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RESEARCH ARTICLE

Physico-chemical, Antioxidant and Sensory Attributes of Ginger (*Zingiber officinale*) Enriched Jaggery of Different Sugarcane Varieties

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Abstract *Zingiber officinale* enriched jaggery of three sugarcane varieties (Co 86032, Co 419 and Co 62175) at 0.05, 0.1 and 0.2 % *Z. officinale* concentrations were evaluated for physico-chemical properties, 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging and reducing power ability, in addition to sensory evaluation by quantitative descriptive analysis method. Physico-chemical analysis of *Z. officinale* enriched jaggery revealed no significant difference between test and control except for total phenolics, tannins and flavonoids that indicated a dose dependent increase for all the varieties. A positive correlation (r = 0.922, 0.883 and 0.881) was observed between total phenolics and antioxidant activity of *Z. officinale* enriched jaggery for all the test varieties. Results of DPPH radical scavenging ability and reducing power potential of *Z. officinale* enriched jaggery showed an increased antioxidant activity. An EC_{50} of 3.098, 3.076 and 3.038 mg/mL was observed in 0.2 % *Z. officinale* enriched jaggery prepared from Co 86032, Co419 and Co 62175, respectively. Sensory evaluation of *Z. officinale* enriched jaggery for different attributes indicated significant ($P > 0.05$) difference between control and enriched jaggery of different sugarcane varieties for color, texture, hardness and taste.

Keywords Jaggery · *Zingiber officinale* · Antioxidant activity · Sensory evaluation

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Abbreviations

BHT	Butylated hydroxytoluene
DPPH	1,1-Diphenyl-2-picrylhydrazyl
QDA	Quantitative descriptive analysis
BHA	Butylated hydroxyanisole
TBHQ	*tert*-Butyl hydroquinone
TCA	Trichloroacetic acid
BSA	Bovine serum albumin
GAE	Gallic acid equivalent
QE	Quercetin equivalent
TAE	Tannic acid equivalent
EC_{50}	Effective concentration for 50 % inhibition

Introduction

The control of oxidative processes during food processing and storage has an impact on the food quality. The oxidized food leads to off-flavors and decreases the organoleptic and nutritional quality of processed foods. Many synthetic antioxidants are in use in food industry to prevent oxidation in foods, but their usage is restricted for their toxicity issues (Botterweck et al. 2000). Plant and plant products serves as a source of natural antioxidants to improve the quality and nutritional value of foods. Among natural antioxidants, phenolic compounds are of special interest due to their wide distribution in the plant kingdom and potential antioxidant activity. Sugarcane contains various phenolic compounds and its extracts have displayed a wide range of biological activities including antioxidant, anti-inflammatory, anti-thrombosis, immune-stimulation and anti-stress effects (El-Abasy et al. 2002; Molina et al. 2000; Ledon et al. 2003; Duarte-Almeida et al. 2006).

Jaggery, a sugar rich plant product consumed worldwide is prepared traditionally by concentrating the juice of sugarcane (*Saccharum officinarum*). Jaggery has great nutritive and medicinal value. Indian Ayurvedic medicine considers jaggery as medicinal sugar for treating throat and lung infections. In vivo studies reported that a dietary supplement of jaggery was found to exhibit health benefits. Dietary jaggery reduced the development of atherosclerosis (Okabe et al. 2009), lowered the incidence of chromosomal aberration due to arsenic toxicity (Nrashanth et al. 2008) and exhibited protective effect against lung damage induced by coal, silica dust and other particulate matter (Sahu and Saxena 1994). Jaggery being a least processed sugar retains phenolics and other phytochemicals with potent biological activities like antioxidant, cytoprotective and anthelmintic activity as reported in literature (Harish Nayaka et al. 2009; Prasad et al. 2010).

Nutraceuticals are widely incorporated in functional foods owing to their therapeutic and health promoting effects. Jaggery enrichment with nutraceuticals may have an added health benefits. The use of and search for plant nutraceuticals for food enrichment have accelerated in recent years. Except the studies on jaggery fortification with vitamin C—Indian gooseberry (Anwaar and Singh 2010) and sensory studies of jaggery chocolates (Khan Chand et al. 2011), the literature lacks information on jaggery enrichment with spices for their flavor and medicinal properties. Spices are esoteric food adjuncts used not only as a flavoring and coloring agents but also as folk medicine and food preservatives (Nakatani 1994; Cutler 1995). Ginger root (*Zingiber officinale*) is a rhizome belonging to the family Zingiberaceae, used medicinally and as a spice and food additive since antiquity for its characteristic flavor and pungency. Asian folk medicine uses ginger to treat a diverse array of ailments and has exhibited various pharmacological activities and as a food preservative (Shukla and Singh 2007; Nicoll and Henein 2009).

