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Development of herbal tea bags for the management of gastritis

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ABSTRACT

Background: Herbal teas are widely consumed beverages globally and are known for their diverse therapeutic properties and health benefits. **Objectives:** This study aimed to evaluate *in vitro* acid-neutralizing properties of an herbal tea made from the dried leaves of *Aegle marmelos*, *Desmodium triflorum*, and *Centella asiatica* as a potential management option for gastritis. **Materials and Methods:** Herbal tea bags (T1-T11) were prepared by blending different ratios of the powdered leaves, and each tea bag was steeped at 100°C for 3, 5, and 7 minutes. The acid-neutralizing capacity was measured using Fordtran's titration method. Infusions showing the highest acid-neutralizing capacity were further tested at varying temperatures (100°C, 80°C, and 60°C) while maintaining a consistent infusion time. The duration of neutralization was assessed using a modified Vatier's artificial stomach model. The results were compared with green tea and distilled water. **Results:** The herbal tea infusions made at 100°C for 5 minutes exhibited significantly higher acid-neutralizing capacities ($p \leq 0.05$). The strongest neutralizing capacities were recorded for T9 (27.10 ± 0.00 mL) and T7 (24.70 ± 0.00 mL), followed by green tea (5.43 ± 0.05 mL) and distilled water (0.73 ± 0.05 mL). T9 also showed the longest neutralization duration, lasting 382.33 ± 2.00 seconds, while green tea and distilled water neutralized for only 42.00 ± 1.00 seconds and 72 ± 1.00 seconds, respectively. **Conclusion:** In conclusion, the T9 formulation, containing only *A. marmelos*, demonstrated the highest acid-neutralizing ability and duration, making it an optimal solution for managing gastritis when steeped at 100°C for 5 minutes.

Keywords: Gastritis, Herbal tea, *Aegle marmelos*, Acid neutralizing capacity, Fordtran's titration method, Vatier's artificial stomach model.

INTRODUCTION

Gastritis is a highly prevalent disease condition, affecting people of all ages worldwide due to inflammation of the gastric mucosa [1]. Various factors, including the fast paced and stressful modern lifestyle, contribute for the development of gastritis [2]. This condition can be exacerbated by various factors such as certain medications like non-steroidal anti-inflammatory drugs (NSAIDs), autoimmunity, chronic alcohol consumption, smoking, viral infections like Epstein-Barr virus, and bacterial infections like *Helicobacter pylori* infection. Gastritis is typically classified into two types as acute and chronic gastritis [3]. Acute gastritis occurs due to numerous factors such as certain drugs, bile, ischemia, viral, fungal, radiation, acute stress and direct trauma [4]. Chronic gastritis is a condition where the lining of the stomach becomes inflamed over time. This inflammation can vary in its severity and location, depending on the underlying cause and how the person's body responds to it [5]. Proton pump inhibitors (PPI), H_2 receptor blockers, antacids such as magnesium and aluminum hydroxide compounds, and prostaglandin derivatives like misoprostol are used as conventional medications to treat gastritis [6, 7]. However, many of these medications can lead to unwanted side effects such as impotence, arrhythmias, hypersensitivity reactions, changes in blood cell production, and gynecomastia, as well as interactions with other drugs [8]. Due to the significant adverse reactions and high recurrence rate, approximately 80% of the global population relies on traditional medicine for primary healthcare, either exclusively or in combination with conventional treatments. Throughout the history, herbal remedies have been central to traditional medical systems and have played a vital role in maintaining human health [9]. In recent years, there has been an increasing interest in alternative therapies, particularly in herbal products derived from medicinal plants due to their benefits [8]. Tea is one of the most popular beverages in the world among a majority of people. Herbal tea, also known as tisane, refers to a blend of dried plant parts used for the medicinal purposes. It encompasses a diverse range of tea products such as herbal, green, black, oolong, and white teas. These teas are made from dried leaves, flowers, fruits, nuts, seeds, barks, grasses, roots, and other botanical elements, which are combined for their medicinal properties. Also, some herbal tea blends with extra herbs to boost their health benefits [10]. Thus, use of herbal teas for the treatment of diseases is an alternative approach used in the present. Numerous scientific studies have demonstrated

the health benefits of these herbal teas. *Hibiscus sabdariffa* L. tea is famous for its significant pharmacological activities such as antioxidant properties [11] and anti-hypertensive properties [12]. *Salvia officinalis* L. a member of Salvia genus has been used in folk medicine and studies have proven pharmacological properties such as antibacterial, anti-inflammatory, anti-cancer, and anti-proliferative activity of the herbal tea [13]. *Lavandula angustifolia* commonly known as lavender is widely cultivated for their medicinal or culinary properties, and the tea [14] is widely used to treat depression and anxiety due to its potent pharmacological activity [15].

