage among people around the globe. Introduced in about 3000 B.C., this flavored drink is known to have many medicinal properties. For instance, tea is known to reduce various cancers, boost immunity, enhance heart function and suppress aging (Sharangi, 2009; Xiong et al., 2015). Depending upon production and processing techniques, tea is categorized mainly into green tea, oolong tea, black tea and white tea. Black tea is a premium variety of fermented tea prepared by crushing, tearing and curling (CTC) operations (Vuong et al., 2011). In comparison with other tea varieties, black CTC tea is highly popular all over the world (Ren et al., 2013). In India, it accounts for about 70% of the total tea consumption (Laddi et al., 2012). In 2010, the global black tea production was estimated to be 2.4 million tonnes with 1.07 million tonnes produced alone in India accounting for 44% of the total global tea production (FAO). Rapid assessment of tea quality is an important step in the supply chain management of this large volume of production and use.

Generally, tea quality is determined by its color, brightness, taste and aroma of the brew. These quality parameters depend on the composition and concentration of several biochemical constituents (Arachchi et al., 2011; Dutta, 2013). During black tea processing, green tea leaves undergo enzymatic oxidation to from an orange red color pigment called theaflavin (TF), a poly-disperse dark brown color pigment called thearubigin (TR) and its groups such as TRSI and TRSII (Türkoğlu et al., 2010; Obanda et al., 2004). Theaflavin is responsible for liquor brightness (LB) and brisk taste, whereas TR contributes towards total liquor color (TLC) (Dutta et al., 2011). Considerable difference in brown color intensity within TR groups contributes to total color and possibly to LB of black tea (Obanda et al., 2004). The astringency taste and special flavor of the tea is governed by the total polyphenol (TP) contents (Bian et al., 2013). Moisture content (MC) is also an important factor that influences the physico-chemical reactions during tea processing and determines the shelf-life of tea (Li et al., 2012). Variation of these constituents results in the change of organoleptic properties, which influence tea quality and, in turn, consumer preference and market price of tea (Laddi et al., 2012; Yan, 2007).

Traditionally, tea quality is assessed by professional tea tasters. Such test results are often highly subjective and biased (Bian et al., 2012; Ren et al., 2013). Alternatively, analytical approaches are also used for determining the concentration of important biochemical present in tea. For instance, TP in tea samples may be determined by titration of brewed tea with potassium permanganate (ISO, 1994). Similarly, analytical methods may be used to determine

* Corresponding author.
E-mail address: panigrahin5@gmail.com (N. Panigrahi).

http://dx.doi.org/10.1016/j.jfoodeng.2016.06.020
0260-8774/

Table 1
Descriptive statistics of the black CTC tea quality parameters.

Tea quality parameters	Min	Max	Mean	STDEV	CV	Skewness	Kurtosis
TLC %	2.74	6.09	4.45	0.78	17.63	−0.32	−0.77
LB %	6.62	19.82	11.92	3.17	26.63	0.54	−0.54
TR (%; w/w)	8.57	17.98	13.74	1.96	14.30	−0.23	−0.42
TRSI (%; w/w)	1.19	7.31	3.88	1.39	35.93	0.08	−0.87
TRSII (%; w/w)	5.27	14.12	8.98	1.60	17.82	0.35	0.34
TF (%; w/w)	0.23	0.88	0.53	0.16	31.12	0.34	−0.77
TP (%; w/w)	7.63	17.24	11.89	2.07	17.38	0.06	−0.51
MC(%; w/w)	5.60	10.40	7.89	0.71	9.04	0.24	2.01

Min, Minimum; Max, Maximum; STDEV, Standard deviation; CV, Coefficient of variation (%); TLC, Total liquor color; LB, Liquor brightness; TR, Thearubigins; TRSI and TRSII, Thearubigin fractions; TF, Theaflavins; TP, Total polyphenol; MC, Moisture content.

phenolic compounds by spectroscopic techniques using their optical density (Roberts and Smith, 1963), catechins using high pressure liquid chromatography (Wang et al., 2003), and caffeines using a Fourier transform infrared spectroscopy (FTIR) based on absorption property measurements (Ohnsmann et al., 2002). However, most of these methods are time-consuming, tedious and expensive (He et al., 2007; Ren et al., 2013; Lee et al., 2014; Xiong et al., 2015).

