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Original article

# Salvadora persica protects libido by reducing corticosterone and elevating the testosterone levels in chronic cigarette smoke exposure rats



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## ABSTRACT

**Background & Objectives:** Cigarette smoke is associated with several diseased states including defects in reproductive behavior. *Salvadora persica* (*S. persica*) known as the toothbrush plant is reported to possess several pharmacological properties including antidepressants and anxiolytics. The present research was done to determine the libido-protective effect of *S. persica* in chronic cigarette smoke-exposed rats.

**Materials and Methods:** The decoction of freshly dried roots of *S. persica* (50, 100, and 200 mg/kg, oral) was administered to the chronic-cigarette smoke-exposed adult rats. The parameters related to libido were recorded using a close-camera circuit (CCTV). Serum corticosterone and testosterone levels were estimated. Further, the phytochemical constituents were identified in the decoction. The data obtained were analyzed using one-way analysis of variance and significance was considered at  $p < 0.05$ .

**Results:** The observation from the study revealed that cigarette smoke exposure reduces the sexual activity parameters significantly ( $p < 0.01$ ), besides elevated the serum corticosterone and suppressed the testosterone levels in rats. Administration of *S. persica* at 200 mg/kg improved significantly ( $p < 0.05$ ) the parameters related to libido. The decoction also reversed the changes in the levels of tested hormones in serum.

**Interpretation and Conclusion:** The findings indicate that a 200 mg/kg *S. persica* decoction can protect libido in chronic cigarette smoke-exposed rats. The activity may be due to the presence of several phytoconstituents such as alkaloid, flavonoids and phytosterols that might produce vasodilatory effect in sex organs and enhance the synthesis of endogenous testosterone to improve libido characteristics weakened by chronic cigarette smoke exposure.

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## 1. Introduction

Cigarette (tobacco) smoking is one of the common habits among the population of all age groups world wide. Chronic smoking is reported to affect the health of the individual and can contribute to ailments such as cancer, cardiovascular and respiratory complications (Carter et al., 2015). Earlier studies suggested that tobacco smoking could adversely affect reproductive health in both

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male and female populations. The chief complaints of tobacco smokers are reported to be erectile dysfunction, arousal disorders, menstruation irregularities besides contributing to enhanced rates of abortions, stillbirths, and several congenital defects (Gades et al., 2005).

Earlier research reported that cigarette smoke could decrease nitric oxide synthetase (NOS) activity by non-adrenergic and non-cholinergic neuronal pathways. The loss of neuronal nitric oxide through enzymatic blockade can damage the endothelium and impairs the eNOS mediated vasodilation leading to male sexual dysfunction (Tengs and Osgood, 2001). Published experimental studies suggested that the female sexual function comprises a complex chain of events that include physical and sensory events. The hormones such as estrogen and testosterone play an important role and were found to be affected by chronic intake of nicotine. Decreased blood flow due to chronic vasoconstriction of female arousal organs such as clitoris, uterine, and labia are also reported to be affected by cigarette smoking (Burri and Spector, 2011).

*Salvadora persica* is a subtropical shrub, found in the Asian sub-continent region such as Arabian Peninsula, Egypt, and India. The plant belongs to the family *Salvadoraceae* and popularly referred to as the toothbrush tree. The roots of the plant are famous in people of African, South American, and Asian populations (Sher et al., 2010). The plant is reported to possess antibacterial and antifungal activity, which makes it suitable for maintaining oral hygiene (Devi et al., 2019). Other pharmacological properties reported for *S. persica* include hypolipidemic, antiulcer, anticonvulsant, antimycotic, antidepressant, and analgesic (Sabbagh et al., 2020). The plant is known to contain active ingredients such as oleic acid, salvadorene, salvadorine, linoleic acid, trimethylamine, lignans, etc (Abdel-Kader et al., 2019).

