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RESEARCH ARTICLE

Microwave-assisted extraction of *Tiliacora triandra* leaves for functional ice cream production

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Abstract

Ice cream is widely enjoyed by consumers of all ages, but its high sugar and fat content may have adverse effects on health. This research aimed to develop a functional form of ice cream by incorporating *Tiliacora triandra* leaves, which are rich in antioxidants. The substances from the leaves were extracted using high-power microwaves at 600 W for 30 sec, repeated three times. The extract was then incorporated into the ice cream recipe, which utilized skim milk powder instead of fresh milk and stevia syrup instead of sugar. The antioxidant activity was assessed using DPPH and ABTS assays, while the total phenolic compounds were measured using the Folin-Ciocalteu assay. The findings indicated that ice cream supplemented with the extract at a 20% leaf ratio (T20) exhibited the highest antioxidant activity against DPPH and ABTS, with values of 54.30 ± 1.42% and 73.83 ± 1.90%, respectively. Additionally, the highest total phenolic compounds content was observed at 3.48 ± 0.10 mg GAE/g sample. The addition of *T. triandra* leaf extract resulted in a significantly darker green color and a firmer texture. However, the ice cream's ability to resist melting showed slight change. Sensory assessment revealed that ice cream enhanced with 5% (T5) and 10% leaf ratios (T10) of the extract received higher scores for taste, color, odor, and overall acceptance compared to T20, and showed no difference from the control (T0). These finding suggest that T10 could serve as a viable alternative for health-conscious consumers seeking functional ice cream options.

Keywords

antioxidants; ice cream; microwave-assisted extraction; sensory evaluation; *Tiliacora triandra*

Introduction

In recent decades, there has been a global increase in awareness regarding the importance of consuming nutritious meals to prevent illnesses and promote health (1). Economic growth and rising incomes have led to changes in lifestyle and dietary habits, with a shift away from traditional foods towards heavily processed meals containing high levels of salt, sugar, and unhealthy fats. These dietary patterns are closely associated with the increasing prevalence of non-communicable diseases (NCDs) such as cancer, metabolic syndrome, inflammatory disorders, cardiovascular disease, diabetes, chronic respiratory diseases, chronic kidney disease, and metabolic syndrome. These medical conditions are having an increasingly

significant impact on health status worldwide, particularly in populations of developing nations where they are more prevalent (2, 3). A more realistic and sustainable approach would be to utilize food-based methods to address the increasing threat of NCDs, rather than relying solely on pharmaceutical medications, which often come with high costs and a range of negative consequences (4).

Modern foods are formulated with compounds that not only provide essential nutrients and satisfy appetites but also enhanced people's mental and physical health. These types of foods are commonly referred to as "functional foods" (5, 6). With the increasing popularity of functional food, consumers are becoming more conscious of food quality and the numerous health benefits associated with different meals. This heightened awareness has led to a significant growth in the desire for and understanding of the importance of consuming nutritious foods within society. To meet these evolving needs, it is imperative to develop innovative functional foods (7, 8).

Tiliacora triandra is a plant belonging to the Menispermaceae family, native to Southeast Asian countries, particularly Thailand, Vietnam and the Laos People's Democratic Republic. It is characterized by thin stems, deep green foliage, and yellow-tinted blooms, and it typically grows as an ascending shrub (9). The aqueous extracts of *T. triandra* leaves are commonly used as an ingredient in various local dishes. Additionally, this plant has a history of use in folk medicine for treating a variety of ailments such as gastrointestinal and skin disorders, malaria, fever, hypertension, diabetes, and alcohol intoxication (10). Numerous studies have investigated and reported on the chemical constituents and pharmacological activities of *T. triandra*, which support its traditional uses such as antioxidant, neuroprotective, immune modulator, antidiabetic, antiplasmodial, anti-pyretic and anti-inflammatory, anticancer, and antimicrobial activities (11). Several active phytochemical compounds responsible for these biological activities have been explored in *T. triandra,* including alkaloids, polysaccharides, polyphenols, flavonoids, beta-carotene, fatty acids, and minerals such as fiber, calcium, iron, vitamin-A, vitamin-C, and phosphorus (9, 12). Accordingly, this valuable plant likely has the potential to be developed as a functional food.

Utilizing microwave radiation, a revolutionary method called microwave-assisted extraction (MAE) may be employed to extract bioactive substances from solid plant samples, including antioxidants, fragrances, essential oils, pigments, and other organic compositions (13). Microwaves are electromagnetic energies with frequencies ranging between 300 MHz and 300 GHz. They consist of two opposing oscillating fields, one magnetic and one electric, which are perpendicular. The direct effect of microwaves on polar materials provides the basis for their heating. Ionic conduction and dipolar rotation are the two mechanisms that transform electromagnetic energy into heat. Heat is generated through the ionic conduction process due to the medium's resistance to ion transport. In this process, ions follow constantly shifting field signals, leading to collisions between molecules and the production of heat as a by-product. This sudden increase in temperature from the interior of the solid sample to the solvent medium causes pressure to build up inside the cells of the plant sample. As a result, solutes separate from the active sites of the sample matrix and release bioactive elements into the solvent (14). Numerous factors, including temperature, microwave power, irradiation period, volume, solvent characteristics, and ratio, can influence the performance of MAE (15). Several advantages of MAE over other extraction methods have been described, such as increased extract yield, reduced solvent usage, high purity, cost-effectiveness, and decreased energy and time consumption (16). Therefore, the MAE technique was chosen for extracting bioactive substances from the *T. triandra* leaves in this research.

Ice cream is a highly popular treat across every continent. However, its comparatively high fat and sugar content raise the risk of obesity and other health issues associated with excessive consumption of these substances. Producing functional ice cream by incorporating beneficial ingredients and reducing harmful components could be an effective approach to addressing this issue. The development of a healthier form of ice cream should prioritize its beneficial health effects, unchanged physical properties, and consumer acceptance (17). Therefore, this research aimed to develop functional ice cream supplemented with *T. triandra* leaf extract using the MAE technique, as well as to determine its physical properties and evaluate sensory acceptance.