Therefore, studies on enrichment of jaggery with spices may lead to a better understanding of the effect of spice phytochemicals on various physico-chemical properties of jaggery. Hence, the present investigation is undertaken to evaluate physico-chemical properties, antioxidant activity and sensory evaluation of *Z. officinale* enriched jaggery from different sugarcane varieties.

Materials and Methods

Chemicals

1,1-Diphenyl-2-picrylhydrazyl (DPPH) purchased from Himedia Laboratories, Mumbai, India and Trolox from Biomol Research Labs, Inc., USA. Coomassie Brilliant Blue G-250, Gallic acid, Trichloroacetic acid (TCA), Butylated hydroxytoluene (BHT) and Bovine serum albumin (BSA) procured from SISCO Research Laboratories Pvt. Ltd., Mumbai, India.

Sugarcane Varieties

Different varieties of sugarcane, viz. Co 86032, Co 419 and Co 62175 were procured from Zonal Agricultural Research Station, V. C. Farm, Mandya 571 405, Karnataka. All the sugarcane varieties obtained were cultivated in the same plot with similar management regimes.

Zingiber officinale enriched jaggery preparation

Zingiber officinale enriched jaggery was prepared following the method described by Jagannadha Rao et al. (2007). *Z. officinale* dried powder at different concentrations (0.05, 0.1 and 0.2 %) was added to sugarcane juice extracted from different sugarcane varieties and pH was adjusted to 6.6 using Milk of Lime [$Ca(OH)_2$]. The juice was initially boiled for 10 min and the scum formed during boiling was completely removed through filtration using muslin cloth. Finally, the juice was heated and concentrated to thick syrup until the temperature reaches 118 °C. The scum formed after subsequent boiling was completely removed. The syrup was cooled and transferred to chocolate moulds to obtain desired shapes. Jaggery prepared without the addition of *Z. officinale* served as control. All the samples were stored at 4 °C in a sealed container for further analysis.

Physico-chemical Characterization

pH

pH was determined with a pH meter (Systronics India Pvt. Ltd., India) in a 5 % w/v jaggery solution at room temperature (Guerra and Mujica 2010).

Color

The color of jaggery in 5 % w/v solution was determined at 540 nm using visible spectrophotometer (Systronics India Ltd. Gujarat, India) with slight modification (Mandal et al. 2006).

Turbidity

The turbidity of jaggery was determined according to the method described by Guerra and Mujica (2010) with slight modification. Jaggery (5 %, w/v) was divided into two

portions. One portion filtered through Whatmann No. 1 filter paper using siliceous earth as filtering aid was used as blank. The second portion was used to measure the percentage of transmittance at 720 nm using a visible spectrophotometer.

Filterability

Filterability of jaggery was measured following the method described by Guerra and Mujica (2010). The rate of filtration of 5 % jaggery solution was compared to solution of pure sucrose, under the same conditions. Two hundred milliliters of pure sucrose (28^0 Brix) solution was filtered through Whatmann No. 1 filter paper and after 3 min, the filtered volume measured and the procedure was repeated for jaggery samples. The percentage of filterability was calculated using the ratio of filtered volumes.

Insoluble Solids

Insoluble solids quantified as per the modified method described by Guerra and Mujica (2010). One gram of jaggery was dissolved in distilled water and filtered through Whatmann No. 1 filter paper. The residue on the filter paper was dried and weighed. The insoluble solids were expressed in percentage on dry weight basis.

Water Activity (a_w)

Water activity was determined using a water activity meter (Novasina, Switzerland) with technology based on the resistive electrolytic measurement principle.

Moisture, Protein, Ash, Reducing Sugars and Sucrose

Moisture, protein, ash, reducing sugars, sucrose content of jaggery was determined following the methods of Official AOAC (Helrich 1990). Results were expressed in percent on dry weight basis (except moisture).