Since it is inevitable to stop the cigarette smoke-induced reactions in the population, one of the better approaches is to increase the use of natural supplements that can reduce the complications of cigarette smoke. *S. persica* being used in many regions of the world as a toothbrush tree was preliminarily tested in our previous study (Rabbani, 2019). In this research, it was observed that *S. persica* had some positive influence on the reproductive behavior altered by the chronic cigarette smoke in rats. The data from this study indicated that administration of *S. persica* extracts at 200 mg/kg increased significantly ( $p < 0.05$ ) the number of approaches, frequency of mounts and latency of intromission in cigarette smoke-exposed rats. However, the study did not establish the effect of the extract on other parameters of libido and the influence of the treatment on the hormonal levels in tested animals. Hence, this study explored the possible libido-protective mechanism of *S. persica* in cigarette smoke-exposed rats.

## 2. Methods

### 2.1. Plant material and preparation of decoction

Fresh dried roots of the plant *Salvadora persica* grown in the Makkah region of Saudi Arabia were collected and authenticated by Dr. Hamdoon, Pharmacognosist in the department of phytochemistry and medicinal chemistry, College of Pharmacy, Qassim University. A voucher sample was deposited in the college's herbarium.

The fresh decoction of the dried, powdered roots of *S. persica* was prepared according to the procedure of Galati et al., 1999 (Galati and Monforte, 1999). The procedure includes boiling 100 g of dried powdered roots of *S. persica* in distilled water (1 L) for a half-hour, followed by filtration and lyophilization of the decoction. The extract powder in lyophilized form was administered every morning, by oral gavage, at three different concentra-

tions such as 50, 100, and 200 mg/kg, in an aqueous volume of 0.5 ml/100 g of body weight.

### 2.2. Animals

Adult Wistar rats of either sex weighing 120–140 gm were used in this study. The experimentation was conducted after getting approval from the institutional ethics committee (Approval ID # 2019-CP-4). Before and during the experiment, the animals were housed in the central animals' house facility maintained under standard lab conditions with room temperature 20–22 °C. They were provided pelleted food and water ad libitum under 12 h dark and light environment.

### 2.3. Experimental grouping

The animals used in the study were divided into seven groups viz., group-1 received normal Saline, (0.5 ml/100 gm), group 2 was given highest test dose of *S. persica*, (200 mg/kg in normal animals), group-3 (Positive control, cigarette smoked exposed) (Ahmadnia et al., 2007), group-4, 5 and 6 animals were treated with 50, 100 and 200 mg/kg of *S. persica*, respectively, orally for 4 weeks (Bhadoriya et al., 2010) (Rabbani, 2019), whereas and group-7 animals were administered Ginseng (100 mg/kg) for 4 weeks orally (Moon et al., 2009). Animals in group 3, 4, 5, 6, and 7 were exposed to cigarette smoke for 6 days in a week for 8-weeks prior to their respective treatment.

### 2.4. Experimental design

The experimental design includes a cigarette smoke chamber of the size 30 × 40 × 80 cm with a hood and an inlet and outlet for cigarette smoke as described by Ypsilantis et al. 2012 (Ypsilantis and Politou, 2011). In brief, the procedure includes daily exposure of individual animal to cigarette smoke (2–3 cigarettes) for a total duration of 30 min (with intermittent exposure to fresh air for 2 min after every 10 min of smoke exposure).

After 8-weeks of treatment, the animals were screened for the libido characteristic and only those were selected for treatment groups that have shown defective libido characteristics. Group 3 received cigarette smoke for a total 12 weeks while Group 4 to 7 were treated with respective treatments following exposure to cigarette smoke. The sexual-desire activity in all the groups was studied after a total 12-weeks duration, that included 8-weeks of only cigarette smoke exposure and 4-weeks of drug treatment along with cigarette smoke in group 3–7.

