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Bronchodilatory and Anti-inflammatory Effects of a Hydro-Ethanolic Extract of *Scoparia dulcis* Linn

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ABSTRACT

Background and Objective: Bronchodilator and anti-inflammatory drugs are very useful in asthma management. The study therefore, aimed at investigating the bronchodilatory and anti-inflammatory effects of an ethanolic extract of Scoparia dulcis Linn (SDE). Materials and Methods: Time taken for pre-convulsive dyspnea and its resolution in histamine and acetylcholine-induced bronchospasm in guinea-pigs after pre-treatment with 2 mg kg⁻¹ chlorpheniramine/atropine, 50, 100, or 250 mg kg⁻¹ of SDE, or 2 mL kg⁻¹ of normal saline *per os* were determined. Resolution of ovalbumin-induced paw oedema in Sprague-Dawley rats were measured for the treatments. The SDE effect on an isolated guinea-pig ileum preparation to identify a possible antihistaminic and/or antimuscarinic activity was carried out. Preliminary phytochemical analysis was also conducted on the extract. Results: SDE prolonged significantly ($p \le 0.01$) the onset of pre-convulsive dyspnea and reduced significantly ($p \le 0.001$) the recovery period. It also showed a significant dose-dependent reduction ($p \le 0.01$ -0.001) in paw edema; comparable to prednisolone and dexamethasone. In vitro, SDE inhibited significantly (p<0.01) the contractile effect of histamine and acetylcholine (comparable to mepyramine and atropine, respectively) on the guinea pig ileum. The extract blocks H₁ histaminic, as well as M3 muscarinic receptors of the tracheobronchial smooth muscles. Phytochemical screening showed the presence of tannins, alkaloids, glycosides, saponins, steroids and phenolic compounds. **Conclusion:** The ethanolic extract of Scoparia dulcis has interesting bronchodilatory and anti-inflammatory effects, as well as anti-histaminic and anti-muscarinic receptor activities; making it a suitable anti-asthmatic drug.

Key words: Asthma, anti-histaminic, anti-muscarinic, pre-convulsive dyspnea, OVA-induced paw oedema

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INTRODUCTION

Acute symptoms of asthma usually arise from bronchospasm and require and respond to bronchodilator therapy. Matsushita *et al.*¹ reported that various chemical mediators (such as histamine and acetylcholine) are said to be released in asthma and other related respiratory disorders. These mediators are known to elicit immediate hypersensitivity reactions, such as bronchial contraction and airway extravasations. Again, late-phase inflammatory responses such as airway oedema and airway hyper-responsiveness also occur². According to Cohn *et al.*³ acute and chronic inflammation can affect not only the airway caliber and airflow, but also underlying bronchial hyper-responsiveness. These situations further enhance susceptibility to bronchospasm. Treatment with antiinflammatory drugs is known to greatly reverse some of these processes. However, the successful response to therapy is reported to often require weeks to achieve and in some cases, may be incomplete⁴. Also, for some patients, the development of chronic inflammation is observed to be associated with permanent alterations in the airway structure which are not prevented by or fully responsive to currently available treatment drugs. This condition is referred to as airway remodelling^{5,6}. It is, thereby, very vital to develop new anti-asthmatic drugs to evaluate the pharmacological effects; not only on allergic immediate bronchoconstriction and hypersensitivity reactions but also on the late-phase airway inflammatory responses¹.

More so, Parmar *et al.*⁷ stated that, there is a report on the seemingly alarming increase in the number of diseases and disorders implicated by synthetic drugs which has prompted a switch over to the use of

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traditional herbal medicine. Hence, there is the need to try herbal formulations, which are highly rich in phytochemicals and are also preferable due to their lesser adverse effects, high availability and affordability and other nutritive values, in the treatment of asthma and other respiratory disorders.

