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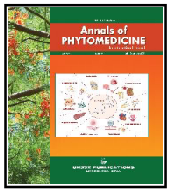

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Development and evaluation of Butterfly pea concentrate using *Clitoria ternatea* L. flower extract

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Abstract

Clitoria ternatea L., Aparajita in Sanskrit and Butterfly pea flower commonly, is a perennial leguminous plant in the Fabaceae family, recognized in Ayurvedic medicine for its cognitive benefits and sedative properties. This study explored the phytochemical profile of *C. ternatea* flowers and the formulation of syrups (S1, S2, S3) derived from them. It assessed the syrup's nutritional composition, sensory attributes, and antioxidant activity. Phytochemical screening demonstrated that flavonoids were present in all extracts, with the aqueous extract exhibiting the strongest presence, alongside exclusive detection of saponins and amino acids in the aqueous solvent. Nutritional analysis revealed that flower syrups have significantly lower moisture content (37.74% to 40.87%) compared to dried flowers (92.4%) while showing greater ash, carbohydrate (48.90 g to 51.6 g), and protein content (up to 6.75 g) than the flowers. Syrups also provided higher energy content (201.53 kcal to 236.21 kcal) suitable for energy-boosting applications. Sensory evaluation indicated that S3 outperformed others in appearance, flavour, aroma, and consistency, making it the most appealing option. Antioxidant assays revealed that the flower extract had the highest total phenolic content (640.6 mg GAE/g) and scavenging activity in the DPPH assay (55.54%), while S3 displayed superior performance in the ABTS and metal chelating assays. These findings suggest that *C. ternatea* flower extracts and their syrups possess significant nutritional and antioxidant properties, with S3 being a promising formulation for food applications due to its sensory appeal and functional benefits.

1. Introduction

Plants have been utilized for therapeutic, religious, nutritional, cosmetic, and beautification purposes since ancient times, with all civilizations and cultures familiar with their applications (Senkal *et al*., 2019; Gecer *et al*., 2020). In India, approximately 50,000 plant species have been documented to date, with only 8,000 to 8,500 explored by researchers for their potential to address human ailments. Plants serve as reservoirs of natural products, which offer a variety of antioxidants and phytochemicals.

C. ternatea, commonly known as Butterfly pea, is recognized as a nootropic herb in Ayurvedic medicine (Chauhan *et al*., 2017). This plant is classified in the kingdom Plantae, phylum Tracheophyta, class Magnoliopsida, and family Fabaceae (Jamil *et al*., 2018). *C. ternatea* is a perennial climber, reaching heights of 2-3 meters, and is widely known for its striking blue flowers (Mukherjee *et al*., 2008). In various regions, it is referred to as *Vishnupriya* or *Aparajita* (Hindi) (Subramanian and Prathyusha, 2011; Mukherjee *et al*., 2008). Beyond its ornamental value, *C. ternatea* is commonly used for revegetation. In Southeast Asia, the blue pigment of the flowers has been traditionally employed as a natural food colorant (Havananda and Luengwilai, 2019; Oguis *et al*., 2019). The plant is widely distributed across India, the Philippines, and other tropical Asian countries, as well as in South and Central America, the Caribbean, and Madagascar (Sivaranjan and Balachandran, 1994; Ambasta, 1986).

Traditionally, *C. ternatea* has been utilized in Ayurvedic medicine for various health issues. Its roots are employed to treat indigestion, constipation, fever, arthritis, sore throat, skin diseases, and eye ailments, while the seeds are used as laxatives and for treating colic and swollen joints. Compounds identified in the flowers include ternatin, anthocyanins, and various flavanol glycosides of kaempferol, quercetin, and myricetin (Mukherjee *et al*., 2008; Kazuma *et al*., 2003).