Aegle marmelos (L.) is a medicinal tree from the Rutaceae family, commonly known as, "Beli"in Sinhala. This plant is native to India and found in Sri Lanka, Bangladesh, Pakistan, Thailand, Myanmar, Egypt [16]. *A. marmelos* has been used in traditional medicine to treat a variety of ailments such as chronic diarrhea, dysentery, peptic ulcer, respiratory infection, heart palpitation, abdominal pain, urinary trouble, vomiting, swelling etc. Different parts of the plant, including the leaves, bark, stem, fruits, roots, and seeds, are known for their medicinal properties. These include antibacterial, antiviral, gastroprotective,antidiarrheal, anti-ulcerative colitis, hepatoprotective, antidiabetic, radioprotective, and cardioprotective effects [17]. The studies have shown that *A. marmelos* consist of polyphenols, flavonoids, alkaloids, terpenoids, coumarins, polysaccharides, and carotenoids in various plant parts respect for the pharmacological activities [18].

Desmodium triflorum Linn is a member of the Fabaceae family. It is a well-known medicinal plant in Sri Lanka and commonly referred to as 'Heen-Undupiyaliya' in Sinhala. In Ayurveda, *D. triflorum* is used to treat conditions such as headaches, eye diseases, dysentery, bone fractures, and snake bites. The leaves, roots, and whole plant are utilized for various therapeutic purposes as anti-proliferative, anthelmintic, anticonvulsant, analgesic, hypoglycemic, and anti-inflammatory conditions [19]. An initial screening of phytochemicals revealed these plants has an abundance of alkaloid, phenolethylamine (the major alkaloid), indole-3-acetic acid, tyrumine, trigonelline, hypaphorine and choline in leaves while the root contains the alkaloids such as hypaphorine N,N dimethyl tryptophan betaine and choline [20]. *Centella asiatica* (L.) Urban, is a perennial herbaceous creeper that belongs to the family Apiaceae. It is commonly known as Gotu kola in Sinhala or Indian pennywort, and it has been used as a traditional herbal medicine in Asiatic countries for hundred years [21]. Previous research has revealed that *C. asiatica* possess antiulcer, antitumor, antioxidant and immunomodulatory properties. *C. asiatica have* been reported to be effective against gastric ulcer caused by ethanol, aspirin, cold resistant stress, pylorus ligation and acetic acid [22]. The phytochemical composition of *C. asiatica* leaves includes proanthocyanins, rutin, naringenin, quinine, flav-3-ol, spartein, phenols, flavonones, steroids, kaempferol, phytates, resveratrol, tannins, and ribalinidine [23]. The medicinal value of *A. marmelos*, *D. triflorum* and *C. asiatica* demonstrate that the potential of using these herbal plants for the development of an herbal tea for the ailment of various diseases. Thus, the present study was conducted to develop herbal tea bags containing dried leaves of *A. marmelos, D. triflorum,* and *C. asiatica,* and to investigate their *in-vitro* acid neutralizing activity and to determine the influence of infusion time and temperature on the acid neutralizing capabilities of the tea.

METHODOLOGY

Plant collection and authentication

The fresh leaves of *A. marmelos, D. triflorum* and *C. asiatica* were collected from the Mahawila Panadura, Sri Lanka (6.7156 N, 79.9391 E) in January 2024. The plants materials were authenticated by the Bandaranaike Memorial Ayurveda Research Institute, Nawinna, Sri Lanka, and the voucher specimens were deposited under reference numbers (Acc. No. 3176 for *A. marmelos*, Acc.No. 3177 for *D. triflorum*, Acc.No. 3178 for *C. asiatica*).