Scoparia dulcis Linn (Scrophulariaceae) is an erect annual shrubby herb with serrated leaves, producing white flowers, that grows to about half a meter in height when fully matured⁸. The fresh or dried aerial part of S. dulcis plant has been reported to be used, by various indigenous tribes in the tropical and subtropical regions, to treat several illnesses such as diabetes and bronchitis⁹. The dried aerial part of Scoparia dulcis is used, in Ghanaian traditional medicine, in the management of asthmatic conditions. However, it has not been evaluated scientifically to determine and establish its effectiveness as an anti-asthmatic agent/drug. This study, therefore, aimed at investigating the bronchodilatory and anti-inflammatory effects of the ethanolic extract of Scoparia dulcis (SDE) using both in vivo and in vitro experimental asthma models.

MATERIALS AND METHODS

Plant collection: The fresh aerial parts of *Scoparia dulcis* plant were obtained between the months of July-September, 2013, from Osene-Adikanfo, Faith Herbal Centre, Mamponteng in the Ashanti region of Ghana, identified and authenticated by the Herbal Medicine Department of the Faculty of Pharmacy and Pharmaceutical Sciences, KNUST, Ghana where a voucher specimen (KNUST/HM1/2013/S027) has been kept.

Preparation of the ethanolic extract of *S. dulcis* **(SDE):** The fresh aerial parts of *Scoparia dulcis* was air-dried and milled into powder. One kilogram (1 kg) of the powder was macerated in 6.35 L of 70% ethanol for 72 h. The suspension was filtered and the ethanol evaporated off in a rotary evaporator (Rotavapor R-210, Buchi, Switzerland) and the concentrated extracts were freeze-dried (Heto Power Dry LL3000, Jouan Nordic, Denmark) to obtain 27.65 g powdered material (percentage yield: 2.77%). The powdered material obtained, referred to in this study as the ethanolic extract of *S. dulcis* (SDE) was then stored at 4°C and reconstituted in a suitable vehicle for use.

Preliminary phytochemical analysis of SDE: Preliminary phytochemical analysis was then carried out on SDE according to the methods described by Sofowara¹⁰ and Trease and Evans¹¹. **Chemicals and reagents:** Ovalbumin (OVA), histamine dihydrochloride, acetylcholine chloride, mepyramine and atropine sulphate were obtained from Sigma Chemical Co. (St. Louis, MO, USA); Salbutamol sulphate, Chlorpheniramine maleate (CPM) and Prednisolone from Letap Pharmaceuticals Ltd (Accra, Ghana); whereas Dexamethasone was purchased from M and G Pharmaceuticals Ltd (Accra, Ghana).

Experimental animals: Male Dunkin Hartley guinea-pigs (255-420 g) were used for the bronchodilator studies, whilst Sprague-Dawley rats (115-160 g) of either sex were used for the antiinflammatory experiment. These were obtained from the Animal Unit of the Department of Pharmacology, Faculty of Pharmacy and Pharmaceutical Sciences, KNUST and fed on standard rodent pellet diet obtained from Agricare Ltd., Tanoso-Kumasi, Ghana and allowed access to drinking water *ad libitum*.

Ethical considerations: Laboratory study was carried out in a level 2 biosafety laboratory. Protocols for the study were approved by the Committee on Animal Research, Publication and Ethics (CARPE). All activities during the studies conformed to accepted principles for laboratory animal use and care (EU directive of 1986: 86/609/EEC). All the technical team observed all institutional biosafety guidelines for protection of personnel and laboratory.

Dosing of drugs to experimental animals: Dosing of the plant extract was done based on its known traditional usage. Dosing was done once daily by gavage for 5 days (anti-inflammation) and 1 day (bronchodilation), at a volume of 1 mL kg⁻¹ at specified concentrations. Individual dose volumes were calculated based on the animal's most recent recorded body weight. The oral route of administration was used because it is the intended human exposure route.

Bronchodilatory effect of SDE: The bronchodilatory effect of SDE was studied using both histamine and acetylcholine-induced bronchospasm paradigms in guinea pigs; where pre-convulsive dyspnea was used as an end point following exposure to the allergen aerosol.