The present study focused on developing a Butterfly pea concentrate using extracts from the flowers of *C. ternatea* leveraging its rich phytochemical profile. Initially, the phytochemical composition of *C. ternatea* flowers extracted in various solvents was evaluated. Subsequently, the developed syrup was analyzed for its antioxidant properties. This research aims to contribute to the formulation of effective natural immunity boosters, highlighting the potential health benefits of *C. ternatea* flowers.

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2. Materials and Methods

In the present investigation, conducted at the Food and Nutrition Research Laboratory of the Department of Family and Community Sciences, University of Allahabad, the experimental site spanned from January to April 2024.

2.1 Sample procurement

Blue butterfly pea (*Clitoria ternatea* L.) flowers were authenticated by Professor Satya Narain, Department of Botany, University of Allahabad, Uttar Pradesh, India (Voucher specimen number: 42). The Blue butterfly pea flowers, Tulsi leaves (*Ocimum tenuiflorum* L.), Mint leaves (*Mentha piperita* L.), Lemongrass (*Cymbopogon citratus* DC.*)*, and Giloy stem (*Tinospora cordifolia* Thunb.) were collected from botanical garden of University of Allahabad, Prayagraj, Uttar Pradesh, India. Spices and sugar were procured from the local market of Prayagraj. These herbs were chosen based on their availability, cultivation as per our weather conditions, attractiveness of colour and flavour, nutritional quality, and functional properties.

2.2 Preparation of extract from each plant materials

Flowers of *C. ternatea* and fresh leaves of tulsi, mint, lemongrass, and giloy stem were dried using a hot air oven for 4 h at 40°C then all the dried samples were ground in an electric blender to get finely grounded powder. The resulting dried samples were sieved for uniformity and stored in labeled zip lock pouches. Spices were slightly roasted, ground and sieved and all of these samples were stored in labelled zip lock pouches for future use. The colour and flavour of the selected herbs were extracted using different methods, such as boiling, squeezing, and steeping in potable water.

2.3 Preparation of extracts for quantitative and qualitative analysis

The procedure of maceration was adopted with slight modification for the extraction purpose of coarse powdered material by soaking with three different solvents (aqueous, 90% ethanol, 90% methanol) in air-tight amber glass bottles at 25°C, with occasional shaking thrice a day for 48 h (Hussain *et al*., 2014; Mamarasulov *et al*., 2020). Following maceration, the soaked coarse powdered material was strained through a double-layered muslin cloth to eliminate any plant debris. The resulting filtrate was then passed through the Whatman No.1 filter paper for further purification. The clear filtrate was stored in an air-tight amber glass container.

2.4 Development of product

The product, named "Butterfly Pea Concentrate," was crafted using butterfly pea flowers, tulsi leaves, mint leaves, giloy stems, lemongrass, sugar, and spices.

2.4.1 Preparation of flower syrup

Fresh flowers were seeped in warm water for 5 h at room temperature then the extract was strained. Flower extract with the addition of refined sugar in 1:1 proportion was boiled at 80°C for 15 min until it reached syrup consistency.

2.4.2 Addition of spice mix in flower syrup

Several formulations of spice mix were attempted using different spice ingredients to obtain a concentrate, which was acceptable to taste by the panellists with Hedonic scale evaluation. A final spice mix consisting of cumin seeds, black pepper, asafoetida, citric acid, and black salt in 10:3:1:10:5 was selected. This spice mix was added to syrup which was cooled at room temperature and transferred in a sterilized bottle. The syrup was kept at 4°C for future use.

2.4.3 Preparation of herbal extract

Tulsi, mint, lemongrass, and giloy stem were dried and powdered separately and mixed in the ratio of 4%, 4%, 4%, and 2% in 25 ml of potable warm water, and the extract was strained into sterilized bottles. Concentrate with three formulations was prepared by mixing different concentrations of the above extracts in spiced flower syrup.

