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DR. FAIZA ASHFAQ (Orcid ID : 0000-0001-8816-3936)

MR. AHMAD BILAL (Orcid ID : 0000-0002-1834-3357)

DR. HAFIZ ANSAR RASUL SULERIA (Orcid ID : 0000-0002-2450-0830)

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Comparing application of conventional and supercritical CO_2 extracts of green tea on coriander sauce in terms of storage stability and sensory acceptance

Faiza Ashfaq[1], Ahmad Bilal[2], Masood Sadiq Butt[3], Saima Tehseen[1], Muhammad Nadeem Akhtar[2] and Hafiz Ansar Rasul Suleria*[4,5,6]

[1]Department of Food Science and Technology, Faculty of Science and Technology, Government College Women University Faisalabad, Pakistan

[2]University Institute of Diet and Nutritional Sciences, Faculty of Allied Health Sciences, The University of Lahore, Lahore, Pakistan

[3]National Institute of Food Science and Technology, Faculty of Food, Nutrition & Home Sciences, University of Agriculture, Faisalabad, Pakistan

[4]UQ Diamantina Institute, Translational Research Institute, Faculty of Medicine, The University of Queensland, 37 Kent Street Woolloongabba, Brisbane, QLD 4102, Australia

[5]Centre for Chemistry and Biotechnology, School of Life and Environmental Sciences, Deakin University, Pigdons Road, Waurn Ponds, Victoria 3216, Australia

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[6]School of Agriculture and Food, The University of Melbourne, Parkville, VIC 3010, Australia

*Corresponding author: hafiz.suleria@uqconnect.edu.au

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Authors Affiliations & Contact

Faiza Ashfaq

Department of Food Science and Technology,

Faculty of Science and Technology,

Government College Women University Faisalabad, Pakistan

Email: kahloonfazi@yahoo.com

Ahmad Bilal

University Institute of Diet and Nutritional Sciences,

Faculty of Allied Health Sciences,

The University of Lahore,

Lahore, Pakistan

Email: ahmed.bilal2@dnsc.uol.edu.pk

Masood Sadiq Butt

National Institute of Food Science and Technology,

Faculty of Food, Nutrition & Home Sciences,

University of Agriculture Faisalabad, Pakistan

Email: drmsbutt@yahoo.com

Saima Tehseen

Department of Food Science and Technology,

Faculty of Science and Technology,

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Government College Women University Faisalabad, Pakistan

Email: dr.saimatehseen@gcwuf.edu.pk

Muhammad Nadeem Akhtar

University Institute of Diet and Nutritional Sciences,

Faculty of Allied Health Sciences,

The University of Lahore,

Lahore, Pakistan

Email: nadeem.akhtar@dnsc.uol.edu.pk

***Correspondence to**

Hafiz Ansar Rasul Suleria

McKenzie Fellow

Department of Agriculture and Food Systems

The University of Melbourne

Level 3, 780 Elizabeth Street, Parkville, Victoria 3010, Australia

T: +61 3 834 44984 **M:** +61 470 439 670

E: hafiz.suleria@uqconnect.edu.au

Abstract

Green tea extract is anticipated to improve storage stability of coriander sauce hence employed in the development of sauces; S_1 carrying 3% of conventional extract (epigallocatechin gallate; EGCG 65.88±2.38 mg/g D.W.) and S_2 containing 2.56% of supercritical CO_2 extract (EGCG 77.23±2.86 mg/g D.W.) then compared against control (S_0). During storage (4 °C), numerous parameters were studied at Day 1, 7, 14, 21 and 28. Maximum polyphenols (mg GAE/100mL) were observed in S_2 (224.40±5.82) followed by S_1 (208.31±5.03) and S_0 (50.11±1.71) and similar trend was noted for antioxidant assays. Further, tea extracts prominently reduced synersis in sauces, *i.e*. 42.79-47.31% in relevance to control and no abnormality was reported in color

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traits. Likewise, deviations in physicochemical aspects of sauce during storage were considerably ($p<0.05$) delayed by either extract. Acceptance index of the treated sauces was higher *i.e.* 77.52±2.77% (S_1) and 78.91±2.83% (S_2) than control (75.66±2.64%).

Keywords: Quantification, Catechins, Antioxidant, Physicochemical, Synersis, Color

Practical applications

Green tea extracts predominantly supercritical CO_2 extract has proven its preservative role in coriander sauce by delaying anomalous changes that may arise during storage without imparting any off-sensory characteristics in the final product. Besides, inclusion of green tea in coriander sauce compliments each other as green tea extract enhances the functionality and quality of coriander sauce whilst, acidic environment of the sauce facilitates in stabilizing green tea polyphenols and flavonoids. Based on health benefits and improved storage stability of the resultant product, the relevant stakeholders should need to bring this innovative idea to reality.

1. INTRODUCTION

Sauces are semi-liquid foods that served as side dishes to varied main menu food products like rice, sandwiches, fried and baked products. Amongst different types of sauces, coriander sauce is often employed in Asian cuisines and its ingredients may vary based on consumer preference and functionality (Kashyap *et al*., 2016; Mehmood *et al*., 2019). Experimental studies explicated that many ingredients like green tea extract, green coffee bean extract, pomegranate peel extract, fresh dill and garlic extract have proven their ability to delay anomalous changes that arise in physicochemical characteristics of sauces such as tomato sauce, chili sauce, soy sauce, pumpkin sauce and thousand island sauce during storage (Kim and Yoo, 2012; Sosa *et al*., 2012; Park, 2015; Choi *et al*., 2018; Ashfaq *et al*., 2019; Mahmood *et al*., 2019; Javanmard and Akbari, 2020; Bortnowska *et al*., 2021).

Green tea (*Camellia sinensis* L.) belongs to Theaceae family, and regarded as a functional food owing to its abundant proportion of polycatechins that accounts up to 30%. Epigallocatechin gallate (EGCG) is one of the most dominant catechins in green tea and possesses potent free radical scavenging activity (Pervin *et al*., 2019). Based on this property, previous studies have established the protective role of green tea polycatechins against lipid oxidation reactions in food

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products. Further, combination of ascorbic acid and green tea extract was also found to facilitate preservation in varied food systems (Salminen and Russoti, 2017; Choi *et al*., 2018).