Determination of Total Phenol Content

The total phenol content of jaggery was determined spectrophotometrically using Folin-Ciocalteu's method (Singleton et al. 1999). A sample aliquot of 100 µL (5 %) was added to 900 µL of water, 1 mL of Folin-Ciocalteu reagent (1:2, v/v) and 2 mL of 10 % sodium carbonate sequentially, mixed thoroughly and incubated for one hour at room temperature. The absorbance was measured at 765 nm in visible spectrophotometer. Gallic acid was used as standard and the total phenolic content expressed as milligrams of Gallic acid equivalent (GAE) per gram sample.

Determination of Total Flavonoid Content

The total flavonoid content of jaggery was determined according to aluminium chloride method (Chang et al. 2002). A sample aliquot of 200 µL (5 %) was made up to 2 mL with distilled water. 100 µL of 10 % aluminium chloride and 100 µL of 1 M potassium acetate were added and incubated for 30 min at room temperature. The absorbance of the reaction mixture was read at 415 nm. Quercetin was used as standard and total flavonoid content expressed in micrograms of quercetin equivalent per gram sample.

Determination of Tannin Content

The tannin content of jaggery was determined according to Folin–Ciocalteu's method (Singleton et al. 1999). A sample aliquot of 100 µL (5 %) was added to 900 µL of water, 1 mL of Folin–Ciocalteu reagent (1:2, v/v) and 2 mL of 10 % sodium carbonate, mixed thoroughly and incubated for 1 h at room temperature. The absorbance was measured at 765 nm in visible spectrophotometer. Tannin acid was used as a standard and the total tannin content expressed as milligrams of tannic acid equivalent (TAE) per gram sample.

Antioxidant Activity

DPPH Radical Scavenging Activity

The DPPH radical scavenging activity of jaggery was evaluated as per the method described by Yamaguchi et al. (1998). An aliquot (l0–50 µL) of 10 % jaggery samples and standard antioxidant (BHT) of various concentrations were made up to 200 µL using distilled water and then mixed with 1 mL of 0.1 mM DPPH in methanol. The mixture was shaken vigorously and allowed to stand for 20 min in the dark at room temperature. The absorbance of the resulting solution was read against control at 517 nm using a spectrophotometer. The ability to scavenge DPPH radical was calculated using the following equation.

$$\text{DPPH Radical Scavenging ability } (\%) = \left[\left(A_{\text{Control}} - A_{\text{sample}}\right)/A_{\text{Control}}\right] \times 100$$

An effective concentration (EC_{50}) for 50 % DPPH radical scavenging activity was also calculated.

Reducing Power Assay

The reducing power of jaggery was determined according to the method reported earlier (Yen and Chen 1995). Different concentrations of jaggery (1–5 mg/mL) or standard antioxidant Trolox (10–50 µg/mL) was mixed with an

equal volume of 0.2 M Phosphate buffers, pH 6.6 and 1 % potassium ferricyanide. The mixture was incubated at 50 °C for 20 min. An equal volume of 10 % trichloroacetic acid was added to the mixture and centrifuged at 3,000*g* for 10 min. The upper layer of the solution was mixed with distilled water and 0.1 % $FeCl_3$ at a ratio of 1:1:2 (v/v/v) and the absorbance measured at 700 nm. The increased absorbance of the reaction mixture indicated increased reducing power.

Sensory Attributes

Zingiber officinale enriched jaggery were evaluated for sensory attributes like color, texture, hardness, chewiness, sweetness, saltiness, pleasantness, spicy and overall acceptance by unstructured scaling method or quantitative descriptive analysis (QDA) (Stone et al. 1974). The panel consisted of 20 people in the group of 20–50 years comprising both male and female, often participated in sensory evaluation of jaggery samples. The descriptors of sensory attributes explained orally to the panelists. Information on *Z. officinale* enriched jaggery was given to a panelist; however, they lacked knowledge of varying percent and type of cane variety. The scorecard consisted of a horizontal line 15 cm long with anchor points 1.5 cm from each end. Each anchor point labeled with a word or expression. A separate horizontal line used for each sensory attribute evaluated. Panelists asked to record each evaluation, by marking a vertical line across the horizontal line at the point according to their intensity or perception of the magnitude of each attribute.

Coded jaggery samples in individual re-sealable bags were served to panelist one at a time and the presentations of the samples randomized. Panelists provided with water and asked to rinse their mouth after evaluating each sample. After the panelist judgment, the distance from the left end of the line to each point marked by the panelist measured and the distance measured recorded as intensity rating between 0.0 and 15.0 for each product evaluated and analyzed statistically.