Materials and Methods

Materials

Skimmed milk powder, whipping cream, stevia syrup, vanilla flavor, and salt were purchased from a local market in Bangkok, Thailand.

Chemicals

In this study, only analytical grade chemicals and reagents were used. Methanol was sourced from QRëC (Chonburi, Thailand). 2,2'-azino-bis (3-ethylbenzthiazoline-6-sulphonic acid) (ABTS) was procured from Roche (Mannheim, Germany). Potassium persulfate ($K_2S_2O_8$) and sodium carbonate anhydrous (Na_2CO_3) were acquired from Ajax Finechem (New South Wales, Australia). Folin-Ciocalteu's phenol reagent, 2,2-diphenyl-1-picrylhydrazyl (DPPH), ascorbic acid and gallic acid monohydrate were obtained from Sigma-Aldrich (St. Louis, MO, USA).

Collection and preparation of plant sample

As illustrated in Fig. 1, the fresh *Tiliacora triandra* specimen (Fig. 2) was collected in June 2022 from a farming region in Tha Mai district, Chanthaburi, Thailand (12°37'28.088"N, 102°1'25.788"E). After collection, the plant specimen was preserved in sterile plastic bags and transported to the laboratory within a few hours. The fresh matured leaves were then washed twice under running water to remove debris. Subsequently, they were air-dried at room temperature (with a relative humidity of 65–70%) overnight to evaporate the remaining water.

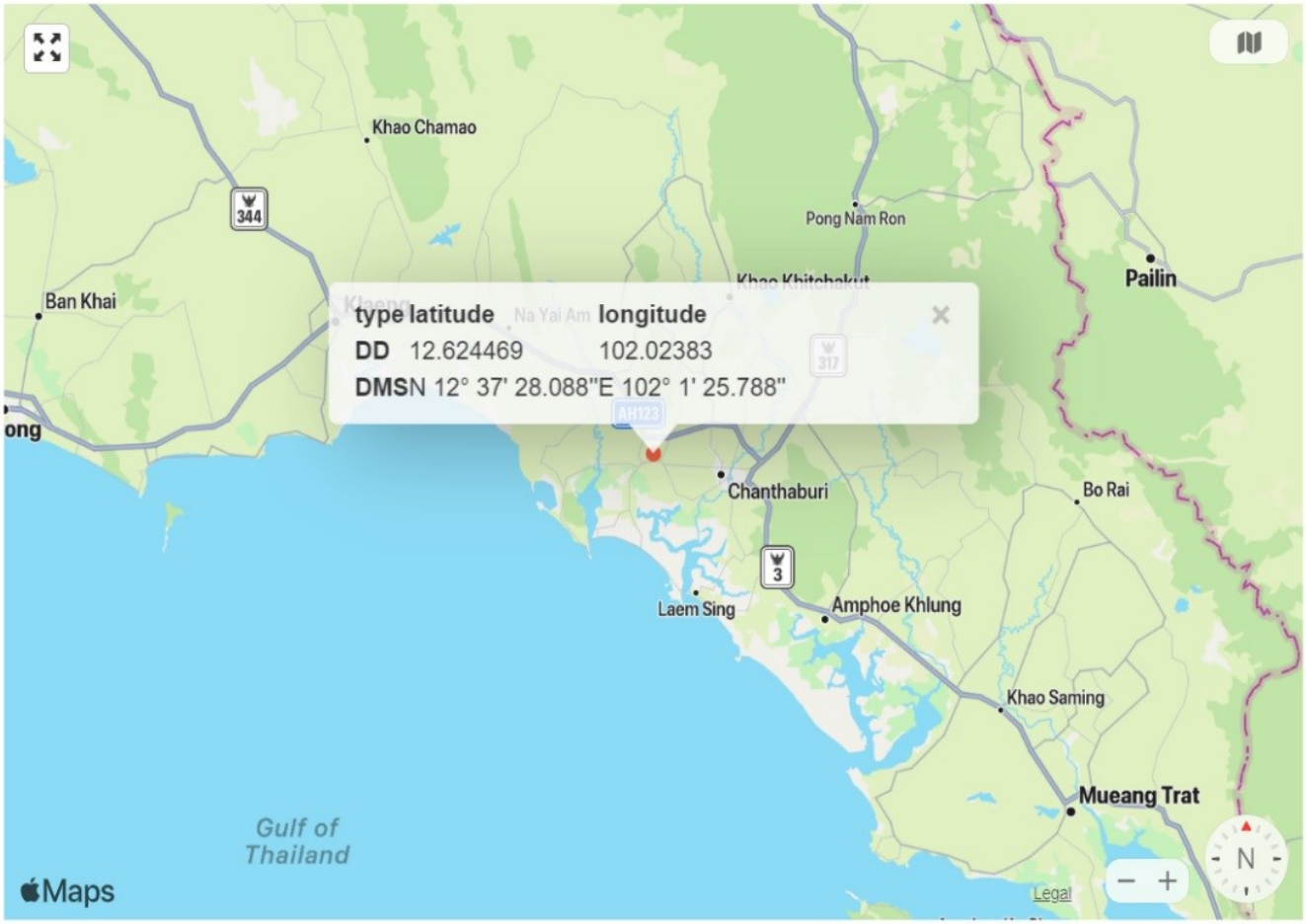


Fig. 1. The specimen sampling site of *Tiliacora triandra* situated in Tha Mai District, Chanthaburi, Thailand.

Fig. 2. *Tiliacora triandra* (Photographed by Narumon Boonman).

An expert in botany from the Department of Agriculture, Plant Varieties Protection, Bangkok Herbarium in Bangkok, Thailand, verified the authenticity of the plant components. The plant specimens were stored by the Bangkok Herbarium under voucher number BK085009.