Histamine-induced Bronchospasm: The bronchodilatory activity as well as the *in vivo* anti-histaminic of SDE was studied in guinea pigs using histamine-induced bronchospasm model^{12,13}.

Guinea-pigs were kept in the experimental area of the Departmental animal house at room temperature

(26±2°C), ambient relative humidity (65±10%) and normal dark-light cycles, with food and water *ad libitum* for 10 days prior to experimentation. Guinea-pigs were then put into six groups (n = 4). Group one served as the normal control group and treated with distilled water alone; Groups 2 and 3 served as the positive control groups and were treated with 10 mg kg⁻¹ salbutamol *per os* and 2 mg kg⁻¹ chlorpheniramine per os (reference comparators) respectively; whereas Groups 3-6 were treated with 50, 100, or 250 mg kg⁻¹ of SDE orally.

Guinea-pigs, which have been fasted for 24 h, were each exposed to an atomized mist of 0.2% histamine aerosol using nebulizer in a Perspex chamber (24×14×24 cm). Guinea-pigs exposed to histamine aerosol showed progressive signs of difficulty in breathing leading to asphyxia and/or convulsions. The time of aerosol exposure to the onset of dyspnea leading to the appearance of convulsions, was recorded as the pre-convulsive time (PCT). This PCT was taken as the basal control value. The animals were removed from the chamber and exposed to fresh air to recover, as soon as pre-convulsive dyspnea commenced. The duration of the persistence of spasmodic symptoms, for each animal was also measured as the Recovery Time (RT). After 24 h. the test drugs were administered and the animals again subjected to histamine aerosol later (at an interval of 2 and 24 h-post drug administration), to determine the PCTs and RTs.

The protection offered by the treatment was calculated, using the formula stated by Singh and Agrawal¹⁴ as:

Protection (%) =
$$\left\{1 - \left(\frac{T1}{T2}\right)\right\} \times 100$$

where, T1 = basal control value and T2 = PCT after administration of test drugs.

Acetylcholine-induced Bronchospasm: This is an experimental model to determine anti-asthmatic, as well as *in vivo* anti-muscarinic/cholinergic activity¹⁵.

The experimental procedure used here was similar to the histamine-induced bronchospasm described earlier, except that here animals were exposed to 1% acetylcholine aerosol and the PCTs and RTs, for each animal, were determined. Moreover, atropine (2 mg kg⁻¹) was used as the reference comparator in place of chlorpheniramine.

Determination of site of action of SDE: An in vitro study was also conducted using guinea pig ileum to ascertain the anti-histaminic and anticholinergic/ antimuscarinic activities of SDE. This study was carried out as described by Koffuor *et al.*¹⁶.

A guinea-pig obtained from the Departmental Animal house was sacrificed, the abdomen cut open and the ileum then taken from the ileo-caecal valve of the small intestine. Small strips of about 3 cm long were cut and kept in Tyrode solution appropriately aerated. A piece of the ileum (about 2 cm long) was then mounted in 20 mL Tyrode solution maintained at 32°C in a Harvard tissue bath (Harvard Apparatus Ltd., Kent, UK). The tissue was constantly aerated and allowed to stabilize in the bath for about 15 min. With a contact time of 30 sec and a time cycle of 1 min, a complete and a Harvard kymograph (Harvard Apparatus Ltd., Kent, UK) speed of 4 mm min⁻¹, a dose-response tracing was generated for acetylcholine (0.1×10-4-0.64×10- 3 mg mL^{-1}), after which a sub-maximal response (about 75% of the maximum response) given by a dose of 40 μ g mL⁻¹ was selected. Equipotent dose (dose that gave similar responses to the sub-maximal response selected for acetylcholine) of histamine (40 μ g mL⁻¹) was obtained and responses were matched. A dose of atropine (8.0 μ g mL⁻¹) was added to the organ bath and left in contact with the tissue for 30 sec after which the equipotent dose of acetylcholine was added to the bath and the response for 30 sec was recorded. The tissue was then washed free of the drugs and the antagonism step was repeated for SDE (1.0 mg mL⁻¹) and the matched dose of acetylcholine. The procedures were performed for mepyramine (0.2 mg mL^{-1}) /histamine and SDE/histamine. The experimental process was repeated thrice.