2.4.4 Formulation of Butterfly pea concentrate

To prepare a flavoured syrup using *C. ternatea* (Butterfly pea), 60% of flower syrup, previously infused with a carefully selected spice mix, served as the base for the formulation. Herbal extracts were subsequently incorporated into the spiced syrup in three distinct formulations (Table 1) and flower syrup (without spice mix) was used as control. The final flavoured syrup produced from this process offers a novel ingredient that can enhance the sensory attributes of various beverages, contributing to both the taste experience and functional properties of the drinks.

Table 1: Butterfly pea concentrate

Materials	Syrup (S1)	Syrup (S2)	Syrup (S3)
Flower syrup	60 %	60 %	60 %
Giloy extract	5%	5%	5%
Lemongrass extract	15%	8%	10%
Tulsi extract	12%	15%	8%
Mint extract	8%	12%	12%

2.5 Phytochemical analysis of the flower extract

In this study, phytochemicals were analyzed using established methods. Tannins and terpenoids were observed through the procedure described by Pandey *et al*. (2013). The presence of glycosides was determined according to the method provided by Harborne *et al*. (1999). Saponins were assessed based on the method outlined by King and Young (1999). Identification of phenols followed the procedure established by Mir *et al*. (2013), while flavonoids were determined utilizing the method adopted by Santhi *et al*. (2016). For protein analysis, the biuret test was employed as described by Santhi *et al*. (2016). Quinones were analyzed using the method described by Ajuru *et al*. (2017), and the presence of starch was tested with iodine according to the protocol outlined by Ganesan and Bhatt (2008).

2.5 Nutritional analysis

AOAC (2012) procedures were followed to determine moisture content (Method 14.004), total ash content (Method 14.006), crude fiber (Method 7.070), fat content (Method 7.062), and protein content (Method 2.057). Carbohydrate content was calculated by difference, and energy content (kcal/100 g) was determined using the Atwater factors as reported by Okoye (1992).

2.6 Estimation of antioxidant activity

2.6.1 Sample extraction for antioxidant activity

Fresh *C. ternatea* flowers were cleaned and washed in water before being dried in a hot air oven for 4 h at a temperature of 40°C. Dried *C. ternatea* flower was ground to powder using a mixer grinder (López Prado *et al.,* 2019). For S3 and control, samples were dried at 80°C for 10 h, and the dried form was then solubilized in solvent for further analysis.

2.6.2 Total phenol content (TPC)

The total polyphenolic content of the samples was determined according to the Folin-Ciocalteau method described by Singirikonda *et al*. (2021). The reaction mixture contains 1 ml distilled water and 20 µl aliquot of the sample extract. There after 100 µl of Folin-Ciocalteau reagent, incubated for 3 min then 800 il 7.5% sodium carbonate was added. There after 600 ul of distilled water was added then incubated for 1 h and measured at 760 nm. Final results were expressed in mg GAE/g.

2.6.3 Total flavonoids content (TFC)

The total flavonoid content of the samples was determined according to the aluminum chloride method described by Do *et al*. (2014)**.** As per the method**,** 2 ml distilled water with 0.5 ml of sample extract with 1 ml of 5% sodium nitrate mixed and incubated for 5 min. After that 1 ml of 5% $AlCl_3$ and 1 ml of 1M NaOH was added. The absorbance was measured immediately at 510 nm. Quercetin was used for the standard curve construction and results were expressed as mg quercetin equivalents (QE)/g of sample.

2.6.4 Ferric reducing antioxidant power (FRAP)

For the determination of FRAP, a method described by Thaipong *et al.* (2006) was used. 200 il of sample extract and 1 ml of freshly prepared FRAP reagent were mixed well. Incubated at 37°C for 30 min. Read the absorbance at 595 nm. FRAP values, expressed as mmol of Fe (II) equivalent /g**.**

2.6.5 DPPH radical scavenging activity

The radical scavenging activity was expressed as percentage (%) of inhibition of the DPPH radical as described by Punit *et al*. (2019), with slight modification. A 100 µl sample was combined with 150 µl of a 0.1 mmol DPPH solution. The mixture was allowed to incubate in the dark at room temperature for 15 min. Methanol served as the blank, and the absorbance was recorded at a wavelength of 515 nm:

%DPPH = Abscontrol – Abssample/Abscontrol × 100

The absorbance of DPPH radical plus methanol is known as Abs control, whereas the absorbance of DPPH radical plus sample extract is known as Abs sample.