Preparation of herbal tea bags and extraction

Collected fresh plant materials were thoroughly washed, air-dried, and then dried in a hot air oven at 40 ^{0}C until a constant weight was obtained. The dried plants were then ground in to coarse powder, and these powder samples were stored in air-tight, light-resistant containers. Eleven different herbal tea bags were prepared by incorporating dry powders of *A. marmelos, D. triflorum, C. asiatica* in different ratios (Table 1) to a constant total weight of 2.00 g. Tea infusions were prepared using the method mentioned by [10] with slight modifications. The tea bags were infused in 90.0 mL of distilled water under two conditions. First, at a constant temperature of 100 °C tea bags were infused for 3, 5, and 7 minutes separately for each sample. According to the results the tea bags which showed the highest activity were selected and they were infused at different temperatures of 100 °C, 80 °C, and 60 °C for a constant of 5 minutes. Each herbal tea infusion was then analyzed individually for its activity.

Preparation of artificial gastric acid

Sodium chloride 2 g, 0.0032 g of pepsin and 7 mL of hydrochloric acid were dissolved in distilled water to make a 1000 mL of artificial gastric acid in a volumetric flask. The pH of the artificial gastric acid was adjusted to 1.20 using an electronic pH meter (Portable pH meter, Milwaukee, Romania) [24].

Determination of *in vitro* acid neutralization capacity using the titration method of Fordtran's model.

Initially, the pH of each herbal tea infusion prepared, green tea (positive control) and distilled water (negative control) were measured. A clean glass burette was filled with the freshly prepared artificial gastric acid. Test samples were heated to 37 ^{o}C while stirring using a magnetic stirrer. The heated test samples were titrated with artificial gastric acid until a pH of 3.0 was reached, while stirring maintained at 30 rpm. The amount of H^+ ions consumed was then calculated using the following equation, based on the volume (mL) of artificial gastric acid consumed during the titration [24].

$$\text{The total consumed } H^+ \text{ ion (mmol)} = 0.063096 \text{ (mmol/mL)} \times V\text{(mL)}$$

Then, based on the results the infusion time that gives the best acid neutralizing ability at 100 ^{0}C was selected as the best infusion time. The herbal tea samples with the best acid neutralizing capacity were tested at different temperatures, 100°C, 90°C, and 60°C while keeping that infusion time constant.

Determination of duration of time of consistent acid neutralization.

A modified Vatier's artificial stomach was used to measure the duration of time taken by herbal tea bags to consistently neutralize artificial gastric acid as described in [19]. The artificial stomach model included a reservoir for gastric acid, a tubing system for secretion and excretion of artificial gastric acid into the reservoir, and a motor system for pumping the acid. Artificial gastric acid 100 mL was combined with 90 mL of each herbal tea infusion separately, within the reservoir at 37 ºC. The magnetic stirring device was used to continuously stir the contents of the artificial stomach reservoir at a speed of 30 rpm. At the same time, artificial gastric juice with a pH 1.2 was pumped in and out with a rate of 3 mL/min. The pH changes in the artificial stomach were continuously monitored with a pH meter connected. When the pH reached its original level of 1.2 again, the duration of the neutralization effect was measured. Distilled water (90 mL) was used as the negative control and 90 mL of green tea infusion was used as positive control [24].

Qualitative analysis of phytochemicals

Each tea infusion underwent preliminary qualitative phytochemical screening to detect various phytoconstituents including alkaloids, phenols, tannins, terpenoids, proteins, saponins, cardiac-glycosides, carbohydrates, steroids, using established methodologies as described in [25, 26]. The phenolic test was done for phenols and Mayer's and Wagner's assay to detect alkaloids. Tannins were detected with ferric chloride test. The froth test was used to detect saponins. The steroids and terpenoids were detected by Liebermann-Burchard test and Salkowski test respectively. Cardiac glycosides were detected using Keller Killani's test. Benedict test was performed to detect carbohydrates and biuret test was used to detect proteins.