Preparation of *T. triandra* extracts

For traditional extraction, 5, 10, and 20 g of *T. triandra* fresh leaves were weighed and placed into separate beakers, each containing 100 mL of distilled water. The leaves were then squeezed by hand and soaked for 15 min. For microwave-assisted extraction, the *T. triandra* leaves were prepared using the traditional method, followed by extraction using a microwave (Samsung, MS23F300EEK/ST, Thailand) at either a low power of 300 W for 60 sec or a high power of 600 W for 30 sec. The extraction process was repeated 3 times, with a rest period equal to the extraction time for each cycle. The extract obtained from each method was filtered through four layers of cheese cloth four times and then preserved at 4°C in an amber glass bottle for further experiments.

Ice cream production

The ingredients of the ice cream included 20 g of skimmed milk powder, 30 mL of water, 30 mL of *T. triandra* leaf extract, 200 mL of whipping cream, 4 mL of stevia syrup, 750 µL of vanilla flavour, and 0.5 g of salt. The control ice cream was given an additional 30 mL of water instead of the extract. The skimmed milk powder was mixed with water, heated to 80°C for 2 min, and then cooled down. Subsequently, stevia syrup, salt, *T. triandra* leaf extract, and vanilla flavour were added and thoroughly mixed. After the addition of these ingredients, the mixture was homogenized with whipped cream. Finally, the mixture was stored in a sterile plastic box sealed with a lid and frozen at -20°C for 12 h.

Preparation of ice cream extracts

The extraction process was conducted following previously published methods with slight modifications (18). Briefly, 20 g samples were blended with 20 mL of methanol for 15 min before being centrifuged at 3,000 rpm for 10 min (Hettich, Universal 320R, Germany). The resulting mixture was then filtered through Whatman® No. 4 filter paper, and the extracts were stored in amber glass bottles at 4°C.

DPPH radical scavenging activity

The analysis was carried out following the method outlined by Kedare and Singh (19) and Kye *et al.* (20) with slight modifications. *T. triandra* leaf extracts were diluted four times, while the ice cream extracts were diluted 2 times with distilled water. A diluted sample (20 µL) was combined with a 0.1 mM DPPH solution in methanol (180 µL) in each well of a 96-well microplate. After a brief shaking, the mixture was left to stand at room temperature for 30 min in the dark. The absorbance at 517 nm was then measured using a microplate reader (Molecular Devices, SpectraMax® M2, USA). The positive and negative controls in the DPPH solution were ascorbic acid at 250 µg/mL and methanol, respectively. The sample in methanol was used as a blank. The percentage of DPPH scavenging capability was calculated using the formula below:

$$\% \text{ DPPH scavenging capability} = [A_0 - (A_1 - B) / A_0] \times 100 \quad \text{(Eqn.1)}$$

Where, A_0 = absorbance of negative control

A_1 = absorbance of sample

B = absorbance of blank

ABTS radical scavenging activity

The capability for ABTS radical scavenging activity was scrutinized utilizing an approach described by Re *et al.* (21) and Monthakantirat *et al.* (22). A stock solution of 4 mM ABTS and 2.45 mM $K_2S_2O_8$ was integrated at a 1:1 ratio and then stored under dark conditions for 12–16 h at room temperature. To adjust the absorbance at 734 nm within the range of 1.0 ± 0.02, the obtained solution (ABTS•) was diluted with methanol. Subsequently, the diluted extract (50 µL) was added to the ABTS• solution (100 µL) in each well of a 96-well microplate. A microplate was delicately mixed and then allowed to sit at room temperature for 15 min in darkness. Absorbance at 734 nm was subsequently determined. Ascorbic acid at 250 µg/mL and methanol were used as the positive and negative control, respectively, in the ABTS• solution. The sample in methanol was utilized as a blank. The percentage of ABTS scavenging capability was determined using the same formula as the percentage for DPPH scavenging capability.

Evaluation of total phenolic content (TPC)

A revised Folin-Ciocalteu technique was utilized to quantify the TPC (23, 24). In this technique, 7.5% Na_2CO_3 (80 µL) and 10% Folin-Ciocalteu's phenol reagent (100 µL) were combined with the diluted extract (20 µL). The absorbance was determined using a microplate reader at 765 nm relative to a blank following a 30-min dark incubation period at room temperature. Gallic acid was used for the calibration curve. The findings were represented as mg GAE/mL extract and mg GAE/g sample for the extracts and ice cream, respectively.

Evaluation of physical characteristics

Determination of melting resistance was conducted according to Ghazizadeh *et al.* (25) with modification. Briefly, after removal from the freezer, 30 g of each ice cream sample were placed on a 2 mm wire mesh above the measurement cylinder. Following a 45-min incubation at 25°C, the amount of melted ice cream was determined. Subsequently, the ice cream was left until completely melted, and the total volume of melted ice cream was measured. The percentage of melting resistance was calculated using the formula:

$$\% \text{ melting resistance} = 100 - [(A / B) \times 100] \quad \text{(Eqn. 2)}$$

where, A = volume of melted ice cream within 45 min

B = volume of total melted ice cream

A colorimeter (HunterLab, ColorQuest XE, USA) was utilized to assess the color of ice cream according to CIE color system, as L* (lightness), a* (redness), and b* (yellowness).

The hardness of the ice cream was determined through a compression test, as described by Chuacharoen

(26) using a texture analyzer (Lloyd Instruments, TAPlus, UK) equipped with software. Prior to evaluation, each sample was placed in a 4 fl oz. plastic cup and maintained at -18°C for 24 h. A cylindrical probe with a diameter of 1 mm was used for the experiment, which was conducted at 25°C and connected to a 1 kN load cell. The penetration depth at the samples' geometrical center was 10 mm, and the penetration speed was adjusted to 2 mm/s. The peak pressure force (g) upon penetration was utilized to indicate the hardness.