2.6.6 Metal chelating activity

The metal chelating activity of the extracts was evaluated by the ferrozine method given by Abramovic *et al*. (2018). An aliquot of 0.5 ml of the extract was combined with 50 µl of ferrous sulfate. After allowing it to react for 5 min, 100 µl of ferrozine was introduced, and the absorbance was measured at 562 nm after a subsequent 10 min incubation. The metal chelating activity was reported as the percentage of inhibition of ferrous sulfate based on the dry weight of the sample.

2.6.7 Reducing capacity

Reducing capacity was determined by following the method of Farooq *et al*. (2018). A mixture consisting of 1 ml of the extract, 2.5 ml of sodium phosphate buffer, and 2.5 ml of 1% w/v potassium ferricyanide was prepared and incubated at 50°C for 20 min. Following this, 2.5 ml of 10% v/v TCA was added, and the samples were centrifuged at 1000 rpm for 10 min. The supernatant obtained from the centrifugation was combined with 2.5 ml of distilled water and 0.5 ml of 0.1% v/v ferric chloride. The absorbance was then measured at 700 nm using a spectrophotometer. The reducing power of the sample was compared to that of ascorbic acid and expressed as micromoles of ascorbic acid equivalents (AAE) per gram of dry weight.

2.6.8 $ABTS^{++}$ Decolorization assay

This assay depends on the ability of different substances to scavenge ABTS [2, 22 - azino-bis (3 ethylbenzothiazoline-6-sulfonic acid) as described by Farooq *et al*. (2018). The radical cation was produced by mixing a 7 mM ABTS stock solution with 2.4 mM potassium persulfate in a 1:1 ratio. This reaction mixture was stored in the dark at room temperature for 12 h. Subsequently, 1 ml of the extract was added to each 2 ml of the ABTS solution. After a 30 min incubation period, the absorbance of the samples was measured at 745 nm where Abs control is the absorbance of ABTS radical in methanol and Abs sample is the absorbance of ABTS radical solution mixed with sample extract/standard. The control was prepared by adding 10 ml of methanol in place of the sample:

%ABTS = Abscontrol – Abssample/Abscontrol × 100

Abs control is the absorbance of ABTS radical in methanol; Abs sample is the absorbance of ABTS radical solution mixed with sample extract/standard. The control was prepared by adding methanol in place of the sample.

2.7 Organoleptic evaluation

The organoleptic characteristics such as colour, odour, taste, and consistency were evaluated based on sensory evaluation by semi-trained panelists with 10 points Hedonic scale method.

2.8 Statistical analysis

Analysis was performed in triplicates. Statistical analysis was performed using the software SPSS 20.0 for Windows (version 10).

3. Results

3.1 Phytochemical analysis

The phytochemical screening of the extracts obtained from the extracts of *C. ternatea* flower revealed significant differences in the presence of various compounds based on the extraction solvent used (Table 2). The presence of saponins and amino acids was exclusive to the aqueous extract (+). Notably, quinones, terpenoids, starch, and tannins were absent across all extracts. The study also revealed that glycosides and phenols were consistently present in all three extracts (aqueous ++, ethanol +, methanol +).