Statistical Analysis

All the experiments were carried out in triplicates ($n = 3$) and the results expressed as mean ± standard deviation (SD) using Microsoft Excel software. The sensory scores subjected to analysis of variances (ANOVA) to determine statistically significant ($P \leq 0.05$) preferences in sensory attributes. Post hoc comparisons made by least significant difference (LSD) and Duncan's multiple range test (DMRT). IBM SPSS Statistical software version 19.0 used to analyze the results.

Results and Discussion

Physico-chemical Characterization of *Z. officinale* Enriched Jaggery

The results of physical properties like pH, color, moisture, turbidity, filterability, insoluble solids, water activity and ash content of *Z. officinale* enriched jaggery are represented in Table 1.

The pH of *Z. officinale* enriched jaggery and its controls of all sugarcane varieties were in the range of 5.66–5.87 that supports the results reported by Guerra and Mujica (2010).The observed pH of jaggery was marginally lower than 5.9 as prescribed by Ecuadorian technical standard (2002) for panela. Lowered pH of jaggery may be due to deficiency of lime added for juice clarification.

Based on the absorbance at 540 nm, the color intensity of jaggery was appraised. Color of jaggery finds to be the primary factor for consumer preference and market, and is dependent on dark compounds formed during processing. Jaggery browning occurs due to caramelization of sugars, oxidation of phenolic compounds, alkaline decomposition of sucrose or by Maillard reaction (Damodaran 2000). *Z. officinale* enrichment jaggery of all sugarcane varieties showed elevated absorbance with increased concentration of *Z. officinale* compared to its respective controls. Control jaggery (0 %) of Co 86032 variety had least color (golden brown) among all controls and enriched jaggery. Hence, darkened color was resulted in all sugarcane variety jaggery upon enrichment with *Z. officinale*.

Moisture content and water activity are two important parameters determine the quality, stability and shelf-life of foods during storage. *Z. officinale* enrichment showed a marked increase (1 %) in moisture content at 0.05 % concentration for Co 86032 and Co 62175 jaggery but a very slight increase in moisture content observed for Co 419 jaggery at the same concentration. In addition, moisture content of jaggery further increased with increase *Z. officinale* concentrations in all sugarcane varieties. Variation in moisture content within the varieties occurs during jaggery processing at the final stages. Water activity, a_w represents the water status in the food system and governs microbial growth (Beuchat 1987; Troller and Christian 1978). a_w of *Z. officinale* enriched jaggery was varied between six and 7 and the results were similar to the results reported for panela (Guerra and Mujica 2010). However, marginally synergism lowering of a_w observed in *Z. officinale* enriched jaggery of all three sugarcane varieties. These results indicated that *Z. officinale* enrichment could offer better shelf-life and promising quality for jaggery during storage. However, a_w in the range 0.60–0.65 finds to be the optimum condition for growth osmophilic and xerophilic microbes such as *Aspergillus euinulatus,*

Table 1 Physical properties of Ginger (*Z. officinale*) enriched jaggery from different sugarcane varieties (Mean ± standard deviation)