***In vitro* lethal toxicity assay for herbal tea bags**

A 1.00 g of *Artemia* egg was added to 1.00 L of prepared artificial seawater which was made by dissolving the 24.60 g of sodium chloride, 0.67 g of potassium chloride, 1.36 g of calcium chloride dihydrate, 6.29 g of magnesium sulfate heptahydrate, 4.66 g of magnesium chloride hexahydrate, and 0.18 g of sodium bicarbonate in 1.00 L of distilled water. The final pH of the artificial seawater was adjusted to pH 8. The mixture was exposed to a light source and aerated for 24 hours until the *Artemia* eggs hatched. Subsequently, 10 alive *Artemia larvae* (nauplii) were introduced into 5.00 mL of best selected (the highest activity given) herbal tea and, green tea infusions, with each test being conducted in triplicate. The samples were then incubated for another 24 hours under the same light conditions for toxicity evaluation and the number of alive napuli after 24 hours were determined. Artificial seawater served as the negative control in this assay [27, 28].

$$\%\ \textit{Artemia}\ \text{death} = \frac{\text{Total napulii- Alive napulii}}{\text{Total napulii}} \times 100\ \%$$

Statistical analysis

All experiments were performed in triplicate (n = 3), and the results were expressed as mean ± standard deviation. Statistical analysis was conducted using GraphPad Prism (version 10). Comparisons between test and control samples were carried out using one-way ANOVA, followed by Tukey's post hoc multiple comparison test. A p-value of < 0.05 was considered statistically significant.

RESULTS

Determination of *in-vitro* acid neutralization capacity using the titration method of Fordtran's model

Neutralizing effects on artificial gastric acids at different infusion times for a constant temperature

The neutralizing capacity of the infusions were determined by the Fordtran's *in vitro* titration model. The volume of artificial gastric acid consumed to reach pH 3 was recorded for the test samples. Table 2 shows the results of *in vitro* acid neutralizing capacity of all tea bag formulations after infusion at 100 ºC for (3 min, 5 min and, 7 min respectively). Notably, most tea bags exhibited their highest neutralizing capacities after 5 minutes infusion. T9 and T7 demonstrated significantly greater neutralizing capacities, with values of 27.10±0.00 mL and 24.70±0.00 mL, respectively. However, T10 showed relatively lower neutralizing capacities, with values of 3.66±0.11 mL. The tea bags which exhibited highest neutralizing capacity at 5 minutes infusion time (T9 and T7) were selected for further analysis.

Neutralizing effect on artificial gastric acid at different infusion temperatures for constant infusion time

The selected tea bags T9 and T7 demonstrated the highest *in-vitro* acid neutralizing capacity across various infusion temperatures while maintaining a constant infusion time of 5 minutes. The peak capacity observed when infused at 100 ºC (Table 3). Subsequently, the findings revealed that both T9 and T7 exhibited significantly higher acid neutralizing capacities ($p < 0.05$) compared to the negative control (distilled water) and positive control (green tea) ($p < 0.05$).

Duration of consistent neutralization effect on artificial gastric acid

According to the results, both T9 and T7 exhibited a duration of consistent neutralization of artificial gastric acid of 381.3±2.00 & 157.7±2.00 seconds while the positive control and negative control exhibited a duration of 42±1.00 s and 72±1.00 s respectively. T9 had the highest duration of consistent neutralization on artificial gastric acid, which was significantly higher ($p<0.05$) than both the positive control and negative control.

Phytochemical composition analysis

A qualitative phytochemical analysis revealed that the best tea infusions (T9 and T7) contained phytoconstituents including phenols, tannins, terpenoids, cardiac glycosides, carbohydrates and steroids.

***In-vitro* lethal toxicity**

According to the results of *in-vitro* lethal toxicity assay, tea bag T7 showed a toxicity of =30% while T9 was =50%.

Figure 1: Fordtran's model

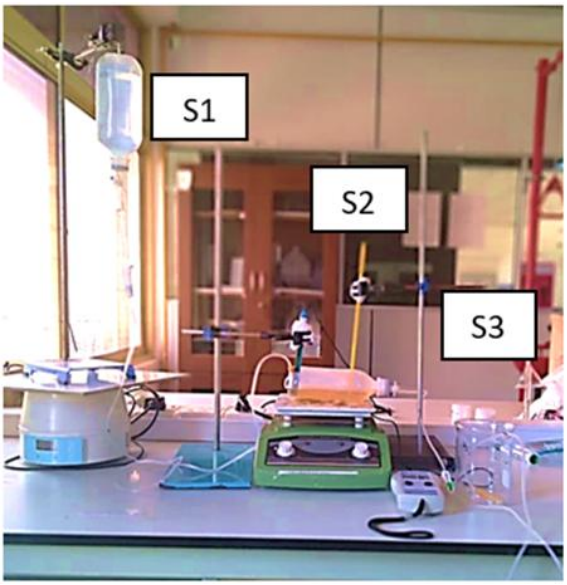

Figure 2: Vatier's model: S1- Reservoir for gastric acid, S2- Stomach Chamber, S3- Discharge chamber