Over the last few decades, the diffuse reflectance spectroscopy (DRS) technique in the visible (Vis), near-infrared (NIR) and shortwave-infrared (SWIR) region has emerged as a rapid, non-invasive and non-destructive technique for the assessment of tea quality. Several studies on the application of DRS for testing meats, fruits, vegetables, grains, dairy products, oils, fishes and beverages have been reported (Huang et al., 2008). For example, the DRS approach has been used for the determination of theaflavin (Hall et al., 1988), total polyphenol (Chen et al., 2006a, 2006b; Bian et al., 2010; Bian et al., 2013; Xiong et al., 2015), moisture content (Hall et al., 1988; Li et al., 2012), free amino acids (Bian et al., 2010, 2013; Ren et al., 2013), soluble sugars (Bian et al., 2013), pH (Li and He, 2010), antioxidant capacity (Zhang et al., 2004), caffeine (Chen et al., 2006a, 2006b; Ren et al., 2013; Lee et al., 2014), and soluble solid content (Li et al., 2007; Li and He., 2010). Spectral

Table 2
Correlation analysis of black CTC tea quality parameters.

Tea quality parameters	TLC	LB	TR	TRSI	TRSII	TF	TP	MC
TLC	1.00							
LB	−0.16	1.00						
TR	0.87[b]	−0.32[b]	1.00					
TRSI	0.79[b]	0.14	0.64[b]	1.00				
TRSII	0.67[b]	−0.56[b]	0.85[b]	0.27[a]	1.00			
TF	0.45[b]	0.77[b]	0.27[a]	0.63[b]	−0.07	1.00		
TP	0.50[b]	0.38[b]	0.25[a]	0.66[b]	−0.07	0.62[b]	1.00	
MC	0.12	−0.48[b]	0.32[b]	−0.12	0.52[b]	−0.32[b]	0.35[b]	1.00

TLC, Total liquor color; LB, Liquor brightness; TR, Thearubigins; TRSI and TRSII, Thearubigin fractions; TF, Theaflavins; TP, Total polyphenol; MC, Moisture content.
[a] Significant at 5% level of significance.
[b] Significant at 1% level of significance.

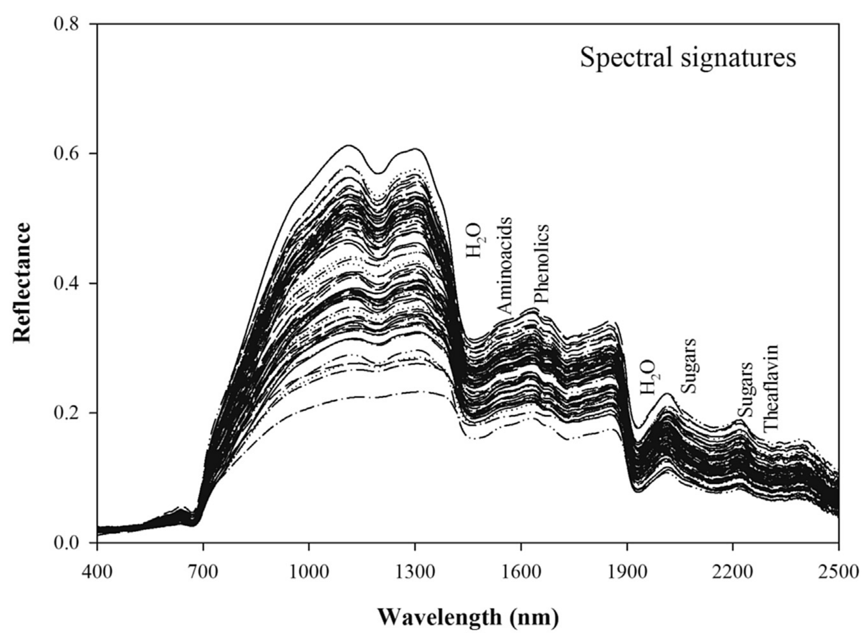

Fig. 1. Spectral reflectance of 81 black CTC tea samples as a function of wavelength