### 2.5. Libido-like activity:

Sexually active adult male and female rats were selected for this study. The sexually receptive stage in the female rats was identified by microscopical observation of the characteristics of cells in the vaginal smear. If the smear showed the presence of a significant number of cornified irregular shaped cells then such rats confirm that they are in the diestrus phase and will be sexually receptive to male approaches (Marcondes et al., 2012). Male rat selected from his previous mating behavior was kept with the diestrus phase female rats in a separate cage with dim light and a calm atmosphere. A close camera circuit was used to record the mating behavior of the pair. Orientation behavior and sexual behavior were analyzed to study the libido activity of the treatments.

The orientation activity included licking, anogenital sniffing, genital brushing, and jumping over each other. Each event was given a 1-score, and the average number over the course of the night was determined. The mating activities was analyzed from the following parameters; percentage libido index = [(number

mated/ number paired) X 100]; Intromission ratio = [(number of intromission/ number of mount + number of intromission)]; Copulatory efficiency = [(number of intromission/ number of mounts) X 100]; Inter copulatory interval = [(average time between intromission)] (Tajuddin et al., 2005).

## 2.6. Biomarker estimation

### 2.6.1. Estimation of serum corticosterone levels -

The principle of corticosterone estimation by ELISA kit is based on a competitive enzyme immunoassay using a combination of specific antibodies to corticosterone and corticosterone-HRP conjugate (HRP-labeled corticosterone) system. The procedure was as per the description given in the user manual of the kit (Biocheck, USA). In short, 96 well plates coated with goat anti-rabbit IgG were added with corticosterone calibrator or samples, HRP-labeled corticosterone, and specific antibody for competitive immunoreaction. After incubation and plate washing, HRP enzyme activity was determined by 3,3',5,5'-tetramethylbenzidine (TMB), and the concentration of corticosterone was calculated in the biological solution (Mou et al., 2017).

### 2.6.2. Estimation of testosterone levels

The serum testosterone was measured by using the commercially available testosterone ELISA kit (Biocheck, USA). About 20 µl of calibrator and serum was added into appropriate wells of strips. About 200 µl of horseradish peroxidase testosterone conjugate was added. The mixture was incubated for 2 h at 37°C. The wells were rinsed and immediately 100 µl of chromogen substrate mixture and 0.01% hydroperoxidase in citrate buffer was added. Absorbance was immediately read at 450 nm in ELISA reader (Arfat et al., 2014).

## 2.7. Phytochemical analysis

Chemical tests were performed to identify the active phytochemical constituents such as carbohydrates, proteins, alkaloids, tannins, glycosides, flavonoids, and triterpenes present in the decoction as per the standard procedures (Kaur and Arora, 2009).

## 2.8. Statistics

Data were presented as mean ± SE. Using the GraphPad Prism 8.0 computer software package, a one-way ANOVA was used to compare the means of different groups, as well as a Tukey posthoc test to examine differences between the means and the interaction between the variables. Differences with a significance level of  $P < 0.05$  were deemed statistically significant.

## 3. Results

### 3.1. Phytochemical analysis

As shown in Table 1, a high concentration of flavonoids was found in the *S. persica* decoction. Additionally, the presence of alkaloids, carbohydrates, glycosides, phytosterols, phenol, and tannins was also noted in the decoction.

### 3.2. Effect of *Salvadora persica* decoction on the orientation behavior before sexual activity in chronic cigarette smoke-exposed rats

The observations of the orientation activities before the sexual act are summarized in table 2. The results suggest that chronic cigarette exposure to the animals decreased significantly ( $p < 0.05$ ) the licking (-34.2%), anogenital sniffing (-25.7%), genital

**Table 1**

Tests to determine the presence of phytochemical constituents present in *S. persica* decoction.