Previously, green tea catechins were extracted via conventional solvent methods but now scientists have discovered green extraction technologies like supercritical CO_2 extraction system to isolate active compounds from food matrix in an efficient way (Sökmen *et al*., 2017; Ashfaq *et al*., 2019). Though, no study has yet compared the efficacy of conventional and supercritical fluid extracts of green tea in food systems. Thus, the aim of this article was to test the impact of conventional and supercritical CO_2 extracts of green tea on coriander sauce during storage, by standardizing its recipe.

2. MATERIALS AND METHODS

Procurement of raw material and chemicals

The research was conducted in the Functional and Nutraceutical Food Research Section, Faculty of Food, Nutrition and Home Sciences, University of Agriculture Faisalabad (UAF), Pakistan. In this study, green tea leaves of Qi-Men variety were acquired from National Tea Research Institute (NTRI), Shinkiari, Mansehra. The standards and reagents were procured from Sigma-Aldrich (Sigma-Aldrich Tokyo, Japan) and Merck (Merck KGaA, Darmstadt, Germany).

Preparation of green tea extracts using two different extraction modes

Conventional solvent extraction

Dried green tea leaves were treated with aqueous ethanol, acetone and ethyl acetate (50% v/v) for 50 min at 50 ℃ followed by filtration using muslin cloth and evaporation of solvent using Rotary Evaporator (Eyela, Japan) at 40±5°C (Dong *et al.* 2011).

Supercritical CO_2 extraction

Dried green tea leaves were placed in supercritical fluid extraction system (SFT-150, capacity: 100 mL) where treated with supercritical CO_2 (99.8% pure) at 50 ℃ as per the guidelines of Imran *et al.* (2021). The pressure of the system was set at three selective pressures; 1500, 3000 and 4500 psi that has the ability to convert gaseous CO_2 into supercritical CO_2 fluid state, carrying gas like diffusive and solvent like solubilizing capacity for easy extraction of its desired moiety *i.e.* epigallocatechin gallate (EGCG). EGCG is a polar moiety resultantly ethanol as a co-

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solvent/modifier was also employed along with supercritical CO_2 to facilitate the extraction process. After 50 min, the set pressure was reduced and the resultant extract was collected in the vials.

Quantification of EGCG by High Pressure Liquid Chromatography (HPLC)

Characterization of epigallocatechin gallate in green tea extracts was done by adopting the method of Sun *et al*. (2010). To prepare the sample, 100 mg of conventional solvent extracts or supercritical CO_2 extracts of green tea were separately added in epindrof vials already carrying 900 uL of mobile phase. Then, the samples were vortexed using gyromixer followed by syringe filtration. The adopted conditions for HPLC system were C_{18} column (250 mm x 4.6 mm, 5.0 µm particle size), auto-sampler with injector of 10 µL sample, 40 ℃ column temperature, gradient mobile phase: solvent A (acetonitrile/acetic acid/water 6:1:193) and solvent B (acetonitrile/acetic acid/water 60:1:139) and flow rate 1 mL/min. EGCG was quantified using UV detector of HPLC system at 280 nm, by comparing retention time of sample peaks with that of standard.

Development of functional sauce

Selection of optimized green tea extracts from both extraction techniques

Among different types of extract, the extracts with optimized level of EGCG from each technology; conventional acetonic extract of green tea and supercritical CO_2 extract of green tea at 3000 psi were selected to compare in sauce formulation as per the guidelines of Ashfaq *et al.* (2019). Two different types of extract enriched sauces; S_1 and S_2 were prepared by incorporating 3% conventional solvent and 2.56% supercritical CO_2 extract of green tea, respectively. Further, each extract proportion was set by quantifying EGCG using HPLC system and provision of equivalent amount of EGCG *i.e.* 197 mg/g D.W. was ensured in the final product. The functionality of EGCG extracted from different extraction sources were then compared against control prototype; S_0 (free from green tea extract).

Preparation of coriander leaf puree

The fresh coriander leaves were sorted and washed with water followed by processing using food processor in the presence of desired proportion of water, resulting in the development of fine purée (Kaur *et al.,* 2018).

Recipe of functional sauce

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Firstly, coriander sauce recipe was standardized by adopting the protocol followed by Kashyap *et al*. (2016). The coriander leaf purée was sauté in olive oil along with incorporation of other ingredients like roasted cumin seeds powder, white pepper powder and salt. After a few minutes, the specific aroma of all ingredients was attained. At this stage, honey and lemon juice were incorporated and cooled at room temperature. Afterwards, this mixture was blended with water as per the recipe. Then, CMC and guar gum in combination of 1:1 was added and homogenized at 7500 rpm for 8 minutes. The prepared sauce was preserved using sodium benzoate however, some of the functional and preservation properties were augmented by incorporating green tea extracts. All the treatments possess same recipe except the difference of green tea extracts.

Insert Table 1 here

Composition and calorific value

Firstly, the sauce samples were evaluated for moisture content. Then, the dried samples were employed to assess crude protein, crude fat, crude fiber and ash as per the standard methods of AOAC (2006). Moreover, total carbohydrate (%) in prepared prototypes was assessed by calculating the difference of other components and calories (kcal/100g) of each sample were analyzed by Atwater formula as described by Goes *et al.* (2016).

$$\text{Carbohydrate content }(\%) = 100 - (\text{moisture} + \text{ash} + \text{crude protein} + \text{crude fat})$$

$$\text{Calories}(\text{kcal/100g}) = 9 * \text{crude fat} + 4 * \text{crude protein} + 4 * \text{carbohydrates})$$

Storage study

The prepared sauce samples were stored at refrigeration temperature (4°C) and tested for varied physiochemical and sensory aspects at certain storage intervals; 1, 7, 14, 21 and 28 days.