Table 2: Phytochemical test of *C. ternatea* flower

Phytochemicals	Aqueous extract	Ethanol extract	Methanol extract
Flavonoids	++	+	+
Saponins	+	–	–
Amino acid	+	–	–
Quinone	–	–	–
Terpenoids	–	–	–
Starch	–	–	–
Glycosides	+	+	+
Phenol	+	+	+
Tannin	–	–	–

Note: + Positive, ++ Strong positive, – Negative

3.2 Nutritional analysis

The composition analysis of flower syrups (S1, S2, S3) and the control (flower syrup) with dried flowers reveals significant differences in nutritional content (Table 3). The moisture content of the flowers was found to be high at 92.4%, whereas the syrup formulations had moderate moisture levels ranging from 37.74% to 40.87%. Ash content, indicating mineral concentration, was higher in the syrups (3.12% to 3.75%) compared to the flowers (2.6%). Carbohydrates significantly increased in the control to syrups, from 48.90 g to 51.6 g, while only 6.7 g were present in the flowers (Figure 1). Fat content remained low across all samples, ranging from 0.24% in flowers to 0.297-0.313% from control to syrups. Protein levels in the syrups increased significantly, reaching 6.75 g in the S3 sample, compared to 0.82 g in the flowers. Energy content varied significantly, with syrups ranging from approximately 201.53 kcal to 236.21 kcal.

Table 3: Nutritional analysis

Formulations and nutritional attributes	Control	S1	S2	S3
Energy (kcal)	201.53 ± 0.00	226.03 ± 0.00	229.23 ± 0.00	236.21 ± 0.00
Moisture (%)	040.87 ± 0.90	040.49 ± 0.54	037.74 ± 0.49	037.84 ± 0.74
Protein (g)	000.77 ± 0.01	006.11 ± 0.25	006.12 ± 0.25	006.75 ± 0.25
Carbohydrate (g)	048.90 ± 0.70	049.70 ± 0.30	050.50 ± 0.60	051.60 ± 0.40
Fat (%)	000.29 ± 0.05	000.31 ± 0.03	000.30 ± 0.03	000.31 ± 0.03
Ash (%)	003.12 ± 0.60	003.68 ± 0.05	003.69 ± 0.03	003.75 ± 0.06

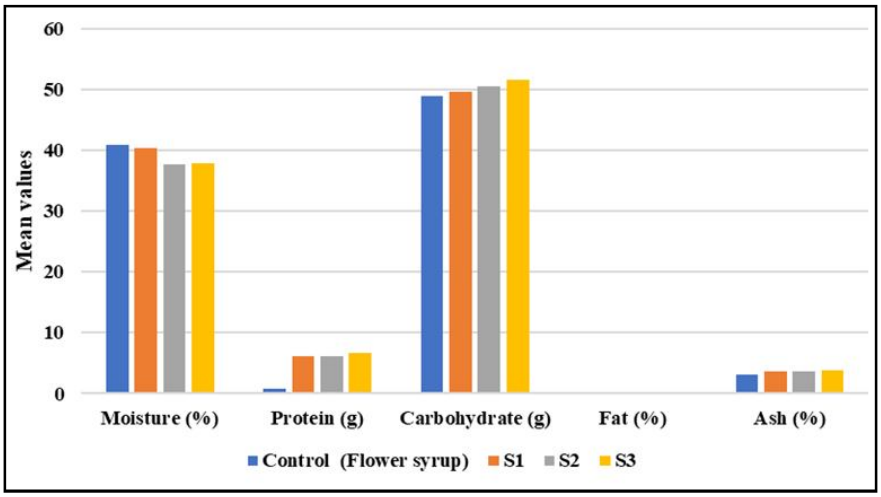

Figure 1: Nutritional analysis.

3.3 Organoleptic evaluation

The sensory evaluation (Table 4) of *C. ternatea* syrups revealed that sample S3 excelled across key attributes, scoring 9.3 for appearance, 10 for flavour, 10 for aroma, and 9.9 for consistency, making it the most appealing option. The control scored 8 for appearance and 7.6 for flavour, while its aroma (8.8) and consistency (8.5) also indicated good quality. In contrast, S1 and S2 received lower scores, particularly in flavour (5.0 and 5.8, respectively), with mean scores of 7.3 for both. The flower extract scored 8.4 for appearance, but lower scores in flavour (7), aroma (6.7), and consistency (7.8), resulting in a mean of 7.47 (Figure 2).