Anti-inflammatory activity of SDE: The effect of SDE in chronic inflammation was evaluated by the OVA-induced paw oedema in rats¹⁷ with modification; Ovalbumin (OVA) was used for induction, in place of formalin used in the original protocol.

Seven groups of five rats were kept each in separate metal cages. Group 1 was normal (non-sensitized) and Group 2 was negative (sensitized) control and thus were given distilled water only. Groups 3 and 4 served as the positive controls and were treated with the standard drugs, dexamethasone (10 mg mL⁻¹) and prednisolone (10 mg kg⁻¹), respectively. Groups 5, 6 and 7 were given daily administration of SDE in dosages of 50, 100 and 250 mg mL⁻¹ body weights, respectively. Animals were treated with test drugs for five consecutive days.

Animals were sensitized with 0.5 mL OVA suspension (0.5 mg mL⁻¹, ovalbumin suspended in paraffin) 7 days before start of experiment-by

intramuscular (i.m.) injection. Initial paw thickness and paw weight of each animal were taken at the start of the experiment, using vernier calliper method¹⁸ and displacement method¹⁹, respectively. Animals were then pre-treated with test drugs 24 and 1 h before oedema induction. Chronic inflammation was induced by injecting 0.1 mL of 0.4% OVA suspension in the left hind paws of rats, causing oedema. Paw thickness and paw weight of each animal were measured 2 h after the induction of inflammation. The ability of test drug to suppress paw inflammation was then expressed as a percentage of inhibition of paw oedema²⁰. The percent inhibition of paw oedema was then determined:

Inhibition of (%) =
$$\left\{1 - \left(\frac{X}{Y}\right)\right\} \times 100$$

where, X = change in paw thickness or weight of treated rats and Y = change in paw thickness or weight of control rats.

Animals were then treated for 3 days and the change in paw oedema measured afterwards. The percentage suppression was then determined.

Statistical analyses: Data obtained in all experiments were expressed as Mean \pm S.E.M. Statistical analyses were done by one-way analysis of variance (ANOVA) with Bonferroni's Multiple Comparison test (*post hoc* test)using Graph-Pad Prism for Windows Version 5.0 (Graph-Pad Software, San Diego, CA, USA). Differences between means of treated groups and the control were regarded as statistically significant at p<0.05.

RESULTS

Phytochemical screening of plant: The preliminary phytochemical analysis of the ethanolic extract of *Scoparia dulcis* showed the presence of tannins, alkaloids, phenols, glycosides, saponins and steroids.

Histamine-induced Bronchospasm: SDE showed significant ($p \le 0.001$) dose-independent protection against histamine-induced bronchospasm with chlorpheniramine showing the highest protection (Fig. 1). In further experiments, the effects of SDE after 24 h post-drug treatment were still significant ($p \le 0.05$) against bronchospasm induced by histamine; whilst the reference comparators showed no significant effect (Fig. 2).

Acetylcholine-induced Bronchospasm: The protection against acetylcholine-induced bronchospasm by all the treatment groups were significant ($p \le 0.05$) for both 2 and 24 h post-drug treatment, except the salbutamol-treated group (Fig. 3). The recovery time for all the treatment groups were also found to be markedly lower ($p \le 0.05$) than the controls after 2 and 24 h post drug treatment (as showed in Fig. 4).