Sensory assessment

Consumer preferences were evaluated with an acceptance test using a 5-point hedonic scale varying between the hedonic terms "1 = extremely disliked" and "5 = extremely liked" (27, 28). The test involved 30 untrained panelists consisting of students and staff at Suan Sunandha Rajabhat University aged between 18–60 years old. It was mandatory for the participants to abstain from smoking, not be pregnant or nursing, have no dietary allergies, and show no signs of experiencing negative responses to dairy-based foods. Each panelist received 25 g of each ice cream sample in light-colored plastic cups given a random 3-digit number, which were served individually in no particular order. Before each sample, the panelists were directed to wash their mouths using distilled water. Sensory parameters were evaluated based on preference for taste, color, odor, texture and overall acceptability. This work gained authorization from the Suan Sunandha Rajabhat University Ethics Committee with approval number COE.1-007/2023. Prior to conducting the sensory evaluation, all panelists were provided with a detailed explanation of the research objectives and participation procedures. They were required to sign consent forms indicating their agreement to participate in the research.

Statistical analysis

Every experiment was conducted in triplicate, and the outcomes were reported as mean ± S.D. Using IBM SPSS Statistics version 24 software (SPSS Inc., Chicago, IL, USA), statistically significant distinctions between the samples were analyzed using a completely randomized design one-way analysis of variance (ANOVA) and Tukey's multiple comparisons test. The parameters were determined to be significant at a significance level of 0.05 ($p < 0.05$).

Results and Discussion

Characteristics of *Tiliacora triandra* leaf extracts

This research compared the extraction of *T. triandra* leaves by the traditional method and the MAE technique. In the DPPH assay, the proportions of DPPH scavenging activity of the extracts using microwaves at 300 W (26.22, 32.34, 40.574%) and 600 W (31.84, 36.14, 44.26%) were significantly higher than those obtained with the traditional method (15.92, 19.22, 19.04%) at leaf ratios of 5%, 10% and 20%, respectively (Fig. 3A). Interestingly, extraction with a 600 W microwave at a 5% leaf ratio significantly inhibited DPPH radicals compared to extraction with a 300 W microwave, but no significant differences were observed at 10% and 20% leaf ratios.

For the ABTS assay, the proportions of ABTS scavenging activity of the extracts using microwaves at 300 W (78.20, 88.35, 90.55%) and 600 W (78.63, 88.96, 92.82%) were significantly higher than those obtained with the traditional method (60.45, 66.11, 68.06%) at all ratios (Fig. 3B). However, the extracts obtained using microwave at 300 W and 600 W at the same leaf ratio exhibited no significant difference in ABTS radical inhibition.

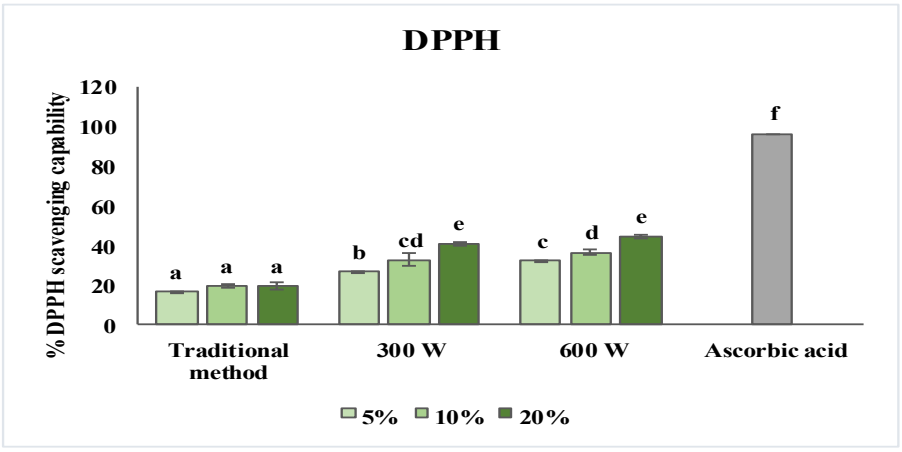
The results of total phenolic compound determination were consistent with the antioxidant activities. The total phenolic content of the extracts using a microwave at 300 W (6.38, 8.74, 10.39 mg GAE/mL extract) and 600 W (7.08, 9.20, 10.91 mg GAE/mL extract) were significantly higher than that obtained with the traditional method (2.84, 3.79, 4.52 mg GAE/mL extract) at all ratios (Fig. 3C). No significant differences between 300 W and 600 W extraction were found when compared at the same ratio.