Table 4: Sensory scores of different parameters of concentrate

Formulations and sensory attributes	Control	Flower extract	S1	S2	S3
Appearance/colour	8.0 ± 0.66	8.4 ± 0.44	7.6 ± 0.15	7.9 ± 0.37	9.3 ± 0.41
Flavour	7.6 ± 0.30	7.0 ± 0.51	5.0 ± 0.21	5.8 ± 0.28	10 ± 0.32
Aroma	8.8 ± 0.59	6.7 ± 0.33	7.8 ± 0.38	7.6 ± 0.27	10 ± 0.50
Consistency	8.5 ± 0.48	7.8 ± 0.21	8.8 ± 0.30	7.9 ± 0.31	9.9 ± 0.32
Mean	8.2 ± 0.30	7.4 ± 0.25	7.3 ± 0.25	7.3 ± 0.20	9.8 ± 0.15

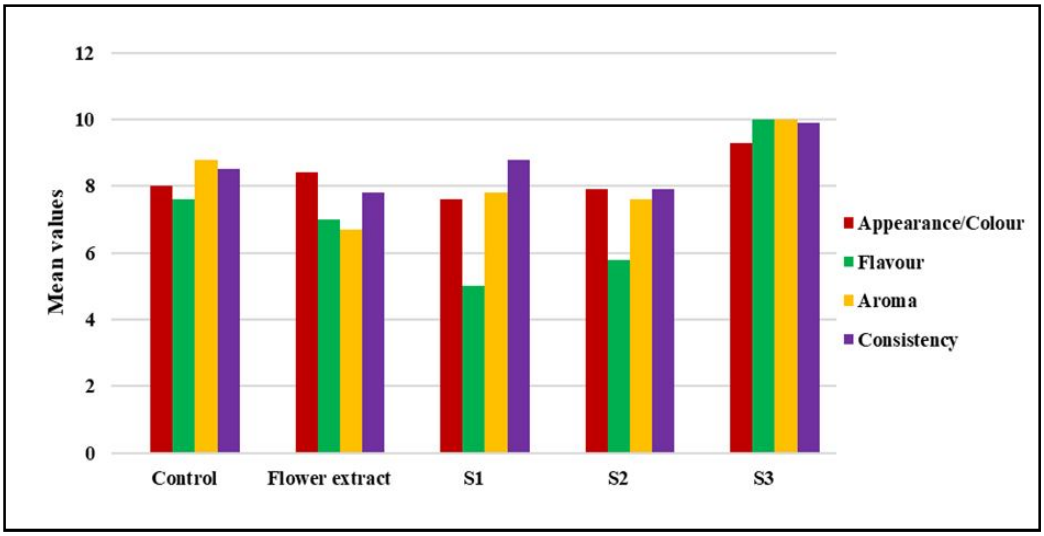

Figure 2: Sensory scores.

3.4 Antioxidant activity

Based on the Hedonic scale evaluation, it was confirmed that S3 was highly acceptable. Its antioxidant activity was compared with that of the control syrup (flower extract with sugar) and the flower extract as discussed in Table 5.

3.4.1 Total phenol content (TPC)

The total phenolic content of the S3 with the control sample and flower extract ranged from 114.6 ± 0.01 mg GAE/g, 113.3 ± 0.005 mg GAE/g and 140.6 ± 0.03 mg GAE/g. The highest total phenolic content was shown in flower extract followed by control then in S3.

3.4.2 Total flavonoids content (TFC)

The impact of flavonoid content in various extracts was systematically evaluated. The total flavonoid content across the samples exhibited a significant range, with the control group displaying a TFC of 116.4 ± 0.09 mg QE/g. In contrast, the flower extract demonstrated a markedly elevated TFC of 128.0 ± 0.02 mg QE/g, while S3 exhibited a TFC of 118.16 ± 0.07 mg QE/g.