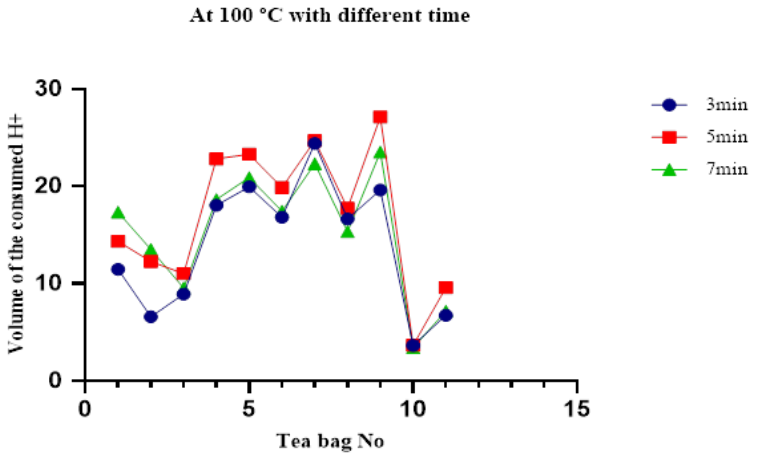

Figure 3: Neutralizing effect of tea bags

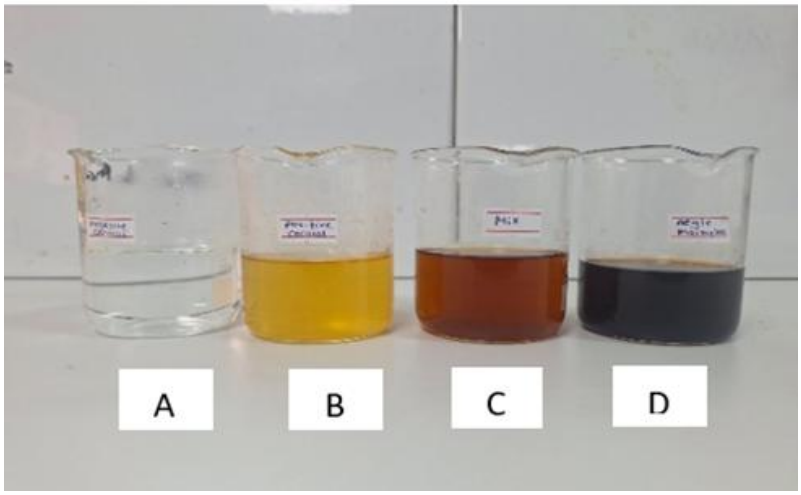

Figure 4: Tea samples (A: Negative control: Distilled water, B: Positive control: Green tea, C: T7, D: T9)

Table 1: Composition of herbal tea bags prepared from *A. marmelos, D. triflorum,* and *C. asiatica* in various ratios

Tea bag No	The powder of *A. marmelos*	The powder of *D. triflorum*	The powder of C. *asiatica*
T1	70%	20%	10%
T2	40%	40%	20%
T3	50%	50%	-
T4	80%	20%	-
T5	80%	-	20%
T6	60%	10%	30%
T7	80%	10%	10%
T8	50%	25%	25%
T9	100%	-	-
T10	-	100%	-
T11	-	-	100%

Table 2: Neutralizing effects on artificial gastric acids at 100 ºC with different time (3min, 5min, and 7min) and consumed H^+ ions