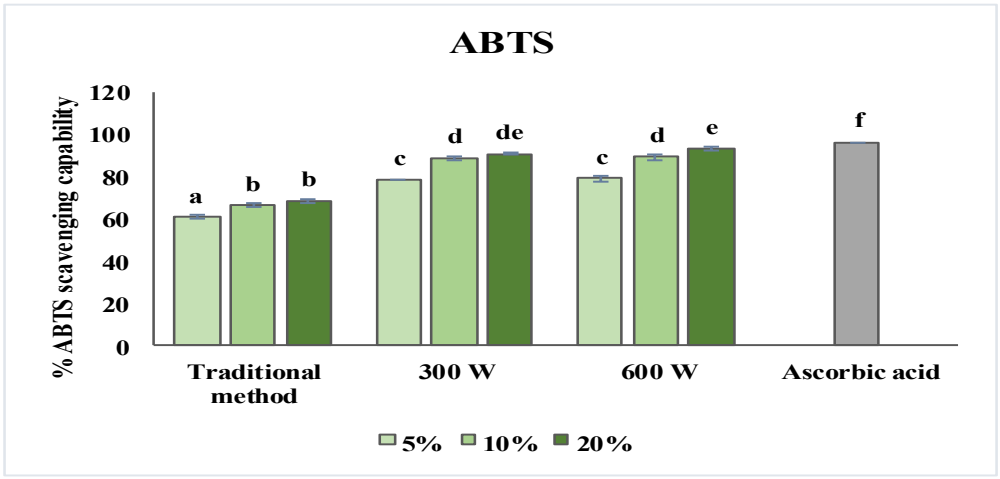
The results indicated that MAE had more potential to extract antioxidants than the traditional method. Jha and Sit (29) described the MAE technique as an efficient extraction method for increasing yield, improving the quality of extracts or biological substances from plant materials, reducing operational time, and being more environmentally friendly. Dielectric constant-based heating, ionic conduction, and molecule dipole rotation are the primary phenomena that take place during microwave exposure. These actions result in three successive steps that make up the extraction procedure: solute separation from the active sites of the sample matrix under elevated pressure and temperature, solvent diffusion throughout the sample matrix, and solute release from the sample matrix into the solvent (30). Solvent characteristics, temperature, microwave power, exposure time, sample matrix particle size, solid-to-liquid ratio, and the number of extraction cycles are significant factors that affect MAE extraction efficiency (15, 31). The optimization of the MAE technique may depend on the purpose of extraction, the type of plant, and the properties of the bioactive compounds to be extracted. For example, optimal conditions to recover phenolic compounds and antioxidants from *Corchorus olitorius* leaves included a microwave power of 305 W for 131 sec, 50% ethanol as solvent, and a sample-to-solvent ratio of 1 g/12 mL (32). Conversely, achieving the highest total phenolic compounds from dried *Moringa oleifera* leaves required a microwave power at 200 W for 400 sec, a 72% ethanol solution and a particle size of 0.5 mm (33). Furthermore, the most favorable conditions for the extraction of rutin, quercetin, genistein, kaempferol, and isorhamnetin from Flos Sophorae Immaturus (Cultivars of *Sophora japonica* L.) differed for each substance when using microwave power in the range of 250–300 W. The optimal extraction time was found to be between 70 and 80 sec, and repeating the extraction process 2–3 times was more effective than conducting only a single round (34). This research represents the first report on the application of MAE in *T. triandra* leaf extraction. Therefore, establishing the optimal conditions in more detail would be beneficial

DPPH	Mean				SD			
	Traditional method	**300 W**	**600 W**	**Ascorbic acid**	**Traditional method**	**300W**	**600W**	**Ascorbic acid**
5%	15.92	26.22	31.84		0.82	0.30	0.60	
10%	19.22	32.34	36.14	95.63	0.97	3.30	1.82	0.12
20%	19.04	40.57	44.26		1.60	0.76	1.12	

ABTS	Mean				SD			
	Traditional method	300 W	600 W	Ascorbic acid	Traditional method	300W	600W	Ascorbic acid
5%	60.45	78.20	78.63		0.96	0.23	1.36	
10%	66.11	88.35	88.96	95.88	0.57	0.61	1.48	0.10
20%	68.06	90.55	92.82		0.83	0.32	0.84	

TPC	Mean			SD		
	Traditional method	300 W	600 W	Traditional method	300W	600W
5%	2.84	6.38	7.08	0.12	0.05	0.30
10%	3.79	8.74	9.20	0.04	0.25	0.11
20%	4.52	10.39	10.91	0.17	0.25	0.66





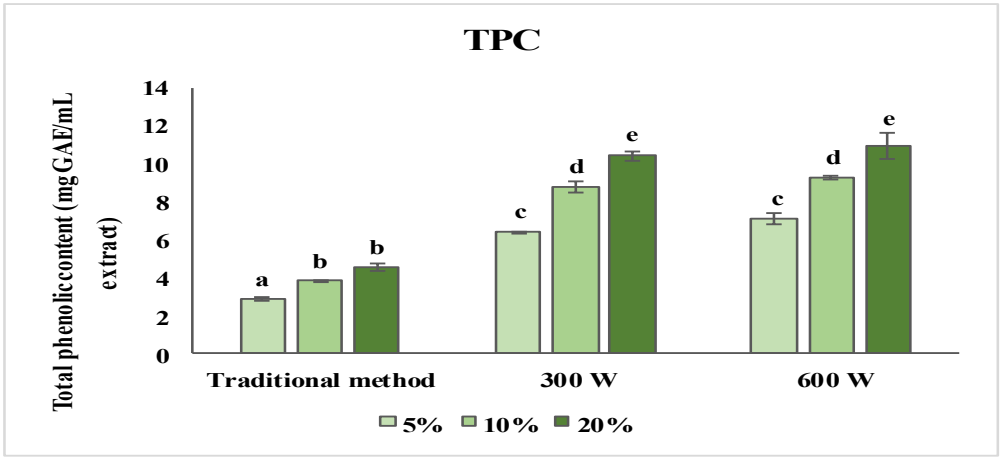


Fig. 3. Leaf extracts from *Tiliacora triandra* exhibiting antioxidant properties and total phenolic content: (A) DPPH scavenging capability; (B) ABTS scavenging capability; (C) Total phenolic content.

for obtaining a higher yield of bioactive compounds from *T. triandra* leaves through a convenient, fast, and highly efficient process.

It is worth noting that the extract at a 5% leaf ratio using a microwave at 600 W showed significantly higher potential for DPPH radical scavenging compared to using a microwave at 300 W and the traditional method. Therefore, the extract obtained using a microwave at 600 W was chosen as a component of functional ice cream for further experiments.

Antioxidant activities and total phenolic content of *T. triandra* ice cream

In this research, 4 ice cream formulas were produced, including T0, a control formula that did not contain *T. triandra* leaf extract, and T5, T10, and T20, which were mixed with 30 mL of *T. triandra* leaves extracted with a 600 W microwave at leaf ratios of 5%, 10% and 20%, respectively (Fig. 4).