Scavenging activities

Total phenolics

Total phenolics in the sauce prototypes were determined by following the protocol as stated by Park *et al*. (2020). The sauce samples (50 µL) or varied concentrations of gallic acid as standard were mixed with 1.0 mL of Na_2CO_3 (20%) then 50 µL of Folin-Ciocalteu reagent was added in each glass tube. Afterwards, this mixture was incubated for 40 min at 25 °C and absorbance was

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noted at 765 nm using microplate reader (Model No. ELx-800 BioTek, USA). Later, phenolics were measured in terms of milligram gallic acid equivalent (GAE)/100mL using calibration curve.

Total flavonoids

Total flavonoids in sauce samples were quantified by adopting the method mentioned by Ashfaq *et al.* (2020). 100 µL of each sauce sample or varied concentrations of quercetin as standard were added in separate glass tubes along with the incorporation of 300 µL of 5% $NaNO_2$. After five minutes of stay, 600 µL of $AlCl_3$ (10%) and later at sixth minute, 2 mL of NaOH (1 M) were added in the similar glass tubes. Lastly, the total volume was made up to 5 mL by including distilled water and absorbance of extract was noted at 510 nm. The results were expressed as quercetin equivalents (QE) by comparing it with standard curve.

DPPH (1, 1-diphenyl-2-picrylhydrazyl) scavenging activity

DPPH scavenging assay in sauce samples were measured by following the procedure described by Kaur *et al.* (2018). Firstly, DPPH solution was prepared by adding 0.004 g of DPPH radical in 100 mL of methanol. Resultant DPPH solution (1 mL) was placed in a glass tube followed by the addition of sauce sample (10 µL). At the end, 200 µL of the reaction mixture was transferred to 96-well plate and incubated in dark for 30 min. Then, optical density (OD) was assessed through ELISA plate reader at 517 nm.

$$\text{DPPH scavenging activity (\%)} = \frac{\text{Control OD - Sample OD}}{\text{Control OD}} \times 100$$

ABTS [2, 2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid) assay

The antioxidants in sauce prototypes were assessed by adopting the procedure mentioned by Vallverdú-Queralt *et al.* (2015). The ABTS solution (5 mL) was diluted with methanol until absorbance reaches at 0.700±0.005. The resultant ABTS solution (180 µL) was mixed with sauce sample (20 µL) and absorbance was recorded at 734 nm. The sample value was then obtained through standard curve of Trolox, expressing the data in terms of Trolox equivalent (TE).

FRAP (Ferric Reducing Antioxidant Power) assay

The ferric reducing antioxidant power of sauce extract was determined by Klug *et al.* (2018). Initially, fresh FRAP solution was prepared by mixing 25 mL of acetate buffer (300 mM), 2.5

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mL of tripyridyltriazine; TPTZ (10 mM) and 2.5 mL of $FeCl_3 \cdot 6H_2O$ solution (20 mM) followed by heating at 37°C. Then, sauce sample and different concentrations of standard *i.e.* $FeSO_4$ (200 μL) were individually mixed with prepared FRAP solution (2800 μL) in a glass tube and stored in dark for 30 min. Afterwards, absorbance was recorded at 593 nm and values were expressed in μM Fe (II)/mL employing standard curve.

Storage stability evaluation

Synersis

The synersis of sauce was noted as per the methodology of Shaikh *et al*. (2020). In this context, 25 g of sauce samples were individually placed in screw-capped centrifuge tubes then stored at 4 °C. After a certain storage interval, triplicates of each sauce formulation was tested by centrifuging the sample using centrifuge machine (M-3K30, Sigma, Germany) at 7500 rpm for 30 min and separated liquid was measured accurately. The synersis values were expressed in percentage by adopting equation as;

$$\text{Synersis (\%)} = \frac{\text{weight of decanted liquid after centrifugation (g)}}{\text{total weight of sample prior to centrifugation (g)}} \times 100$$

pH value

The pH of the selected samples was measured using a digital pH meter (Ino Lab 720, Germany) where probe of the pH meter was penetrated into the sample (100±0.01 g) taken in a 250 mL beaker and stable readings were recorded (Rengsutthi and Charoenrein, 2011).

Total acidity (TA)

Total acidity was calculated by accurately placing sauce sample (5 mL) in a beaker. To each sample, 20 mL of distilled water was added followed by titration with 0.1 M sodium hydroxide to an endpoint of pH 8.0±0.2. The volume of sodium hydroxide (NaOH) consumed to neutralize the acidity of the sample was noted in triplicates and total acidity was expressed as % citric acid equivalent (Kaur *et al*., 2018).

$$\text{Total acidity (\%)} = \frac{\text{average Vol. of NaOH} \times \text{normality of NaOH} \times \text{factor miliequivalent citric acid (0.064)}}{\text{weight of sample}} \times 100$$

Total soluble solids

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The total soluble solids (TSS) of sauce samples were assessed at room temperature using digital hand refractometer (TAMCO, Model No. 90021, Japan) and readings were expressed as °Brix (Imran *et al.* 2021).

Viscosity

The viscosity was of sauce sample was measured at 4 °C using Brookfield viscometer (Model DV-II+; Brookfield Engg., Labs, Inc., Middleboro, MA, USA) with spindle # 4 rotating at 100 rpm. The readings were taken at 30^{th} second shearing time. All the readings were recorded in triplicates and results were presented as mPas while keeping the torque maintained at all times between 10 and 100% (Oke *et al*., 2010).

Water activity

The water activity of the sauce samples was determined by using Hygropalm water activity meter; Rotronic a_w-Dio (Szafrańska *et al*., 2020). The sample was placed in a cup of Aw meter *i.e.* then fixed into the measuring chamber and water activity readings were recorded in triplicate on its remote.