Sugarcane variety	Co 86032				Co 419				Co 62175			
Z. officinale Concentration	0 % Ctrl	0.05 %	0.1 %	0.2 %	0 % Ctrl	0.05 %	0.1 %	0.2 %	0 % Ctrl	0.05 %	0.1 %	0.2 %
pH	5.80 ± 0.04	5.81 ± 0.04	5.81 ± 0.04	5.82 ± 0.04	5.69 ± 0.01	5.66 ± 0.01	5.66 ± 0.01	5.67 ± 0.01	5.82 ± 0.02	5.85 ± 0.02	5.87 ± 0.02	5.85 ± 0.02
Colour (OD at 540 nm)	0.798 ± 0.004	1.067 ± 0.004	1.067 ± 0.004	1.067 ± 0.004	0.905 ± 0.004	1.213 ± 0.004	1.435 ± 0.004	1.657 ± 0.004	1.157 ± 0.01	1.356 ± 0.015	1.359 ± 0.012	1.362 ± 0.014
Moisture (%)	5.1 ± 0.04	6.025 ± 0.04	6.121 ± 0.040	6.579 ± 0.040	5.625 ± 0.03	5.638 ± 0.03	5.750 ± 0.03	5.936 ± 0.03	4.8 ± 0.01	5.851 ± 0.01	5.894 ± 0.01	5.923 ± 0.01
Turbidity (% Transmittance at 700 nm)	36.2 ± 0.04	38.7 ± 0.04	41.9 ± 0.04	44.3 ± 0.04	29.6 ± 0.03	31.5 ± 0.03	35.0 ± 0.03	38.8 ± 0.03	19.6 ± 0.04	20.6 ± 0.04	21.5 ± 0.04	23.5 ± 0.04
Filterability (%)	79.17 ± 0.02	80.0 ± 0.02	82.92 ± 0.02	84.21 ± 0.04	70.83 ± 0.03	76.04 ± 0.03	76.54 ± 0.03	77.08 ± 0.03	64.58 ± 0.02	79.88 ± 0.02	80.21 ± 0.02	81.25 ± 0.02
Insoluble solids (g/100 g)	5.34 ± 0.02	6.71 ± 0.02	7.55 ± 0.02	8.55 ± .02	7.39 ± 0.02	8.35 ± 0.02	8.54 ± 0.02	8.74 ± 0.02	7.53 ± 0.02	8.59 ± 0.02	9.28 ± 0.02	9.97 ± 0.02
Water Activity, a_w (%)	0.699	0.714	0.671	0.658	0.678	0.674	0.662	0.629	0.689	0.659	0.629	0.621
Ash (%)	0.03	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.03	0.04	0.04	0.04

*Aspergillus candidus, Aspergillus chevalieri, Saccharomyces rouxii*and *Saccharomyces bisporus* and thus supports their growth on jaggery and results in spoilage (Beuchat 1981).

Turbidity of *Z. officinale* enriched jaggery quantified by measuring percentage transmittance at 720 nm. *Z. officinale* enriched jaggery of all sugarcane varieties showed a gradual increase in turbidity from its control with dose dependent enrichment. Both control and enriched jaggery of Co 62175 variety found to show lower turbidity than Co 86032 and Co 419 variety's jaggery. About 8–9 %, increase in turbidity was observed between control and enriched jaggery at 0.2 % *Z. officinale* concentration in both Co 86032 and Co 419 variety's jaggery. Increased turbidity of *Z. officinale* enriched jaggery demonstrated that *Z. officinale* could be the last option for juice clarification.

Zingiber officinale enriched jaggery showed a marginal increase in filterability upon spice enrichment with its control of Co 86032 variety. However, results showed initial remarkable increased (6 and 15 %) filterability at 0.05 % *Z. officinale* enriched jaggery of the varieties Co 419 and Co 62175 respectively than its control and slightly progressive increased filterability with increase in *Z. officinale* enrichment. In addition, *Z. officinale* enriched jaggery showed continuous raise in insoluble solid contents with dose enhanced spice enrichment but the ash content was differed by 0.01 % in enriched jaggery of all sugarcane varieties irrespective of their *Z. officinale* concentrations from its control.

The results of chemical properties like sucrose, reducing sugars, proteins, total phenols, tannins and total flavonoids of *Z. officinale* enriched jaggery are represented in Table 2.

Sucrose and reducing sugar content of *Z. officinale* enriched jaggery of different sugarcane varieties showed no significant difference upon *Z. officinale* addition from its control. However, a very marginal increase in both sucrose and reducing content observed for all sugarcane variety's jaggery upon *Z. officinale* enrichment and followed dose dependent spice addition.

Protein content of *Z. officinale* enriched jaggery as determined by Bradford's method indicated no significant difference in protein content between enriched and control of Co 86032 and Co 419 variety's jaggery. *Z. officinale* enrichment showed a synergistic increase in protein content for Co 62175 jaggery and about 0.4 mg/g of protein content enhanced at 0.2 % *Z. officinale* addition than its control.

A dose dependency increase in total phenol, tannin and flavonoid contents was resulted in *Z. officinale* enriched jaggery in all sugarcane varieties. Jaggery prepared from Co 86032, Co 419 and Co 62175 exhibited increase in 11.1, 12.0 and 16.5 % phenol; 15.4, 14.6 and 16.2 % tannin and 10.6, 6.7 and 7.7 % flavonoid contents, respectively from its control at 0.05 % *Z. officinale* enrichment.