In the DPPH assay, T20 exhibited the highest percentages of DPPH scavenging activity (54.30%) followed by T10 (48.02%), T5 (36.32%) and T0 (30.75%), respectively (Fig. 5A).

In the ABTS assay, the obtained results were similar to the DPPH assay in that T20 had the highest percentages of ABTS scavenging activity (73.83%), followed by T10 (67.82%), T5 (63.22%) and T0 (57.00%), respectively (Fig. 5B).

The total phenolic content of all ice cream formulas significantly increased according to the leaf ratios of the extracts. T20 had the highest amount of total phenolic compound (3.48 mg GAE/g sample), which was statistically significant, followed by T10 (2.83 mg GAE/g sample), T5 (2.27 mg GAE/g sample) and T0 (1.90 mg GAE/g sample), respectively (Fig. 5C).

The addition of *T. triandra* leaf extract by MAE to the ice cream resulted in significantly increased antioxidant activity and total phenolic compounds according to the leaf ratio when compared to the control formula, thus making ice cream a potential antioxidant product. The introduction of *T. triandra* freeze-dried powder in the highest quantity to the sherbet produced the highest TPC value, which correlated with greater FRAP and DPPH values, as reported by Chuacharoen (26). A broad array of antioxidants, including phenolic compounds, chlorophyll, alkaloids, anthocyanins, carotenoids, flavonoids, gallic acid, cyanidin and quercetin were extracted from *T. triandra* leaves (9). The protective properties of these bioactive chemicals against increased quantities of free radicals and reactive oxygen species (ROS) in the human body make them highly intriguing. Thus, the ingesting of functional foods with antioxidants has received enormous attention from health-conscious consumers due to their beneficial roles in human health.

Physical properties of *T. triandra* ice cream

This research also investigated whether supplementation of *T. triandra* leaf extract into the ice cream affects its physical properties. The results of all 4 functional ice cream formulas are depicted in Table 1.

The color parameters of the functional ice cream were expressed as quantities of L^*, a^*, and b^*. Significantly, T20 showed the lowest $L^*$and a^* values but the highest b^* value compared to other formulas. This indicated that adding *T. triandra* leaf extract at a higher leaf ratio affected the ice cream by making it darker green. This effect was likely caused by the presence of natural pigments in *T. triandra* leaves, such as chlorophyll, anthocyanins, and carotenoids (9).

When examining the texture of each ice cream formula, it was revealed that adding *T. triandra* leaf extract

Table 1. Physical properties of *Tiliacora triandra* ice cream.

Sample	Melting resistance (%)	Color			Hardness
		*L**	*a**	*b**	(N)
T0	27.33 ± 2.10^{a}	90.12 ± 0.34^{d}	-0.68 ± 0.11^{c}	8.55 ± 0.28^{a}	23.89 ± 0.96^{a}
T5	27.65 ± 0.44^{a}	82.36 ± 0.22^{c}	-1.48 ± 0.04^{b}	9.42 ± 0.21^{a}	23.83 ± 0.26^{a}
T10	28.80 ± 1.40^{a}	80.10 ± 0.20^{b}	-1.63 ± 0.05^{b}	11.20 ± 0.23^{b}	24.98 ± 0.09^{ab}
T20	28.88 ± 2.42^{a}	74.86 ± 0.18^{a}	-1.79 ± 0.06^{a}	12.73 ± 0.61^{c}	26.82 ± 1.56^{b}

Note: Data are means ± standard deviation of three replications; the same letter within the same column indicates no statistically significant difference.

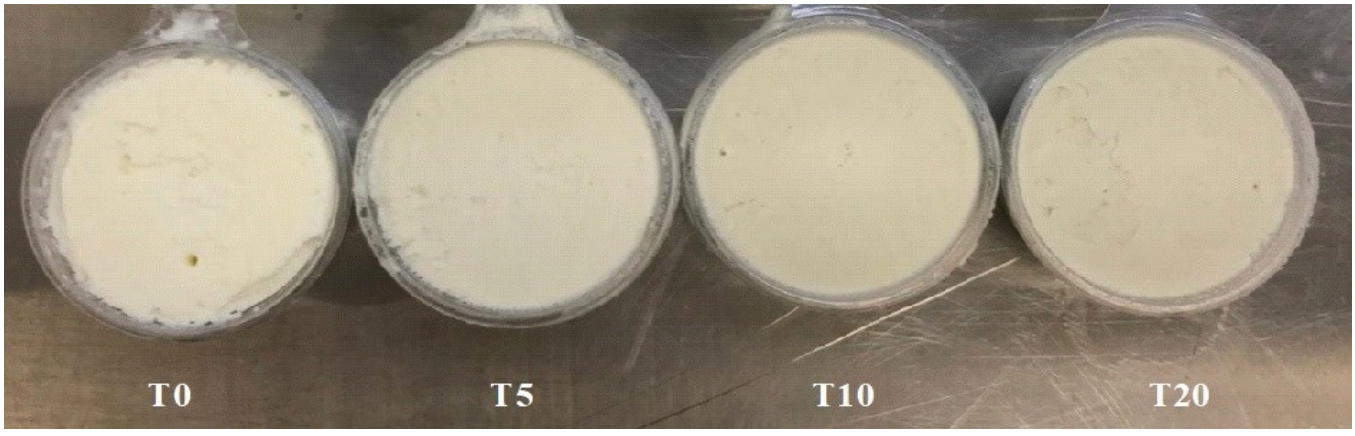


Fig. 4. Presence of ice cream supplemented with *Tiliacora triandra* leaf extract.