Color profile index

The color profile index of the prepared sauce was performed as per the guidelines of Shahzad *et al.* (2021) and Sami *et al*. (2021). The sauce samples were assessed for color parameters; CIEL* (lightness), CIEa* (–a greenness and +a redness) and CIEb* (–b blueness and +b yellowness) using bench-top colorimeter (CIELAB SPACE, Color Tech-PCM, USA). Further, chroma, hue angle and browning index were determined by adopting the following formulas.

$$\text{Chroma} = [a^{*2} + b^{*2}]^{1/2}$$

$$\text{Hue angle} = \tan^{-1}(b^*/a^*)$$

$$\text{Browning Index} = 100\,(x - 0.31)/0.172$$

$$x = CIEa^* + 1.75(CIEL^*)/5.645(CIEL^*) + CIEa^* - 3.012(CIEb^*)$$

Sensory acceptance

The sensory parameters such as color, flavor, taste, texture and overall-acceptability were evaluated at set storage intervals (Goes *et al*., 2016). The sauce samples were evaluated for sensory response by a trained panel of 15 assessors aged between 25 and 50 years old using nine-

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point hedonic scale, ranging from 1; extremely dislike to 9; extremely like. The sensory scoring of the developed sauce samples was carried out in the Sensory Evaluation Laboratory of the Faculty of Food, Nutrition and Home Sciences, UAF, Pakistan. The sauce samples were presented to the panelists in transparent bottles, carrying random codes, at room temperature under white fluorescent light, in their individual booths. Further, panelists were advised to shake the bottles well before testing and supplied with mineral water and unsalted crackers to clean their palate between the samples. On the basis of above information, acceptance index was calculated by following the expression herein;

$$\text{Acceptance Index (\%)} = \frac{\text{average score attained by the product}}{9} \times 100$$

Statistical analysis

The obtained results were subjected to statistical modeling to probe the efficacy of each parameter using statistical software Statistix 8.1 (Mason *et al.* 2003). Microsoft Excel (version 2013) was employed for handling of data and graphical demonstration. Triplicate readings were performed for laboratory experiments excluding sensory response (n=15). Data were presented as mean±standard deviation (SD). Composition and HPLC analysis of EGCG in green tea extracts was quantified via one-way analysis of variance (ANOVA) under completely randomized design (CRD) whilst, storage study was analyzed by two-way ANOVA under CRD involving two dependant variables; treatments and storage intervals. Differences were considered significant (p<0.05) and separation between means was assessed by Tukey's honest significant difference (HSD) test.

3. RESULTS AND DISCUSSION

HPLC quantification of EGCG in green tea extracts

The highest yield of EGCG was measured through supercritical CO_2 (SC-CO_2) extract of green tea at 3000 psi (77.23±2.86 mg/g D.W.) followed by SC-CO_2 extract at 4500 psi (74.12±2.70 mg/g D.W.) and SC-CO_2 extract at 1500 psi (70.49±2.45 mg/g D.W.). Whilst, conventional solvent extracts of green tea explicated lesser proportions of EGCG as compared to SC-CO_2 extracts. However, yield of EGCG in ethanolic extract of green tea *i.e.* 52.67±2.27 mg/g D.W. that lies between 39.01±1.73 (ethyl acetate) to 65.88±2.38 (acetone) mg/g D.W. Hence, acetonic extract of green tea better retained EGCG then other conventional extracts.

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Insert Figure 1 here

Recently, aqueous ethanol, acetone and ethyl acetate were compared to extract green tea polycatechins and it was found that acetonic extract of green tea possesses maximum extraction of polyphenols *i.e.* 1325.81±64.85 mg GAE/100g followed by ethanol and ethyl acetate as viewed in the current study (Ashfaq *et al*., 2019). Another group of researchers mentioned that catechins in supercritical fluid extract of green tea were 60.56 mg/g at 2900 psi and 60℃ (Serdar *et al*., 2019). Moreover, purity of EGCG in total polyphenol content of green tea was in the range of 70.7 to 76.5% at varied temperature, pressure, pH and flow rate like conditions (Mondal and De, 2018). All of the aforementioned research findings were in corroboration to the outcomes of the current study.

Composition and calorific value

The ash and carbohydrates samples demonstrated significant difference (p<0.05) while moisture, crude protein, crude fat and calories depicted non-momentous variations. The sauce composition indicated highest moisture content in S_0 (77.91±3.42%) followed by S_2 (76.63±3.81%) and S_1 (76.18±3.52%). However, ash was highest in S_2 (1.19±0.04%) whilst minimum in case of S_0 (1.05±0.03%). Further, crude fat was maximally reported in S_0 (6.34±0.30%) followed by S_2 (6.25±0.25%) and S_1 (6.21±0.29%). Additionally, crude protein and carbohydrates were highest in S_1 (1.43±0.07 and 15.00±0.65%) followed by S_2 (1.42±0.07 and 14.51±0.63%) while S_0 lagged behind with values noted as 1.37±0.06 and 13.33±0.57%. Moreover, maximum calories were noted in S_1 (121.61±4.89 kcal/100g) trailed by S_2 (119.97±4.12 kcal/100g) whilst, the lowest calories were reported in S_0 as 115.86±5.11 kcal/100g, because of lowest protein and carbohydrate contents.

Insert Figure 2 here

The coriander puree is totally based on chemical composition of coriander and desired proportion of water. In this regard, the moisture content in coriander purée designed by Kaur *et al*. (2018) was ranged between 90.81±0.84 and 92.12±0.86%. Earlier, Kashyap *et al*. (2016) developed the coriander sauce in which total solids were accounted up to 24.72%, this was somewhat closer to the total solids of coriander sauce prepared in the current study. In another study, effect of green tea and bay leaf extracts was studied on marinated anchovies and it was found that moisture (60.44±2.60 to 62.92±0.79), protein (21.90±0.90 to 23.89±0.60) and ash

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(3.07±0.04 to 3.57±0.09) demonstrated significant variations on incorporation of bioactive moieties. However in the current study, carbohydrate and ash presented significant differences (Fıçıcılar *et al.*, 2018). Recently, Elhassaneen (2021) incorporated green tea extract in yoghurt and studied its chemical composition like total solids, protein and fat. The inclusion of green tea extract (1%) in yoghurt resulted in increase in total solids from 11.23±0.129 (control) to 11.49±0.115% and protein from 3.81±0.0608 to 3.95±0.076% and reduction in fat from 1.57±0.0577 to 1.42±0.0577%. Similar trend was noted in the current study on inclusion of green tea extract in coriander sauce.