Name of phytochemicals	Test procedure	Observation	Inference
Alkaloids	Decoction + Mayer's reagent	Yellow color precipitate	+
Carbohydrates	Decoction + Naphthol + Sulphuric acid	Violet color solution	+
Glycosides	Decoction + Water, shake	Formation of foam	+
Phytosterols	Decoction + 2 ml CHCl <sub>3</sub> + 2 ml H <sub>2</sub> SO <sub>4</sub>	Yellow color develops	+
Flavonoids	Decoction + few drops of NaOH	Intense yellow color that cleared on adding dil. HCL	++
Phenol and tannins	Decoction + few drops of FeCl <sub>3</sub>	Blue-black coloration	+

+ Mild present,

++ Strongly present.

grooming (-23.6%), and climbing responses (-23.9%) in comparison to control group. There was no major difference in response when *S. persica* was given at 50 and 100 mg/kg, although the improvement was observed in comparison to cigarette smoke-exposed animals. Also, the highest tested of *S. persica* (200 mg/kg) did not show significant disparity in the parameters when compared with the control animals. However, when a highest dose of *S. persica* was tested, a significant ( $p < 0.05$ ) increase in the number of licking (+18.64%) and climbing response (+24.5%) was found compared to the challenge animals. On the other hand, administration of ginseng at 100 mg/kg indicated significant ( $p < 0.01$ ) improvement in all the characteristics of orientation preceding to the sexual activity compared to cigarette smoke-exposed rats.

### 3.3. Effect of *Salvadora persica* decoction on the sexual behavior in chronic cigarette smoke-exposed rats

The results obtained indicated that cigarette smoke exposure decreased the sexual activity parameters significantly such as percentage libido index (-19.8%,  $p < 0.05$ ), intromission ratio (-16.2%,  $p < 0.05$ ), copulatory efficiency (-19.6%,  $p < 0.01$ ), and intercopulatory interval (+32.9%,  $p < 0.001$ ) as compared to the untreated control group. The administration of lower doses of *S. persica* did not make any significant difference in the diminished response except that *S. persica* at 100 mg/kg improved significantly ( $p < 0.05$ ) the copulatory efficiency (+13.2%) compared to the cigarette smoked group. The highest tested dose of *S. persica* showed significant ( $p < 0.05$ ) enhancement of intromission ratio (+16.1%) and copulatory efficiency (+14.3%) besides reducing the intercopulatory interval (-5.9%) when the comparison was made with cigarette smoke-exposed animals. Ginseng tested as standard aphrodisiac drug on the other hand developed significant reversal ( $p < 0.05$ ) in the diminished percentage libido index (+18.3%), intromission ratio (+19.4%), and copulatory efficiency (+19.8%) with a reduction in the intercopulatory interval (-10.6%) in the cigarette smoke-exposed animals. on the otherhand, *S. persica* at 200 mg/kg did not alter the tested parameters in normal animals. (Table 3).

### 3.4. Effect of *Salvadora persica* decoction on the serum corticosterone level in chronic cigarette smoke-exposed rats

There was significant ( $p < 0.05$ ) increase in serum corticosterone level in cigarette smoke exposed animals when compared to the control group of animals. The percentage increase was found

**Table 2**  
Effect of *Salvadora persica* decoction on the orientation behavior before sexual activity in chronic cigarette smoke-exposed rats.

Treatment	Licking	Anogenital sniffing	Genital grooming	Climbing
Control	12.16 ± 1.08	14.31 ± 1.01	26.81 ± 1.22	8.01 ± 0.80
<i>S. persica</i> (200 mg/kg)	11.92 ± 1.21	15.01 ± 0.98	26.77 ± 1.08	7.78 ± 0.69
Cigarette smoke exposed (CSE)	7.99 ± 0.28 <sup>***</sup>	10.63 ± 0.75 <sup>*</sup>	20.48 ± 2.06 <sup>*</sup>	6.09 ± 0.31 <sup>*</sup>
CSE + <i>S. persica</i> (50 mg/kg)	8.01 ± 0.36	8.07 ± 0.66	17.66 ± 1.76	6.04 ± 0.29
CSE + <i>S. persica</i> (100 mg/kg)	8.96 ± 0.44	9.01 ± 0.42	19.49 ± 1.59	7.16 ± 0.62
CSE + <i>S. persica</i> (200 mg/kg)	9.48 ± 0.51 <sup>a</sup>	11.71 ± 0.49	21.72 ± 1.09	7.58 ± 0.47 <sup>a</sup>
CSE + Ginseng (100 mg/kg)	10.94 ± 0.32 <sup>c</sup>	12.97 ± 0.81 <sup>a</sup>	27.40 ± 1.69 <sup>a</sup>	8.73 ± 0.53 <sup>b</sup>