Tea bag No	Neutralizing capacity at 3min (Volume, mL)	Neutralizing capacity at 5min (Volume, mL)	Neutralizing capacity at 7min (Volume, mL)	mmol of H^+ consumed at 3min	mmol of H^+ consumed at 5min	mmol of H^+ consumed at 7min
T1	11.47± 0.05	14.33±0.05	17.33±0.05	0.72±0.00	0.90±0.00	1.09±0.00
T2	6.6±0.00	12.27±0.05	13.50±0.00	0.41±0.00	0.77±0.00	0.85±0.00
T3	8.9±0.00	11.00±0.00	9.56±0.05	0.56±0.00	0.69±0.00	0.60±0.00
T4	18.03±0.05	22.8±0.00	18.63±0.05	1.13±0.00	1.43±0.00	1.17±0.00
T5	19.93±0.05	23.30±0.10	20.90±0.10	1.25±0.00	1.47±0.00	1.31±0.00
T6	16.8±0.00	19.87±0.11	17.43±0.05	1.06±0.00	1.25±0.00	1.09±0.00
T7	24.4±0.00	24.70±0.00	22.30±0.00	1.53±0.00	1.54±0.00	1.40±0.00
T8	16.63±0.11	17.73±0.05	15.33±0.05	1.04±0.00	1.18±0.00	0.96±0.00
T9	19.60±0.00	27.10±0.00	23.50±0.00	1.23±0.00	1.70±0.00	1.48±0.00
T10	3.63±0.05	3.66±0.11	3.40±0.10	0.22±0.00	0.23±0.00	0.21±0.00
T11	6.73±0.05	9.60±0.10	7.16±0.05	0.42±0.00	0.60±0.00	0.45±0.00

Table 3: Neutralizing effect on artificial gastric acid at different infusion temperatures for constant infusion time (5 minutes)

Test sample	60 ºC (mL)	80 ºC (mL)	100 ºC (mL)
T7	15.00±0.10	15.70±0.10	24.70±0.00
T9	13.43±0.05	18.10±0.10	27.10±0.00
Green tea	-	-	5.433±0.05
Distilled water	-	-	0.7333±0.05

Significant $p<0.05$ compared to distilled water, $p<0.05$ compared to green tea. Values are presented as average ± SD (n=3).

Table 4: Duration of consistent neutralization effect on artificial gastric acid

Test Sample	Duration of consistent neutralization (seconds)
T9	381.3±2.00
T7	157.7±2.00
Green tea	42±1.00
Distilled water	72±1.00

Significant $p<0.05$ compared to distilled water, $p<0.05$ compared to green tea. Values are presented as average ± SD (n=3).

Table 5. Qualitative analysis of phytochemical screening

Phytochemicals	T9	T7
Alkaloids	+	-
Phenols	-	+
Tannins	+	+
Proteins	-	-
Saponin	+	-
Cardiac glycosides	+	+
Carbohydrates	+	+
Steroids	-	-
Terpenoids	+	+

Where; + Positive, - Negative

DISCUSSION

Medicinal plants are a staple of almost every culture and civilization as a source of medicine. A large number of contemporary medications are made from medicinal plants, which are thought to be abundant sources of traditional remedies. They have been used to treat illnesses, preserve food, add flavor, and prevent disease outbreaks for thousands of years. Many plant species cultivated globally have biological traits that are typically attributed to the secondary metabolites they generate [29]. Approximately 80% of people in developing countries still receive

their primary medical care from traditional medicine, which is mostly based on plant species. Approximately 25% of US pharmaceutical prescriptions currently include at least one component sourced from plants. These medicinal herbs are also commonly used to treat gastrointestinal problems, such as peptic ulcers, irritable bowel syndrome, and inflammatory bowel disease [30].

In many parts of the world, people voluntarily and regularly consume herbal teas and medicinal plant formulations because of their therapeutic and healing characteristics. The main factors contributing to the popularity of these herbal drinks are the wide availability of herbal teas and medicinal plant formulations, their affordability, their near-complete lack of adverse effects and biological aggression, and their recent tendency to complement or substitute traditional medications and drugs. Numerous health benefits and therapeutic activities are known to be associated with their consumption, including stimulant, relaxant, calming, detoxification, and metabolic regulatory features; antioxidant, hepatoprotective, choleretic, diuretic, inflammatory, and even anticancer properties; anti-anemic, hypoglycemic, and neuroprotective effects [31].

Furthermore, the use of herbal products, especially those made from medicinal plants, and alternative therapies have gained popularity in recent years. The most important sources of novel medications are plant extracts and their formulations, which have also demonstrated encouraging outcomes in the treatment of stomach ulcers [8].

This study successfully developed and evaluated herbal tea bags containing *A. marmelos*, *D. triflorum*, and *C. asiatica* for acid-neutralizing capacity and the duration of consistent neutralization on artificial gastric acid. Fordtran's titration model and Vatier's artificial stomach model were used in the present study to determine the *in vitro* antacid activity. These models mimic some of the regular physiological functioning of a human stomach, are commonly used in studies to investigate the gastroprotective activity of medicinal plants.