Scavenging activities

Statistical inference indicated significant effect ($p<0.05$) of treatments and storage on total polyphenols, flavonoids and scavenging assays involving DPPH, ABTS and FRAP reagents. However, interaction effect in case of phytochemistry and scavenging assays were non-significant as the behavior of green tea extract treated groups were more or less similar except in ABTS assay. Maximum phenolic content (mg GAE/100mL) and flavonoids (mg QE/100mL) were observed in S_2 (224.40±5.82 and 172.47±5.24) followed by S_1 (208.31±5.03 and 166.95±4.57) whilst S_0 lagged behind with values reported as 50.11±1.71 and 26.06±1.00, correspondingly. This difference is because of numerous phenolic acids and flavonoids that exist in green tea extracts. Further, supercritical fluid extractor is more efficient in isolating varied bioactive compounds. With progression in storage, obvious decrement was observed in polyphenols and flavonoids that reduced from 169.17±4.78 to 151.02±3.47 mg GAE/100mL and 127.03±4.13 to 116.87±3.07 mg QE/100mL, respectively. Likewise, DPPH, ABTS and FRAP radical scavenging potential was maximally reported in S_2 with corresponding values reported as 60.33±0.76%, 14.53±0.51 µM Trolox/mL and 18.87±0.85 µM Fe^{2+}/mL followed by S_1 58.81±0.57%, 11.85±0.42 µM Trolox/mL and 15.65±0.60 µM Fe^{2+}/mL. However, these values were minimally found in S_0 (26.32±0.29%, 6.02±0.27 µM Trolox/mL and 9.06±0.35 µM Fe^{2+}/mL) as expected due to the absence of green tea extract. Over the storage period, the values for DPPH , ABTS and FRAP assays reached to 44.32±0.41%, 9.37±0.33 µM Trolox/mL and 11.94±0.48 µM Fe^{2+}/mL from 52.81±0.66%, 12.84±0.49µM Trolox/mL and 17.71±0.71 µM Fe^{2+}/mL, accordingly.

Insert Table 2 here

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Recently, Ashfaq *et al*. (2019) determined total polyphenols in green tea extract enriched soup and it was found to be varying between 46.66±2.39 (conventional solvent extract) and 49.19±2.36 (Supercritical fluid extract) mg GAE/100mL against control 18.19±0.89 mg GAE/100mL. During storage (96 hours), significant decrement was noted in total polyphenol content that reduced from 39.43±1.98 to 36.02±1.82 mg GAE/100mL. Moreover, the antioxidant activity is directly proportional to total polyphenols hence, it is deduced that soup carrying supercritical fluid extract of green tea possesses higher antioxidant activity. This is in harmony to the present study findings. Additionally, Kashyap *et al.* (2016) formulated the coriander sauce and assessed its antioxidant activity as 21.50%, the lesser antioxidant activity in the mentioned study might be due to the absence of green tea extract in it. However, this value is somewhat closer to the antioxidant activity of control coriander sauce hence corresponds to the current study. Later, Jayawardana *et al*. (2019) studied the antioxidant activity of green tea and black tea extracts on uncured pork sausages and found green tea significantly higher in antioxidant activity in response to its total polyphenol content. One of their peers, Lončarević *et al*. (2019) found that incorporation of green tea extract in white chocolate improved the antioxidant activity up to 6 times and hence could preserve it for 12 months. All these studies indicated preservative aptitude of green tea extract in varied food formulations owing to its higher antioxidant activity, which is in corroboration to the present study outcomes.

Other ingredients of sauce like honey indicated its total polyphenol content as 64.792 to 131.528 mg GAE/100g (Ceylan *et al*., 2019), whereas total polyphenols of lemon at different temperature conditions using ultrasound or soxhlet extractor indicated from 29.16 to 73.27 mg GAE/100g (Jagannath and Biradar, 2019). Further, total polyphenols in white pepper and cumin seeds were accounted up to 63.40±0.096 and ranged from 2.24±0.33 to 5.97±0.02 mg GAE/g, respectively (Rebey *et al*., 2012; Olalere *et al*., 2019). Besides, total polyphenols in virgin olive oil were reported as 500 mg/L (Gorzynik-Debicka *et al*., 2018). However, total polyphenols in coriander leaf were observed as 94-109 g GAE/100g (Laribi *et al*., 2015). Considering total polyphenol content of all these ingredients in accordance to their proportion in the set recipe, the expected results should be 30.82 (control), 162.62 (conventional extract) and 259.93 (supercritical fluid extract) mg GAE/100g. These findings are in accordance to the present study outcomes however, the minor differences might be due to the geographical conditions or varietal differences that could be clearly analyzed through the expected value of control group.

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Storage stability attributes

Statistical analysis portrayed significant difference (*$p<0.05$*) with respect to treatments and storage on synersis, TSS, viscosity and water activity. The percentage reduction in level of synersis in sauce samples were 42.79 and 47.31% due to the presence of green tea extract whereas, synersis increased up to 44.82% during storage. Total soluble solids was more in the presence of green tea extract based sauce samples *i.e.* 14.49 and 11.57% and decreased significantly up to 9.23% during storage. Considering viscosity, the increase was significant with respect to treatments and storage with percentage increase ranged between 24.08 and 36.07 and decrease in viscosity was up to 19.27% throughout storage. Moreover, water activity decreased in the presence of green tea extract up to 14.28 and 20.23%, respectively whereas, water activity increased while storage by 27.69%. Additionally, pH and acidity depicted significant variations regarding storage however, the effect of treatments was non-momentous. Treatment means for pH and acidity varied non-substantially however, the existence of green tea raised the pH up to 0.87 and 5.04% and suppressed acidity by 5.55 and 9.26%, respectively. During storage, reduction in pH and increase in acidity was momentous *i.e.* 17.97 and 19.23%, correspondingly. Further, CIEa* and CIEb* are statistically different hence calculated chroma and hue angle also varies significantly regarding treatments and storage whilst CIEL* varied non-substantially. The hue angle of S_1 was more towards greenish hue while color tonality of S_0 and S_2 were at par and more towards yellowish hue. Using CIEL*, CIEa* and CIEb*, the browning index (BI) of different sauce treatments was calculated which showed significant variations with respect to treatments and storage. BI for S_0 was calculated as 54.57±2.25, however, S_1 was found to be 44.49±2.03 and S_2 as 60.23±2.44. The browning index was more in case of control, while tendency of browning in S_2 was more owing to yellowish hue of supercritical fluid extract of green tea. Furthermore, the browning index accelerates as the storage time for sauce extends.