Determination of Site of Action: Graded doseresponses on a guinea pig ileum were obtained after applying various doses of acetylcholine and histamine (Fig. 5a-d). The SDE produced significant ($p \le 0.001$) inhibition (74.2±1.8%) of the selected sub-maximal dose of acetylcholine comparable to atropine (92.6±0.6%; $p \le 0.001$). The selected sub-maximal dose



Fig. 1(a-b): (a) Percentage protection and (b) Recovery time by SDE, Chlorpheniramine (CPM), Salbutamol (SBM) and Distilled Water (DW) in histamine-induced bronchospasm in guinea pigs after 2 h post-drug treatment. Values plotted are Means±SEM (n=4), *: p≤0.05, ***: p≤0.001



Fig. 2(a-b): (a) Percentage protection and (b) Recovery time offered by SDE, Chlorpheniramine (CPM), Salbutamol (SBM) and Distilled Water (DW) in histamine-induced bronchospasm in guinea pigs after 24 h post-drug treatment. Values plotted are Means±SEM (n = 4). ns: p>0.05, *: p≤0.05, **: p≤0.01, ***: p≤0.001







Fig. 4(a-b): Effect of SDE, Atropine (ATR), Salbutamol (SBM) and Distilled Water (DW) on duration of spasmodic symptoms in acetylcholine-induced guinea pigs after (a) 2 and (b) 24 h post-drug treatment. Values plotted are Means±SEM of n = 4, *: p≤0.05, **: p≤0.01, ***: p≤0.001

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Fig. 5(a-d): Dose response tracing for (a) Acetylcholine (b) It's respective antagonism by SDE (c) Histamine and (d) It's respective antagonism by SDE



Fig. 6(a-b): Mean change in paw oedema (a) Paw thickness and (b) Paw weight of sensitized rats after 2 days pretreatment with SDE, Dexamethasone (DEXA), Prednisolone (PRED) and Distilled Water (DW). Values plotted are Means±SEM of n = 4, ns: p>0.05, *: p<0.05, **: p<0.01, ***: p<0.001</p>

of histamine was also significantly inhibited by SDE (74.4 \pm 2.2%; p≤0.001) in a manner similar to mepyramine (87.7 \pm 2.6%; p≤0.001) as showed in Table 1.

Anti-Inflammatory effect: SDE showed a dosedependent significant reduction ($p \le 0.05$) in paw oedema, comparable to prednisolone and dexamethasone. However, dexamethasone showed the highest inhibition or suppression of paw oedema in all cases (Fig. 6 and 7).

Table 1:	Responses	for	the	antagonism	of	Acetylcholine and
	Histamine b	y Atr	opine	, Mepyramine	and	Ethanolic extract of
	S. dulcis (SE	DE) o	n an I	solated Guine	a-pi	g Ileum

	Inhibition of	Inhibition of agonist in the presence of (%)					
Agonist	Atropine	Mepyramine	SDE				
Acetylcholine	92.6±0.6		74.2±1.8				
Histamine		87.7±2.6	74.4±2.2				
Values are Mean	$s \pm SEM (n = 3)$	07.7±2.0	/+.+±2.				

DISCUSSION

The results of the present study revealed bronchodilatory, anti-histaminic and anti-cholinergic



Fig. 7(a-b): Mean change in paw oedema (a) Paw thickness and (b) Paw weight of sensitized rats after 3 days treatment with SDE, Dexamethasone (DEXA), Prednisolone (PRED) and Distilled Water (DW). Values plotted are Means±SEM of n = 4, **: p≤0.01, ***: p≤0.001

effects of SDE. Experimental animal model of asthma is characterized by allergen-induced immediate airway constriction and late airway reactivity to a pharmacological vasoconstrictor such as histamine, acetylcholine or leukotrienes²¹. Guinea-pigs were thereby used because of the extreme sensitivity of their airways to the primary mediators of bronchoconstriction, including histamine and acetylcholine and also due to its similarity to that seen in humans²².