Fordtran's model is a titration method where a typical physiological environment of the stomach is provided by maintaining a temperature of 37°C and simulating stomach movements through stirring at a rate of 30 rpm. In this model the test solution is titrated with artificial gastric juice until a target pH of 3 is reached. The volume of gastric juice consumed is used to calculate the total hydrogen ions neutralized by the tested substance [24].

The modified Vatier's artificial stomach model is designed to simulate the dynamic functions of a human stomach, including acid secretion and gastric emptying. This model comprises a pH monitoring system, a stomach compartment, and a peristaltic pump. The stomach compartment is further divided into three sections: the reservoir, the secretory flux, and the gastric emptying flux. The secretory flux simulates acid secretion, while the emptying flux represents gastric emptying. Gastric secretions and emptying occur at a rate of 3 mL/min. The reservoir, kept at 37°C and stirred at 30 rpm, ensures conditions closely resemble those of the human stomach. The duration of the neutralization effect is measured by monitoring when the pH returns to its initial value (pH 1.2) after adding the test substance [24].
In this study, the tea bag formulations demonstrated significant acid-neutralizing capacity, particularly after 5 minutes of infusion at 100 ºC. T9 (*A. marmelos*) and T7 (a combination of *A. marmelos, D. triflorum, C. asiatica*) had the best acid-neutralizing capacities. These findings suggest that these formulations are highly effective at neutralizing artificial gastric acid. The comparison with green tea, which has a lower acid neutralizing capacity, emphasizes the potential of the formulated herbal tea bags remarking as a treatment option for gastritis. The effectiveness of *A. marmelos* in neutralizing gastric acid is consistent with previous research indicating its gastro-protective properties, and the addition of *D. triflorum* and *C. asiatica* may further enhance these effects.

In addition to their potent neutralizing properties, T9 and T7 demonstrated a prolonged duration of consistent acid neutralization. T9 showed neutralization effect for a longer period, exceeding both the positive control (green tea) and negative control (distilled water). This prolonged duration is critical for gastritis management because it indicates the herbal tea formulations can provide long term relief from gastritis. The ability of these formulations to sustain a higher pH level in the artificial stomach model supports their potential efficacy in providing long term relief from gastric irritation and ulceration.

Further, formulations T7 and T9 revealed the presence of significant bioactive compounds, including tannins, terpenoids, carbohydrates, and cardiac glycosides. Notably, proteins and steroids were absent in both formulations. T9 contained alkaloids and saponins, whereas T7 contained phenols. These phytochemicals are known for their health benefits, including anti-inflammatory, anti-cancer, and antioxidant properties. Therefore, apart from the gastroprotective activity these herbal teas may provide other beneficial health effects. Moreover, studies have demonstrated the possible defense against gastrointestinal problems of phytochemicals including flavonoids and polyphenols [32].

The brine shrimp lethality assay indicated low toxicity levels for both formulations, with T9 exhibiting slightly higher toxicity compared to T7. While these toxicity levels do not raise immediate safety concerns, they warrant further investigation into the long-term safety and potential side effects of these formulations before considering clinical applications. Continued research is essential to fully understand the implications of these findings and to ensure the safe use of these phytochemical-rich formulations in therapeutic settings.

CONCLUSION

The study demonstrates that the prepared herbal tea bags have a significant acid-neutralizing ability and a prolonged neutralization effect. Further studies are recommended to isolate the bioactive substances which provides the gastroprotective benefits. It is also necessary to investigate the exact mechanisms of action that underlie the herbal tea formulations' protecting and acid-neutralizing capacity. The research can be expanded by *in-vivo* experiments employing animal models and human stomach epithelial cell lines. Studying the effects of the tea formulations on *H. pylori* inhibition, mucosal barrier integrity, and stomach acid secretion would provide a thorough understanding of their pharmacological actions. In addition, stability studies of tea bags should be conducted to ensure their shelf life and stability activity under various environmental conditions.

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Authors' contributions

PMK conceived the research study. PMK and SLAG designed the *in vitro* assay methods. WADJT, SMKP, and TMSAT conducted the study, performed the *in vitro* assays, analyzed the results, and drafted the manuscript. PMK and SLAG finalized the manuscript.

Conflict of interest

The authors declared no conflict of interest.

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