Insert Table 3 here

Insert Table 4 here

A group of scientists, Kulawik *et al.* (2019) employed green tea extract based edible films on salmon sushi at 4 °C for preservation and they tested its physicochemical characteristics like pH and water activity. Over the storage (1 to 8^{th} day), the decrease in pH was viewed from 5.65±0.06 to 5.55±0.06 however, increase in water activity was from 0.976±0.001 to

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0.979±0.002, this trend was similar as reported in the present study. In corroboration to the current study, Elhassaneen (2021) employed green tea extract in yoghurt and checked its viscosity which was found more in the presence of green tea extract as compared to control. Recently, Mehmood *et al*. (2019) found that incorporation of garlic like antioxidants in chili sauce at a rate of 10% resulted in increased total soluble solids and viscosity from 33.77±0.06 to 39.90±0.17 °B (18.15%) and 10539.33±64.58 to 13271.00±206.21 mPas (20.59%), correspondingly. These outcomes are in corroboration with the findings of the current study. Further, Amirdivani and Baba (2013) viewed that extent of synersis in yoghurt increases during storage however, the presence of green tea extract at the rate of 2% in yoghurt resulted in lower level of synersis during initial days of storage, as viewed in the current study.

Earlier, Salminen and Russotti (2017) studied the combined effect of green tea extract (0.1%) and ascorbic acid (3%) in preventing browning of fresh apple slices and found this combination effective in controlling browning up to 14 days at 48 °C as compared to ascorbic acid alone. Similar effect was noted in the current study, the increase in browning index was controlled due to the presence of green tea extracts except supercritical fluid extract treatment which itself adds yellowish hue. Later, Ashfaq *et al*. (2019) found the efficacy of green tea extract on chicken soup during 96 hours storage. The study demonstrated significant decrease in CIEa* and CIEb*, whereas CIEL* showed non-momentous decline during storage, this was similar to the present study plan.

Sensory acceptance

Statistical analysis demonstrated considerable impact ($p<0.05$) amongst treatments with respect to color, flavor, taste and overall-acceptability while texture differed non-substantially. However, storage intervals demonstrated significant variations among all the sensory aspects. The Figure 3 shows maximum score for color of sauce samples at Day 1st was 7.58±0.32 (S_2) followed by 7.35±0.27 (S_0) and 7.22±0.25 (S_1). During storage, the scores of color reduced significantly and reached to 7.08±0.24, 6.57±0.20 and 6.73±0.23 for S_2, S_0 and S_1 at termination, respectively. The highest score for flavor of sauce was 7.61±0.32 (S_0) trailed by 7.29±0.27 (S_2), whereas the lowest score for flavor was attained by S_1 *i.e.* 7.18±0.23. At the termination of storage period, obvious decline was observed in flavor characteristics and scores reached to 5.53±0.19, 6.61±0.25 and 6.39±0.21 for S_0, S_2 and S_1, accordingly. For taste, the maximum score was

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assigned to S_0 (7.48±0.31) followed by S_2 (7.43±0.29) and S_1 (7.36±0.31). Further, storage demonstrated significant decrease in taste score with corresponding values reached to 5.84±0.20, 6.65±0.24 and 6.48±0.21, at Day 28th. However, the assessors were unable to notice any significant variation in texture within treatments. But, momentous reduction was noted in texture score with respect to storage, varied from Day 1 to 28 as 7.42±0.30 to 6.81±0.25 (S_1), 7.36±0.32 to 6.79±0.22 (S_2) and 7.25±0.31 to 6.62±0.22 (S_0), respectively. Regarding overall-acceptability of the resultant sauce prototypes, maximum score was allocated to S_0 (7.47±0.35 that reached to 6.08±0.19 at the end of storage duration) followed by S_2 from 7.32±0.30 (Day 1) to 6.59±0.24 (Day 28), whereas S_1 lagged behind with score of 7.15±0.29 (initiation) to 6.37±0.21 (termination). The acceptance index showed considerable ($p<0.05$) difference regarding treatments and storage intervals. The acceptance index of S_0, S_1 and S_2 were 82.58±3.07, 80.73±2.39 and 82.18±2.87 at Day 1 although, it decreased with the progression in storage period but acceptance index reduced more in S_0 (68.09±2.04) as compared to treated samples; S_1 (72.84±2.17) and S_2 (74.93±2.32). It is because the presence of green tea polycatechins prevents abnormal changes in taste, color, flavor and texture during storage.

Insert Figure 3 here

Insert Table 5 here

Insert Table 6 here

In a recent study, Ashfaq *et al.* (2019) prepared green tea extract enriched chicken soup and the scores of the judges were within the acceptable limits. The color of soup samples were maximally reported in control samples (7.25±0.37) whereas, color score for green extract enriched soup were in the range of 6.90±0.32 to 7.09±0.28. However in the current study, the supercritical fluid extract enriched sauce got maximum acceptability followed by control and conventional green tea extract based sauce samples. One of their peers, Jayawardana *et al.* (2019) found that incorporation of green tea extract as an antioxidant on uncured pork sausages did not impact significantly on sensory profile of the sausages. Likewise, Lončarević *et al.* (2019) mentioned that inclusion of green tea extract in white chocolate did not impart any anomalous changes in its olfactory aspects. All these studies results were in accordance to the current study outcomes. In harmony to the current study, Elhassaneen (2021) employed green tea

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extract in yoghurt and checked its response on appearance, flavor and texture. The study rated these aspects better in the existence of green tea extract as compared to control.

4. CONCLUSIONS

The inclusion of green tea extract predominantly supercritical CO_2 extract in coriander sauce is responsible for higher free radical scavenging activities owing to its abundant polyphenol content. Considering chemical composition, carbohydrate and ash contents of the sauce samples showed significant difference. Based on free radical scavenging attributes, green tea extracts possess the potential to suppress the undesirable changes that normally occur in coriander sauce during storage such as increase in level of synersis & browning and reduction in viscosity. Initially, green tea extracts negatively impact on taste, flavor and overall-impression of sauce samples but these characteristics settles with the progression in storage in relevance to control sample. Thus, incorporation of green tea extract in sauce facilitates better acceptance index as storage proceeds. This suggested that application of green tea extract in coriander sauce facilitates satisfactory storage stability and organoleptic response during storage.