Histamine and acetylcholine were both used separately as spasmogens in the form of aerosols, to cause immediate bronchoconstriction in guinea-pigs. SDE showed significant prolongation of onset of bronchospasm in guinea-pigs ($p \le 0.05$), against both histamine and acetylcholine (Fig. 1-3). The protection offered by SDE was found comparable to both chlorpheniramine and atropine (reference drugs) in the different experiments. This may be suggestive of an anti-histaminic and anti-cholinergic activity. Chlorpheniramine is a histamine H₁ receptor antagonist, whilst atropine is a competitive antagonist for the muscarinic acetylcholine receptor types: M1, M2, M3, M4 and M_5^{23} . Receptor antagonists bind to specific receptors thereby preventing the agonist or immune mediators from binding to and activating the receptor. Anti-histaminic and anti-muscarinic agents are, moreover, sometimes classified as bronchodilators as they cause relaxation of bronchial smooth muscles; which is result of increased tone due to parasympathetic stimulation²⁴.

In order to verify the anti-muscarinic or anti-histaminic property of SDE, the effect of the extract was also investigated on the contractility of acetylcholine and histamine on an isolated guinea-pig ileum preparation (Fig. 5a-d). The isolated guinea-pig ileum is a low tone tissue which has muscarinic receptor subtypes M_1 , M_2 and M_3 and histaminic receptor subtypes H_1 , H_2 and H₃^{25,26}. SDE was found in vitro to inhibit the contractile effect of both histamine and acetylcholine on the guinea-pig ileum (Table 1). The response of isolated guinea-pig airways and/or tissues to pharmacological agonists has been compared directly with humans to determine whether they are a good model for human airways. It was found that there were similar responses between human and guinea-pig airways when exposed to acetylcholine, histamine, methacholine and other allergens following sensitization²⁷. Similar studies found that histamine activates the H₁ receptors in smooth muscles of the guinea-pig ileum to release Ca2+ from intracellular stores of the smooth muscles, causing contraction of the ileum. Acetylcholine in the guinea-pig ileum is also known to have muscarinic effects and thus act on muscarinic receptors which are predominant on the ileum wall^{28,29}. The most imperative of these receptors in contraction of the guinea-pig ileum have been established to be the M3 receptor subtypes. Activation of these receptors directly by acetylcholine on the longitudinal muscles causes contractions of the guinea-pig ileum³⁰. The probable mechanism of action of SDE therefore may be blockage of the H₁ and Ach (M_3) receptors of the smooth muscles found in the bronchioles and tracheae; hence, its inhibition of bronchoconstriction induced by histamine or acetylcholine (i.e. prolonging the onset of pre-convulsive dyspnea) as observed.

Besides, SDE showed significant reduction in the duration of broncho-spasmolytic symptoms ($p \le 0.01$); comparable to that of salbutamol (Fig. 1, 2 and 4).

Salbutamol is a short-acting \beta2-adrenergic receptor agonist. For a drug to cause bronchodilation and produce a therapeutic response in asthma, it must be able to stimulate the β -receptors on the tracheae and bronchioles. Typical examples include salmeterol, noradrenaline and salbutamol. These β-adrenergic drugs bind to the receptors on the cell membrane of the airways, causing conformational changes in the part of the receptor adjacent to G-protein. Adenylate cyclase is then activated leading to increased intracellular levels of cyclic AMP and a reduction in cytosolic calcium ion concentration²⁸. This results in bronchial smooth muscle relaxation (i.e., bronchodilation). Thus, β-adrenergic agonists mediate bronchial-relaxation via hyper-polarization and decreased spike activity of the smooth muscle cells found on the tracheae and bronchioles³¹. Hence, the bronchodilatory effect of SDE may also be due to the contributive action of the extract having β -adrenergic stimulatory effect on adrenoceptors.

In the anti-inflammatory experiment, all the animals injected with ovalbumin (OVA) exhibited chronic inflammation, which manifested as increase in paw weight and thickness. The OVA is known to induce asthma attacks in humans and some studies have also demonstrated its potency to induce chronic airway inflammation and tissue remodelling in animals^{32,33}. Chronic inflammation (induced by OVA) involves an early neurogenic component which is mediated by substance P, leukotrienes and polymorphonuclear cells and followed by a later tissue mediated response where histamine, 5-hydroxytryptamine (serotonin), prostaglandins and bradykinin are known to be involved^{34,35}.