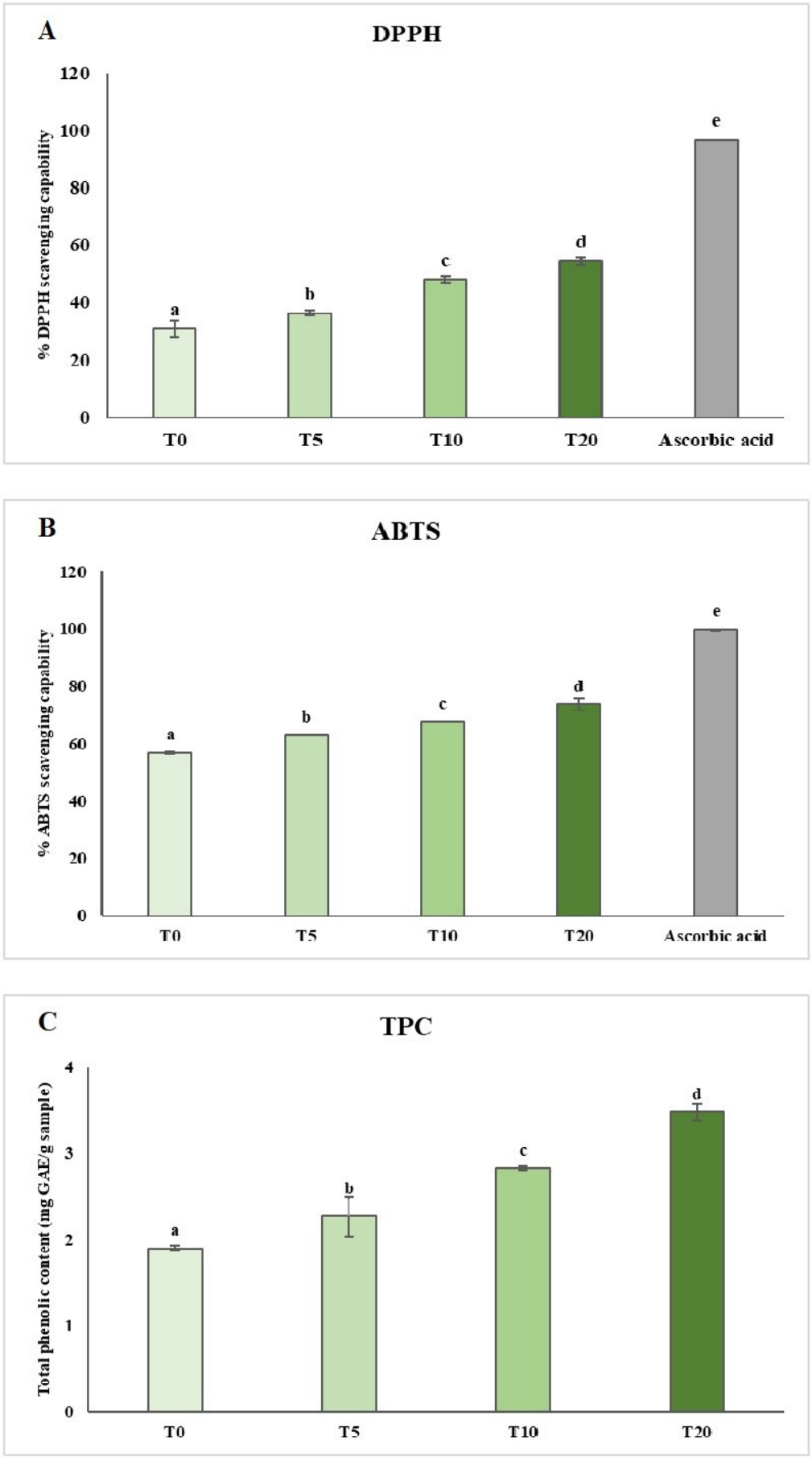


Fig. 5. Antioxidant activities and total phenolic content of *Tiliacora triandra* ice cream: (A) DPPH scavenging capability; (B) ABTS scavenging capability; (C) Total phenolic content.

at a higher leaf ratio resulted in a significantly harder texture. T20 showed the highest hardness, followed by T10, T5 and T0, respectively. This finding was consistent with the increase in the hardness of the sherbet by adding higher concentrations of freeze-dried *T. triandra* powder (26).

In this study, *T. triandra* leaf extract induced a slight increase in melting resistance, but it was not statistically significant. This observation aligns with findings from several researchers indicating that adding higher amounts of plant extracts to ice cream made the texture harder and the melting slower. In a concentration-dependent way, the inclusion of pomegranate, clove, and chicory peel extracts drastically improved the melting resistance of ice cream, as found by Ghazizadeh *et al.* (25). When producing functional ice cream, Cornelia *et al.* (35) discovered that a greater quantity of cinnamon extract and a higher soy milk ratio resulted in a longer melting period. Sayuti *et al.* (36) demonstrated that adding more *Melastoma malabathricum* L. leaf juice to the ice cream resulted in an extended melting time, while less leaf juice added caused the ice cream to melt faster. One of the key characteristics of ice cream that influences sensory quality is its melting rate, which is influenced by a number of factors including the total solid content, ice crystal size, fat size and network and the amount of air used during manufacture (37). Thus, these variables may vary if *T. triandra* leaf extract is used, particularly because the plant extract contains more solids, which improves the texture and melting rate of ice cream.