Values are represented as Mean ± S.E.M, N=8; CSE: cigarette smoke exposure; **Statistics:** One way Anova followed by post-hoc test Tukey; <sup>\*</sup>p<0.05, <sup>\*\*</sup>p<0.01 compared with control; <sup>a</sup>p<0.05, <sup>b</sup>p<0.01, <sup>c</sup>p<0.001 compared with CSE group.

**Table 3**  
Effect of *Salvadora persica* decoction on the sexual behavior in chronic cigarette smoke-exposed rats.

Treatment	% Libido index	Intromission ratio	Copulatory efficiency	Intercopulatory interval (S)
Control	71.10 ± 6.41	0.37 ± 0.02	96.11 ± 4.31	688.21 ± 14.78
<i>S. persica</i> (200 mg/kg)	72.39 ± 5.59	0.38 ± 0.03	95.47 ± 5.38	695.46 ± 12.92
Cigarette smoke exposed (CSE)	51.24 ± 4.86 <sup>*</sup>	0.31 ± 0.01 <sup>*</sup>	77.20 ± 3.26 <sup>**</sup>	914.65 ± 15.23 <sup>***</sup>
CSE + <i>S. persica</i> (50 mg/kg)	50.69 ± 6.08	0.28 ± 0.03	78.26 ± 4.81	902.66 ± 14.79
CSE + <i>S. persica</i> (100 mg/kg)	59.26 ± 6.24	0.33 ± 0.02	87.39 ± 2.94 <sup>a</sup>	889.16 ± 17.39
CSE + <i>S. persica</i> (200 mg/kg)	62.30 ± 5.11	0.36 ± 0.02 <sup>a</sup>	88.21 ± 3.08 <sup>a</sup>	860.49 ± 14.93 <sup>a</sup>
CSE + Ginseng (100 mg/kg)	69.53 ± 6.61 <sup>a</sup>	0.37 ± 0.01 <sup>b</sup>	92.55 ± 4.82 <sup>a</sup>	817.52 ± 13.29 <sup>a</sup>

Values are represented as Mean ± S.E.M, N=8; CSE: cigarette smoke exposure; **Statistics:** One way Anova followed by post-hoc test Tukey; <sup>\*</sup>p<0.05, <sup>\*\*</sup>p<0.01 compared with control; <sup>a</sup>p<0.05, <sup>b</sup>p<0.01, <sup>c</sup>p<0.001 compared with CSE group.

to be + 95.6%. The treatment with *S. persica* produced a significant ( $p < 0.05$ ) suppression at 200 mg/kg (−34.3%), while other doses did not show any important changes. Ginseng at 100 mg/kg exhibited a significant (−40.8%,  $p < 0.05$ ) reduction of serum corticosterone compared to the cigarette-exposed animals. No significant change was observed when *S. persica* was tested at 200 mg/kg on control animals. (Fig. 1).