Inhibition of OVA-induced paw oedema in rats was therefore used as a chronic allergic inflammatory model to investigate the anti-inflammatory activity of the plant extract. SDE showed a dose-dependent significant reduction ($p \le 0.05$) in paw oedema, comparable to prednisolone and dexamethasone, as shown in Fig. 6 and 7. Prednisolone and dexamethasone are both glucocorticoids and irreversibly bind with Glucocorticoid Receptors (GR) Alpha GR and Beta GR. The steroid-receptor complexes dimerise and interact with cellular DNA in the nucleus, binding to steroid-response elements and modifying gene transcription. They thus induce synthesis of some proteins and inhibit synthesis of others; leading to inhibition or inactivation of the synthesis and release of certain immune and inflammatory mediators²³. The extract might therefore be acting similarly as prednisolone and dexamethasone in inhibiting/

suppressing inflammation. Thus, SDE may have the ability to inhibit the synthesis and/or release of inflammatory mediators (such as histamine, serotonin, substance P and leukotrienes).

The present studies indicated the anti-inflammatory properties of ethanolic extract of *S. dulcis*. This finding is similar to previous works done^{36,37}; which confirms the plant as having anti-inflammatory properties. These works suggested that *S. dulcis* possessed anti-inflammatory activities and its anti-inflammatory mechanisms appear to be related to the reduction of the levels of cyclo-oxygenase (COX-2), Nitric Oxide (NO), tumour necrosis factor (TNF- α) and interleukin (IL-1) in inflamed tissues, as well as the inhibition of malondialdehyde (MDA) levels via increasing the activities of superoxide dismutase, glutathione peroxidase and glutathione reductase in the liver (using the λ -carrageenan-induced paw oedema model in mice).

With regards to the occurrence of airway inflammation in the tracheo-bronchial tree of asthmatic patients, the results suggest that the anti-inflammatory property of *S. dulcis* might also contribute to the therapeutic effect of this plant on asthma. However, the effect of *S. dulcis* on airway inflammation specifically should be investigated in further studies.

More so, Matsushita et al.1 stated that asthmatic symptoms include the immediate hypersensitivity reactions and the late phase inflammatory responses; consequently, a variety of medicines such as bronchodilators, corticosteroids and several anti-allergics are used together as combination therapies for asthma treatment. Thus, asthma is well managed if a drug has anti-inflammatory and bronchodilatory effects as well as anti-histaminic and anti-cholinergic receptor activities. Hence, the ability/capacity of SDE to exhibit antianti-cholinergic, bronchodilatory and histaminic, anti-inflammatory properties make it a better alternative remedy for the effective management of asthma and possibly chronic bronchitis and other respiratory diseases.

Phytoconstituents like steroids, tannins, saponins, alkaloids and phenols are reported to possess bronchodilatory, anti-asthmatic and anti-inflammatory properties^{38,39}. Besides, phytochemical analyses of *Scoparia dulcis* as an herb revealed that it is rich in these phytochemicals^{40,41}. In the present study, preliminary phytochemical screening showed that SDE contains phenols, tannins, saponins, steroids and alkaloids. Thus, the pharmacological properties observed can be attributed to these phytochemical constituents present. However, further studies are very important to isolate

and characterize the active phytoconstituents responsible for these actions; and also to establish molecular mechanisms, especially the role of cytokines and other inflammatory mediators, in the anti-asthmatic and antiinflammatory activities of SDE.

CONCLUSION

In conclusion, the results of the study indicated that the ethanolic extract of *Scoparia dulcis* has bronchodilatory effect, via its anti-histaminic and anti-muscarinic receptor activities, as well as anti-inflammatory properties. These positive effects help verify its anecdotal use in the management of asthma.

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