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AUTHOR CONTRIBUTIONS

M.S.B. supervised this project. F.A. wrote the original draft. F.A. and A.B. carried out all the analysis and assessed the data through statistical software. S.T., M.N.A. and H.A.R.S. provided valuable suggestions to accomplish the whole manuscript. All the authors read and approved the final manuscript.

CONFLICTS OF INTEREST

All authors declare no conflicts of interest in this research paper.

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TABLE 1. Formulation of green tea extract incorporated coriander sauce samples

Ingredients %	Treatments		
	S_0	**S_1**	**S_2**
Coriander leaf puree	16.38	13.38	13.82
Roasted cumin seeds (*Cuminum cyminum* L.)	1	1	1
Finely ground white pepper	0.5	0.5	0.5
Water	60	60	60
Honey	8	8	8
Lemon juice	7	7	7
Extra-virgin olive oil	5	5	5
Salt	1.5	1.5	1.5
CMC:Guar Gum (1:1)	0.6	0.6	0.6
Sodium benzoate	0.02	0.02	0.02
Solvent extract of green tea	-	3	-
Supercritical fluid extract of green tea	-	-	2.56

†S_0 (control sauce: free from green tea extract), S_1 (3% green tea solvent extract incorporated sauce) and S_2 (2.56% green tea supercritical CO_2 extract incorporated sauce).

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TABLE 2. Effect of treatments and storage on scavenging activities of green tea extract incorporated coriander sauce samples

Parameters	Treatments	Storage Intervals (Days)					
		1st	7th	14th	21st	28th	Means
TP (mg GAE/100mL)	S_0	59.78±2.20	56.12±2.18	51.76±1.73	44.56±1.26	38.31±1.17	50.11±1.71c
	S_1	216.19±5.63	213.73±5.25	209.06±5.18	203.95±4.95	198.62±4.13	208.31±5.03b
	S_2	231.54±6.52	228.13±6.39	225.77±5.26	220.42±5.81	216.13±5.10	224.40±5.82a
Means		169.17±4.78a	165.99±4.61ab	162.20±4.06ab	156.31±4.01ab	151.02±3.47b	
TF (mg QE/100mL)	S_0	32.45±1.34	29.03±1.27	26.59±1.05	22.94±0.79	19.28±0.55	26.06±1.00b
	S_1	172.16±5.12	169.09±4.90	166.65±4.68	164.34±4.11	162.52±4.02	166.95±4.57a
	S_2	176.49±5.93	175.67±5.72	172.13±5.11	169.25±4.79	168.82±4.63	172.47±5.24a
Means		127.03±4.13a	124.60±3..96ab	121.79±3.61ab	118.84±3.23ab	116.87±3.07b	
DPPH (%)	S_0	31.96±0.36	29.57±0.32	26.81±0.29	22.32±0.25	20.95±0.24	26.32±0.29b
	S_1	62.87±0.78	60.19±0.65	58.61±0.54	57.53±0.51	54.85±0.39	58.81±0.57a
	S_2	63.60±0.84	62.04±0.82	59.63±0.76	59.22±0.75	57.15±0.61	60.33±0.76a
Means		52.81±0.66a	50.60±0.60ab	48.35±0.53bc	46.36±0.50cd	44.32±0.41d	
ABTS (µM Trolox/mL)	S_0	8.74±0.36f	7.23±0.34fg	5.59±0.29gh	4.17±0.21h	4.35±0.17h	6.02±0.27c
	S_1	13.85±0.47bc	12.04±0.43de	11.65±0.42de	11.13±0.41e	10.57±0.37e	11.85±0.42b
	S_2	15.92±0.64a	15.26±0.51ab	14.87±0.49abc	13.40±0.47cd	13.19±0.45cd	14.53±0.51a
Means		12.84±0.49a	11.51±0.43b	10.70±0.40c	9.57±0.36d	9.37±0.33d	
FRAP (µM	S_0	12.45±0.45	10.01±0.35	9.38±0.33	7.27±0.31	6.22±0.30	9.06±0.35c

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Fe^{2+}/mL)	**S_1**	18.84±0.74	17.19±0.71	15.67±0.63	13.43±0.49	13.11±0.43	15.65±0.60b
	S_2	21.85±0.94	20.17±0.92	18.06±0.84	17.79±0.83	16.48±0.71	18.87±0.85a
Means		17.71±0.71a	15.79±0.66b	14.37±0.60c	12.83±0.54d	11.94±0.48d	

*Data values represent mean±SD (n=3); **Two-way ANOVA followed by Tukey's HSD multiple comparison tests; ***Values containing different alphabets vary significantly (*$p<0.05$*).

†S_0 (control sauce: free from green tea extract), S_1 (3% green tea solvent extract incorporated sauce) and S_2 (2.56% green tea supercritical CO_2 extract incorporated sauce).

‡TPC: Total phenolics; TF: Total Flavonoids; DPPH: 1, 1-diphenyl-2-picrylhydrazyl; ABTS: 2, 2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid; FRAP: Ferric Reducing Antioxidant Power.

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TABLE 3. Effect of treatments on storage stability attributes of green tea extract incorporated coriander sauce samples

Parameters	Treatments		
	S_0	S_1	S_2
Synersis (%)	11.73±0.52[a]	6.71±0.25[b]	6.18±0.21[c]
pH	4.56±0.25	4.52±0.23	4.33±0.20
TA (% citric acid equivalent)	0.54±0.02	0.57±0.02	0.59±0.03
TSS (°B)	32.22±1.64[b]	36.89±1.90[a]	35.95±1.60[a]
Viscosity (mPas)	8643.60±209.13[c]	11761.60±347.92[a]	10725.00±331.45[b]
Aw	0.84±0.03[a]	0.67±0.02[c]	0.72±0.02[b]
CIEL*	32.46±1.65	32.31±1.62	32.12±1.63
CIEa*	-1.45±0.06[b]	-2.26±0.11[a]	-1.53±0.05[b]
CIEb*	14.82±0.74[b]	13.15±0.65[c]	15.76±0.77[a]
Chroma	14.88±0.72[a]	13.34±0.69[b]	15.83±0.75[a]
Hue angle	95.62±4.78[b]	99.79±4.89[a]	95.55±4.76[b]
BI	54.57±2.25[b]	44.49±2.03[c]	60.23±2.44[a]

*Data values represent mean±SD (n=3); **Two-way ANOVA followed by Tukey's HSD multiple comparison tests; ***Values containing different alphabets vary significantly (*$p<0.05$*).