3.4.3 Ferric reducing antioxidant power (FRAP)

The Ferric reducing antioxidant power (FRAP) assay confirmed the flower extract's strong reducing power at 12.45 ± 0.4 mmol Fe (II) equivalent, far surpassing the control (0.58 ± 0.0 mmol Fe (II) equivalent) and S3 (1.47 ± 0.08 mmol Fe (II) equivalent).

3.4.4 DPPH radical scavenging activity

The radical scavenging activity, using DPPH assay, the flower extract demonstrated a scavenging activity of 55.54 ± 0.02%, significantly higher than the control, *i.e.*, 22.2 ± 0.03% and S3 at 17.61 ± 0.0%.

3.4.5 Metal chelating activity

In metal chelating activity, S3 excelled at 56.65 ± 0.9%, with the flower extract at 41.8 ± 1.6% and the control at 52.66 ± 1.6%.

3.4.6 Reducing capacity

The total reducing capacity also favored S3 (86.19 ± 0.90 mmol AAE/g), closely followed by the flower extract (83.19 ± 1.78 mmol AAE/g).

3.4.7 $ABTS^{++}$ decolorization assay

In the ABTS assay, S3 showed the highest activity at 62.54 ± 0.04%, followed closely by the flower extract (60.82 ± 0.09%) and lowest in control at 53.71 ± 0.03%.

Table 5: Antioxidant parameters of product v/s flower extract and control

Antioxidant parameters/ samples	Control	Flower extract	S3
TPC (mg GAE/g)	113.3 ± 0.005^{c}	140.6 ± 0.03^{a}	114.6 ± 0.01^{b}
TFC (mg QE/g)	116.4 ± 0.09^{c}	128.0 ± 0.02^{a}	118.1 ± 0.07^{b}
DPPH (%)	22.20 ± 0.03^{b}	55.54 ± 0.02^{a}	17.61 ± 0.00^{c}
ABTS (%)	53.71 ± 0.03^{b}	60.82 ± 0.09^{c}	62.54 ± 0.04^{a}
FRAP (Mmol Fe (II) Equivalent)	0.58 ± 0.00^{c}	12.45 ± 0.40^{a}	01.47 ± 0.08^{b}
Metal chelating activity (%)	52.66 ± 1.60^{b}	41.80 ± 1.60^{c}	56.65 ± 0.9a
Reducing capacity (mmol AAE/g)	63.67 ± 1.50^{c}	83.19 ± 1.78^{b}	86.19 ± 0.90^{a}

Note: Mean values with the same letter in the same column (a,b,c) for a specific extract type do not differ significantly at $p<0.05$.

4. Discussion

In the present study, the ingredients chosen for the formulation of syrup includes the base which is the *C. tertatea* flower extract syrup, different spices, and extract of herbs. For phytochemical screening, the *C. tertatea* flower was dispersed in three solvents namely ethanol, methanol, and aqueous to make extracts. The results in the present study recorded the presence of flavonoids, phenol, and glycoside notable in all three extracts while the aqueous extract showed a stronger presence of flavonoids which is supported by the previous study of Yee *et al*. (2020). The presence of saponins and amino acids was exclusive to the aqueous extract that may be due to their amphiphilic nature (Rai *et al*., 2023). All extracts lacked quinones, terpenoids, starch, and tannins, which is in line with other research (Tripathi *et al*., 2022; Mahajan *et al*., 2022). These findings show that solvents play an important role in the extraction of phytochemicals (Aggarwal *et al*., 2022).