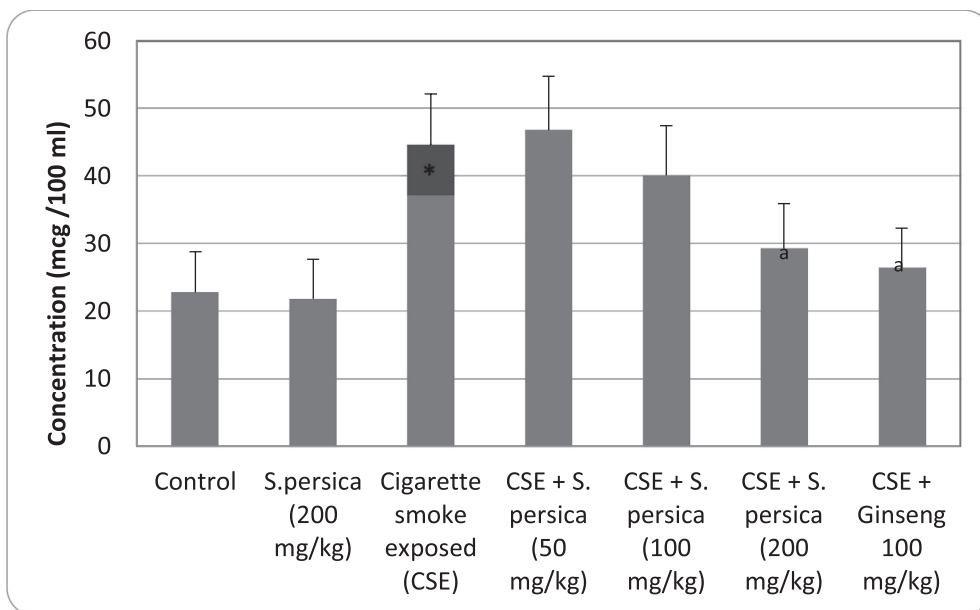
3.5. Effect of *S. Persica* decoction on the serum testosterone levels in cigarette smoke-exposed animals.

The serum biomarker estimation of testosterone indicated that cigarette smoke exposure reduced the level significantly (−21.1%,  $p < 0.01$ ) as compared to the control animals. However, the highest

dose of *S. persica* (200 mg/kg) did not produce any change in the normal animals. The administration of *S. persica* at 200 mg produced significant (+14.3%,  $p < 0.05$ ) elevation in the level of testosterone when compared to the cigarette smoked animals. The other doses of *S. persica* although produced improvement in the level of testosterone but non-significantly. The administration of ginseng showed a significant (+21.4%,  $p < 0.01$ ) improvement in the level of serum testosterone in the challenged group (Fig. 2).

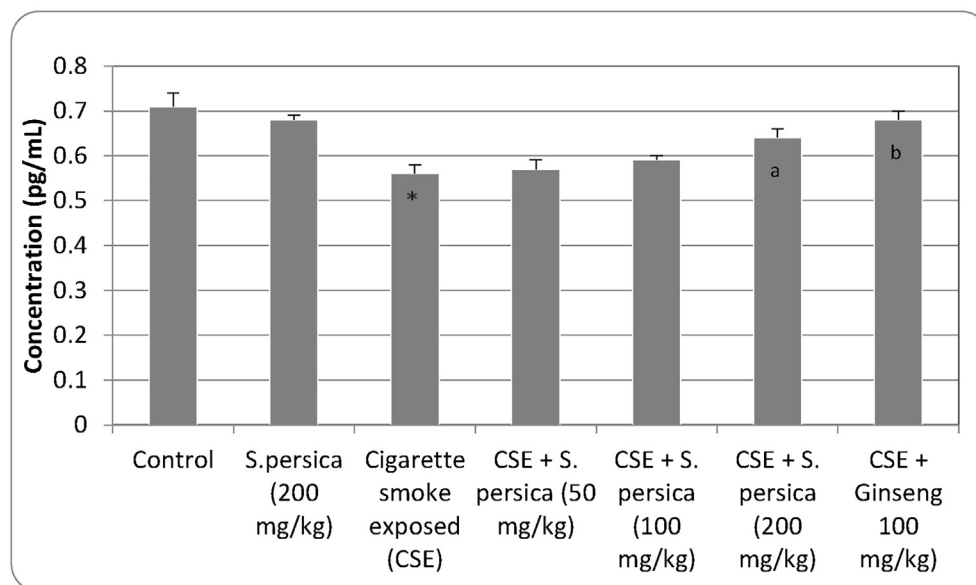
4. Discussion

The data from this study indicated that chronic cigarette smoke exposure significantly reduced the orientation characters preceding the sexual activity such as licking, anogenital sniffing, genital