†S_0 (control sauce: free from green tea extract), S_1 (3% green tea solvent extract incorporated sauce) and S_2 (2.56% green tea supercritical CO_2 extract incorporated sauce).

‡TS: Total Solids; TA: Total Acidity; Aw: Water Activity.

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TABLE 4. Impact of storage intervals on storage stability attributes of green tea extract incorporated coriander sauce samples

Parameters	Storage intervals (Days)				
	1st	7th	14th	21st	28th
Synersis (%)	5.92±0.17^{e}	7.06±0.21^{d}	7.88±0.26^{c}	9.47±0.35^{b}	10.73±0.39^{a}
pH	4.95±0.23^{a}	4.69±0.25^{ab}	4.43±0.22^{bc}	4.23±0.21^{c}	4.06±0.20^{c}
TA (% citric acid equivalent)	0.52±0.023^{d}	0.54±0.021^{cd}	0.57±0.026^{bc}	0.59±0.031^{ab}	0.62±0.034^{a}
TSS (°B)	36.72±1.91^{a}	36.05±1.89^{a}	34.91±1.75^{ab}	34.08±1.76^{b}	33.33±1.72^{b}
Viscosity (mPas)	11325.00±339.49^{a}	10941.33±328.15^{ab}	10476.67±321.01^{bc}	9995.33±297.94^{c}	9143.00±215.28^{d}
Aw	0.65±0.02^{e}	0.71±0.02^{d}	0.73±0.02^{c}	0.79±0.03^{b}	0.83±0.03^{a}
CIEL*	33.12±1.64	32.68±1.62	32.28±1.63	31.83±1.60	31.57±1.59
CIEa*	-1.86±0.07^{a}	-1.82±0.09^{a}	-1.76±0.06^{ab}	-1.66±0.08^{b}	-1.62±0.06^{b}
CIEb*	13.77±0.67^{c}	14.13±0.69^{bc}	14.60±0.71^{ab}	15.01±0.74^{ab}	15.37±0.76^{a}
Chroma	13.90±0.67^{c}	14.25±0.69^{bc}	14.71±0.72^{ab}	15.11±0.75^{ab}	15.46±0.74^{a}
Hue angle	97.88±4.87^{a}	97.51±4.85^{a}	96.99±4.75^{ab}	96.44±4.82^{b}	96.10±4.78^{b}
BI	46.95±1.63^{d}	49.68±2.19^{cd}	53.06±2.38^{bc}	56.53±2.56^{ab}	59.27±2.61^{a}

*Data values represent mean±SD (n=3); **Two-way ANOVA followed by Tukey's HSD multiple comparison tests; ***Values containing different alphabets vary significantly ($p<0.05$)

†TS: Total Solids; TA: Total Acidity; Aw: Water Activity.

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TABLE 5. Effect of treatments on sensory acceptance of green tea extract incorporated sauce samples

Parameters	Treatments		
	S_0	S_1	S_2
Color	7.06±0.25^{b}	7.03±0.23^{b}	7.33±0.32^{a}
Flavor	6.68±0.25^{b}	6.92±0.30^{ab}	6.96±0.25^{a}
Taste	6.46±0.21^{b}	6.98±0.34^{a}	7.07±0.33^{a}
Texture	7.02±0.32	7.19±0.36	7.11±0.33
Overall-acceptability	6.83±0.27^{ab}	6.77±0.29^{b}	7.04±0.32^{a}
Acceptance index (%)	75.66±2.64^{b}	77.52±2.77^{ab}	78.91±2.83^{a}

*Data values represent mean±SD (n=15); **Two-way ANOVA followed by Tukey's HSD multiple comparison tests; ***Values containing different alphabets vary significantly (*$p<0.05$*)

†S_0 (control sauce: free from green tea extract), S_1 (3% green tea solvent extract incorporated sauce) and S_2 (2.56% green tea supercritical fluid extract incorporated sauce).

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TABLE 6. Impact of storage intervals on sensory acceptance of green tea extract incorporated sauce samples

Parameters	Storage intervals (Days)				
	1st	7th	14th	21st	28th
Color	7.38±0.35[a]	7.31±0.34[ab]	7.19±0.29[ab]	7.03±0.27[bc]	6.79±0.26[c]
Taste	7.42±0.35[a]	7.11±0.34[b]	6.83±0.33[b]	6.50±0.32[c]	6.32±0.29[c]
Flavor	7.36±0.34[a]	7.28±0.33[a]	6.86±0.31[b]	6.57±0.28[b]	6.18±0.26[c]
Texture	7.34±0.34[a]	7.27±0.31[a]	7.17±0.32[ab]	7.01±0.31[ab]	6.74±0.32[b]
Overall-acceptability	7.31±0.36[a]	7.14±0.33[a]	6.95±0.32[ab]	6.65±0.30[bc]	6.35±0.27[c]
Acceptance index (%)	81.83±2.90[a]	80.21±2.86[ab]	77.81±2.67[bc]	75.02±2.44[cd]	71.96±2.43[d]

*Data values represent mean±SD (n=15); **Two-way ANOVA followed by Tukey's HSD multiple comparison tests; ***Values containing different alphabets vary significantly ($p<0.05$)

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Figure legends:

FIGURE 1. HPLC quantification of EGCG from solvent and supercritical CO_2 extracts of green tea.

FIGURE 2. Percentage composition of green tea extract incorporated coriander sauce samples.

FIGURE 3. Organoleptic evaluation of green tea extract incorporated sauce samples during storage.

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