Table 2 Chemical properties of Ginger (*Z. officinale*) enriched jaggery from different sugarcane varieties (Mean ± standard deviation)

Sugarcane variety	Co 86032				Co 419				Co 62175			
Z. officinale Concentration	0 % Ctrl	0.05 %	0.1 %	0.2 %	0 % Ctrl	0.05 %	0.1 %	0.2 %	0 % Ctrl	0.05 %	0.1 %	0.2 %
Sucrose (%)	71.44 ± 0.01	71.53 ± 0.01	71.63 ± 0.01	71.66 ± 0.01	72.76 ± 0.01	72.44 ± 0.01	72.45 ± 0.01	72.76 ± 0.01	73.00 ± 0.02	73.57 ± 0.02	73.64 ± 0.02	73.69 ± 0.02
Reducing sugar (%)	17.28 ± 0.02	17.34 ± 0.02	17.54 ± 0.02	17.65 ± 0.02	17.09 ± 0.01	17.72 ± 0.01	17.82 ± 0.01	17.82 ± 0.01	17.42 ± 0.02	17.42 ± 0.02	17.43 ± 0.02	17.46 ± 0.02
Protein (mg/g)	0.93 ± 0.01	0.93 ± 0.01	1.05 ± 0.01	1.07 ± 0.01	1.09 ± 0.02	1.14 ± 0.02	1.16 ± 0.02	1.18 ± 0.02	1.21 ± 0.04	1.29 ± 0.04	1.46 ± 0.04	1.65 ± 0.04
Total Phenol (mg/g)	3.16 ± 0.04	3.51 ± 0.04	3.65 ± 0.04	3.81 ± 0.04	3.43 ± 0.05	3.84 ± 0.05	3.94 ± 0.05	4.06 ± 0.05	3.76 ± 0.02	4.38 ± 0.02	4.79 ± 0.02	5.09 ± 0.02
Total Tannins (mg/g)	4.48 ± 0.03	5.17 ± 0.03	5.39 ± 0.03	5.61 ± 0.03	4.86 ± 0.04	5.57 ± 0.04	5.76 ± 0.04	5.95 ± 0.04	5.32 ± 0.04	6.18 ± 0.04	6.31 ± 0.04	6.58 ± 0.04
Total Flavanoids (mg/ml)	0.47 ± 0.02	0.52 ± 0.02	0.56 ± 0.02	0.58 ± 0.02	0.60 ± 0.02	0.64 ± 0.02	0.69 ± 0.02	0.76 ± 0.02	0.65 ± 0.02	0.70 ± 0.02	0.75 ± 0.02	0.80 ± 0.02

Antioxidant Activity of *Z. officinale* Enriched Jaggery

Antioxidant activity of *Z. officinale* enriched jaggery was measured by two in vitro assays, i.e., DPPH radical scavenging ability and reducing power assay. The antioxidant activity of plant extracts containing polyphenols is due to their ability to be donors of hydrogen atoms or electrons and to capture the free radicals. DPPH assay is one of the tests used to prove the ability of the components of the *Z. officinale* enriched jaggery to act as donors of hydrogen atoms. DPPH is a stable free radical, and in its radical form absorbs at 517 nm whose absorption decreases after acceptance of an electron or hydrogen atom from an antioxidant due to the formation of its non-radical form DPPH-H (Blios 1958). The degree of decolorization of DPPH is a stoichiometric measure of the antioxidant potential of test samples. The scavenging ability of *Z. officinale* enriched jaggery of all three sugarcane varieties were expressed in terms of EC_{50} values as shown in Table 3. All enriched jaggery showed concentration dependent free radical scavenging activity. *Z. officinale* enrichment decreased EC_{50} concentration than its control jaggery irrespective of sugarcane varieties. At 0.2 % enrichment, Jaggery of Co 86032, Co 419 and Co 62175 had EC_{50} of 3.098, 3.076 and 3.038 mg/mL, respectively. EC_{50} of BHT, used as standard was 7.5 µg/mL. Both enriched and control jaggery showed higher (450 folds) EC_{50} concentration than standard BHT. Results of DPPH radical assay showed a positive correlation ($r = 0.922$, 0.883 and 0.881) with total phenolics of Co 86032, Co 419 and Co 62175 jaggery, respectively. High correlations between total phenolics and scavenging of DPPH radical indicated that polyphenols present in the *Z. officinale* enriched jaggery are the main antioxidants.