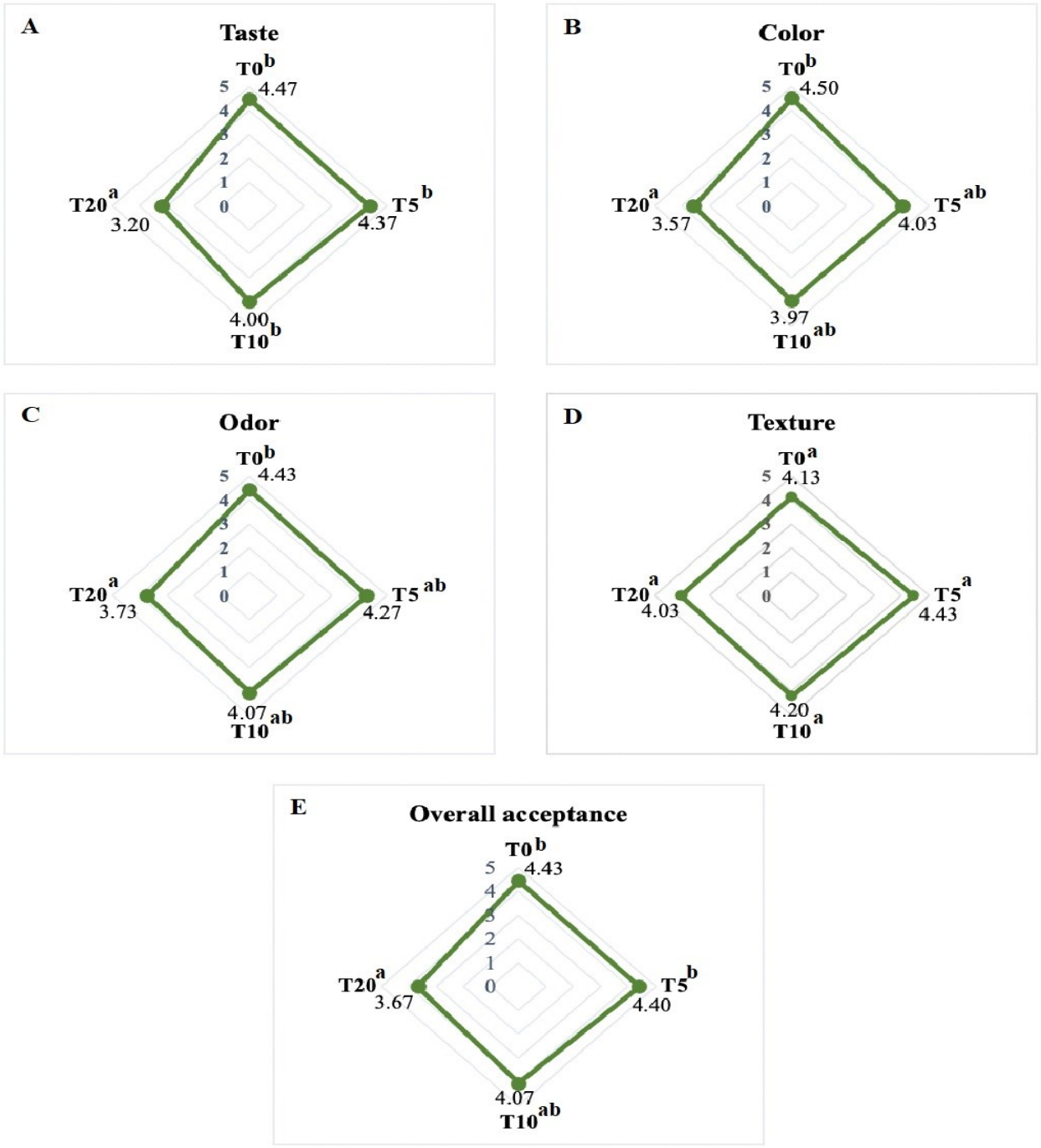


Fig. 6. Sensory evaluation of *Tiliacora triandra* ice cream: (A) Taste; (B) Color; (C) Odor; (D) Texture; (E) Overall acceptance.

Sensory assessment of *T. triandra* ice cream

It is critical to explore customer preferences for product attributes while developing novel products. In this study, the sensory evaluation results for each ice cream formula were assessed according to taste, color, odor, texture and overall acceptability, which are summarized in Fig. 6. T5 and T10 received significantly higher scores for taste, color, odor and overall acceptability than T20, and they were not different from the control T0. The texture scores for all 4 ice cream formulas were not significantly different. It appears that T5 and T10 were more accepted by consumers than T20.

The results revealed that the extract with a higher leaf ratio induced a negative effect on taste, color, odor and overall acceptability scores. This finding aligns with the sensory evaluations of the sherbet samples, where appearance/color, flavor, consistency, foreign taste, and overall acceptance were considerably diminished as the percentages of freeze-dried *T. triandra* powder increased (26). Additionally, a similar study found that supplementing more *T. triandra* leaf juice to a Thai layered dessert resulted in a lower level of acceptance being perceived (38). These results might be associated with the dark green color, foreign taste, and unpleasant smell of fresh *T. triandra* leaf juice (39). Although *T. triandra* leaf juice has been applied as an ingredient in many savory dishes for a long time, adding it to desserts may still have limitations and should be done in appropriate amounts.

Nowadays, functional foods are gaining more attention among health-conscious consumers, leading to the addition or modification of healthful ingredients that enhance consumer fitness and health. However, several studies have indicated that the influence of sensory properties may outweigh the influence of health benefits (8). Additionally, it is recommended that informing consumers on how to assess the health advantages of functional meals might be one of the main techniques to boosts public acceptance of these foods and enhances consumer health.

Conclusion

This research found that the extract of *Tiliacora triandra* leaves using microwaves at 600 W for 30 sec for 3 cycles exhibited higher antioxidants than other methods. Therefore, it was chosen to be combined with ice cream for comparison to the control formula. Adding a higher leaf ratio of *T. triandra* leaf extract made the ice cream have significantly more antioxidant activities, a darker green color, and a harder texture but slightly affected the melting resistance. The ice cream supplemented with the extract at a 10% leaf ratio (T10) is suitable for further development into functional ice cream because it has a high level of antioxidants and appropriate physical properties. It is also accepted by consumers.

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Authors' contributions

NB conducted the design of the study and coordination, carried out the plant collection and the sensory evaluation. CW participated in determination of antioxidant activities. JC evaluated the physical properties. PW performed the experimental design and statistical analysis. SC participated in the ice cream production. SP carried out the preparation of plant specimen for species authentication, the sample extraction, drafted and revised the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

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