The nutritional composition of flower syrups (S1, S2, S3) and the control (flower syrup) with dried flowers reveals significant differences in nutritional content. The flowers had high moisture content (92.4%) typical of plant materials, whereas the syrups had moderate moisture levels (37.74%-40.87%). The syrups exhibited significantly higher ash content (3.12%-3.75%), indicating more concentrated minerals than the flowers (2.6%). Carbohydrate content in the syrups increased from 48.90 g in the control to 51.6 g, compared to just 6.7 g in the flowers, largely due to added sugars, making the syrups energy-dense at 201.53-236.21 kcal, versus 32.24 kcal in the flowers. Protein levels also surged in the syrups, especially in S3 (6.75 g), compared to 0.82 g in the flowers, likely due to herbal extracts like giloy (Pandey *et al*., 2016), lemongrass (Sambo *et al*., 2024), mint (Salve *et al*., 2020) and basil (Danso *et al*., 2013) as they contain a significant amount of protein. Fat content remained low across all samples, indicating that *C. ternatea* is a low-fat option. A study by Multisona *et al*. (2024) recorded that *C. ternatea* flowers contain 2.5% fat, 2.2% carbohydrates, 2.1% fibre, and 0.32% protein, with a moisture content of 90.1%. And rich in minerals, including calcium, magnesium, potassium, zinc, sodium and iron. Overall, the syrups present a more concentrated, energy-dense product suitable for use as an energy drink.

The sensory evaluation of *C. ternatea* syrups demonstrated that S3 outperformed all other samples across the key sensory attributes. It was particularly distinguished by its superior flavour, aroma, appearance, and consistency, positioning it as the most favorable formulation. The control sample, while exhibiting acceptable quality, did not achieve the same level of sensory appeal as S3, particularly in terms of flavour and consistency, though it maintained a satisfactory aroma. In contrast, S1 and S2 were rated lower, with flavour being a significant limiting factor in their overall sensory evaluation. The flower extract, despite receiving favorable scores for appearance, was rated lower in terms of flavour, aroma, and consistency, resulting in a less favourable overall sensory profile. These findings suggest that S3 provides the most optimal sensory attributes among the tested formulations, with other syrups and flower extract offering varying degrees of sensory acceptability.

Based on sensory evaluation S3 was most acceptable. Antioxidant parameters for three samples: the control, S3, and the flower extract. The antioxidant activities of the control, S3, and flower extract were evaluated across various parameters, revealing significant differences. With the highest levels of TPC and TFC among the samples, the antioxidant analysis showed notable variations. This suggests that the flower extract is rich in antioxidant compound, phytochemical and has values higher than those reported previously by Jeyaraj *et al*. (2022) in *C. ternatea* and Bragueto *et al*. (2019) in *Calendula Officinalis*. Additionally, the floral extract showed high reducing power in the FRAP, which is less than the value previously found in research done by Jeyaraj *et al*. (2021), and superior scavenging activity in the DPPH test, which is also seen in the previous study of Escher *et al*. (2020).

However, S3 outperformed the flower extract in the ABTS assay and showed greater metal chelating activity, indicating its potential antioxidant capacity in certain parameters despite lower TPC and TFC. Additionally, S3 exhibited the highest total reducing capacity. These results suggest that while the flower extract provides stronger antioxidant properties due to its higher phenolic and flavonoid content, S3 demonstrates significant antioxidant activity across specific assays, making it a viable option for formulations requiring

antioxidant functionality. These findings are consistent with previous studies of Lakshan *et al*. (2019), which reported notable antioxidant properties in *C. ternatea*-based beverage.

5. Conclusion

The present study reveals that *C. ternatea* flowers hold significant potential as a nutraceutical ingredient due to their high antioxidant capacity and favorable nutritional profile. The analysis highlights the critical influence of extraction solvents on the availability of phytochemicals, with aqueous and ethanol extractions effectively preserving flavonoids and distinct compounds. Nutritional evaluations demonstrate that the formulated syrups are rich in carbohydrates and minerals, making them suitable as energy-dense dietary supplements. Among the syrups, S3 was particularly noted for its superior sensory qualities, indicating its promise for food applications. The remarkable total phenolic content (TPC) and total clavonoid content (TFC) underscore the extract's health benefits. Thus, *C. ternatea* emerges as a valuable ingredient in health and nutrition, requiring further investigation into optimal extraction methods and the environmental factors affecting compound stability and efficacy.

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Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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