Further, reducing capacity assay provides a measure of compound's ability to donate electrons and reduce the oxidized intermediates formed in peroxidation process. The assay is based on the reduction of Fe^{+3}-ferricyanide complex that is monitored by measuring the formation of perl's blue at 700 nm. Increasing absorbance indicates an increase in reductive ability (Olayinka and Anthony 2010). Since reducing power of a compound serves as a significant indicator of its antioxidant activity (Meir et al. 1995), *Z. officinale* enriched jaggery assayed for reducing power ability. In Fig. 1, *Z. officinale* enriched jaggery of all cane varieties exhibited in vitro ferric reducing potential in a dose dependent manner. The absorbance of enriched jaggery at 700 nm had increased with increase in spice enrichment than its respective controls. Trolox, used as a standard showed absorbance of 1.39 at 50 µg/mL. The reducing potential of *Z. officinale* enrich jaggery (0.2 %) increased by 23.22, 26.00 and 24.53 % than its control of Co 86032, Co 419 and Co 62175, respectively.

Table 3 DPPH radical scavenging activity of Ginger (*Z. officinale*) enriched jaggery from different sugarcane varieties (Mean ± standard deviation)

Sugarcane variety	Co 86032				Co 419				Co 62175				Standard Antioxidant BHT
Z. officinale Concentration	0 % Ctrl	0.05 %	0.1 %	0.2 %	0 % Ctrl	0.05 %	0.1 %	0.2 %	0 % Ctrl	0.05 %	0.1 %	0.2 %	
EC_{50} in mg/mL	3.624 ± 0.061	3.500 ± 0.132	3.161** ± 0.120	3.098** ± 0.076	3.622 ± 0.032	3.457* ± 0.056	3.345* ± 0.110	3.076 ± 0.026	3.886 ± 0.154	3.847** ± 0.029	3.635* ± 0.050	3.038** ± 0.022	0.0075

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

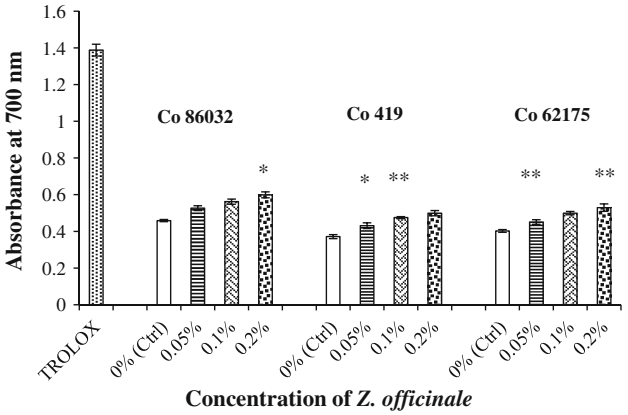

Fig. 1 Reducing power of Ginger (*Z. officinale*) enriched jaggery (5 mg/mL) from different sugarcane varieties and standard Trolox antioxidant (50 μg/mL) (*$P < 0.05$; **$P < 0.01$, ***$P < 0.001$)

Natural antioxidants play an important role in the prevention and interception of oxidative damage and have great impact on the safety and acceptability of the food system. They keep the food stable against oxidation and act as a potent preservative by controlling microbial growth. The traditional practice of adding antioxidants during processing can still play a very important role as added compounds have additional potential for enhancing endogenous antioxidant systems. In addition, antioxidant activity of plant is often associated with polyphenols that with hydrogen donating capacity inhibits free radical induced oxidation (Yen et al. 1993). The phenolic compounds of sugarcane juice exhibited antioxidant potential (Duarte Almeida et al. 2006) and conferred various biological activities. The antioxidant compounds extracted from jaggery showed stronger antioxidant potential than BHT in earlier reports (Nakasone et al. 1996). In our own studies (Harish Nayaka et al. 2009) jaggery showed strong DPPH radical scavenging ability (EC_{50} − 7.81 μg/mL) and reducing capacity with absorbance of 2.66 at 20 mg/mL at 700 nm. A plant-derived food additive, especially polyphenolic compounds has been ascribed health-promoting properties, as for example in terms of prevention of chronic cardiovascular diseases (Harborne and Williams 2000). *Z. officinale* rhizome used as spices and condiments in many food preparations found to possess both in vitro and in vivo antioxidant action and protection against free radical damage (Masuda et al. 2004; Ahmed et al. 2000). In addition, active ingredients of rhizome also contributed for a wide array of biological activities (Young et al. 2005). In present investigation, *Z. officinale* enrichment during jaggery processing resulted synergistic increase in both total phenolic content and anti-oxidative potential of jaggery, and hence the combination of nutritional and medicinal benefits determines ginger-jaggery as a functional food.

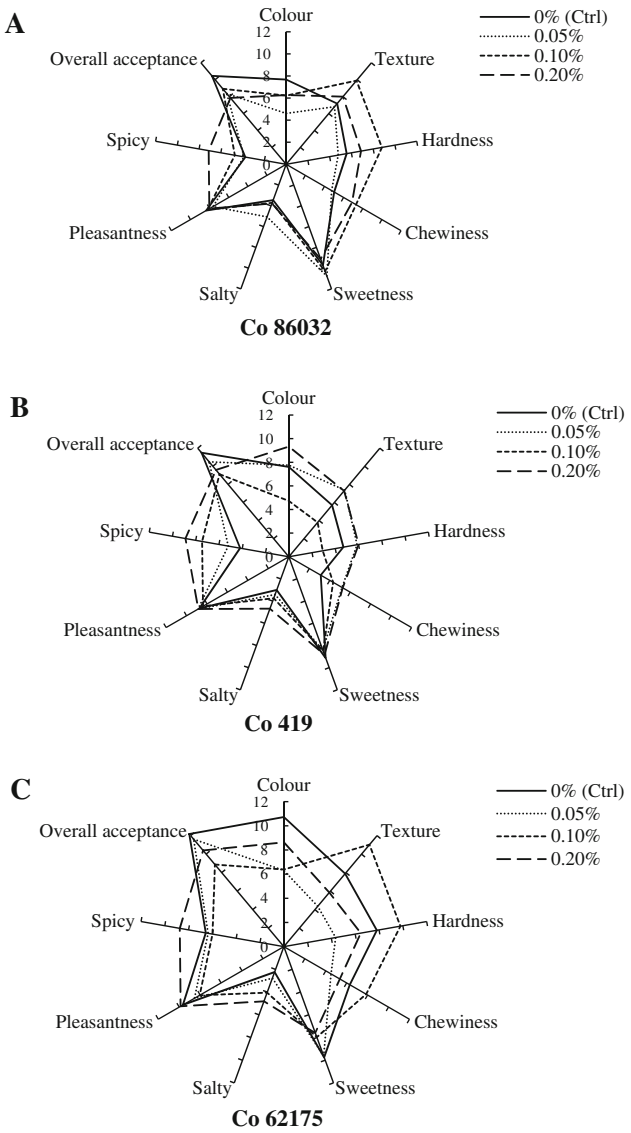

Fig. 2 Star diagram of sensory attributes of Ginger (*Z. officinale*) enriched jaggery from Co 86032 (**a**), Co 419 (**b**) and Co 62175 (**c**) sugarcane varieties

Sensory Attributes of *Z. officinale* Enriched Jaggery

Sensory attributes such as color, texture, hardness, chewiness, sweetness, salty, pleasantness, spicy and overall acceptance of *Z. officinale* enriched jaggery of three sugarcane varieties were evaluated by a quantitative descriptive analysis method (Fig. 2). *Z. officinale* enriched jaggery of Co 86032, Co 419 and Co 62175 had showed a statistical significant difference for sensory attributes such as color, texture, hardness, chewiness and spicy. However, data indicated texture, hardness, chewiness and spicy attributes enhanced in dose dependent *Z. officinale* enrichment. Neither sweetness nor pleasantness altered upon spice enrichment but panelist preferred much acceptance for control jaggery than *Z. officinale* enriched jaggery.

Conclusions

The results of the present investigation revealed that the addition of *Z. officinale* dried powder during jaggery preparation from different sugarcane varieties indicated an enhanced phenolic content and antioxidant potential as evidenced by DPPH radical scavenging and reducing power assays. The sucrose and reducing sugar content of *Z. officinale* enriched jaggery not affected upon enrichment of *Z. officinale*. The sweetness and pleasantness of jaggery were same as that of the control for all sugarcane varieties tested. Hence, *Z. officinale* enriched jaggery used as a substitute for regular jaggery with additional health benefits.

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