**Fig. 1.** Effect of *Salvadora persica* decoction on the serum corticosterone level in chronic cigarette smoke-exposed rats. Values are represented as Mean ± S.E.M, N = 6, **Statistics:** One-way Anova followed by posthoc test Tukey; <sup>\*</sup>p < 0.05 compared with control. <sup>a</sup>p < 0.05 compared with the CSE group.





**Fig. 2.** Effect of *S. persica* decoction on the serum testosterone levels in cigarette smoke-exposed animals. Values are represented as Mean  $\pm$  S.E.M, N = 6; **Statistics:** One-way Anova followed by posthoc test Tukey: \*\* $p < 0.01$  compared with control. <sup>a</sup> $p < 0.05$ , <sup>b</sup> $p < 0.01$  compared with CSE group.

grooming, and jumping compared to the control group (Table 1). The data also suggested that cigarette smoke reduced the percentage libido index, intromission ratio, copulatory efficiency and increased the intercopulatory interval (Table 2). These characteristics in rodents are reported to relate the sexual desire when opposite sexes approach each other (Tajuddin et al., 2005).

Cigarette smoking is known to increase the risk of sexual dysfunction in both male–female subjects compared to non-smokers (Gades et al., 2005). Our observation confirms these findings highlighting that chronic cigarette smoke exposure affects the sexual activity in both male and female rats (Tables 1 and 2). As discussed before, modulation in the vasculature activity of the sexually sensitive organs in both males and females could be responsible for the reduction in sexual functions (Tengs and Osgood, 2001; Burri and Spector, 2011). The data from these studies revealed that cigarette smoke exposure increases the synthesis of free radicals such as superoxide anions through activation of the NADH oxidase enzyme family (Orosz et al., 2007). The excess generation of superoxide anions is reported to shunt NO into a peroxynitrite pathway that lessens the vasoactive availability of NO (Peluffo et al., 2009).

The research conducted earlier also provides a link between cigarette smoking and the action of Rho-associated kinase (ROK). The inhibition of ROK by NO was proposed to sensitize the calcium contractility in the smooth muscles leading to arousal phenomenon during sexual activity (Chitale et al., 2001). Cigarette smoking by reducing the NO synthesis is reported to prevent this mechanism causing decreased libido in smokers (Hidaka et al., 2010).

The data from this study indicated that administration of *S. persica* at 200 mg/kg improved the orientation behaviors such as licking and climbing responses in both male and female rats (Table 1). This dose further enhanced the percentage libido index, intromission ratio, copulatory efficiency and reduce the intercopulatory intervals in cigarette smoke-exposed rats. Through the other parameters such as the percentage libido index showed improvement but it was found to be statistically inconsequential when compared with the positive control group (Table 2). Our previous study has indicated that *S. persica* at 200 mg/kg exhibited some improvement in the reproductive behavior such as a number of approaches, frequency of mounts, and latency of intromission

without establishing the possible mechanism for the action (Rabbani, 2019). An improvement in the intromission ratio, copulatory efficiency and intercopulatory interval, and enhancement of percentage libido index suggests that *S. persica* might have protected the sex-drive instinct in cigarette smoke-exposed rats.

Plant-derived products in the past have been reported to enhance the libido in both sexes due to the presence of aphrodisiac components (Singh and Mukherjee, 1998). Ginseng is one such example that has been extensively studied and found to possess a potent aphrodisiac effect (Chauhan et al., 2014). These findings can be confirmed from the present study data, where ginseng (100 mg/kg) improved the orientation and sexual activity characteristics in cigarette smoke-exposed rats (Table 1 and 2). There is strong evidence that indicates that the presence of ginsenosides in ginseng could be responsible for this activity and can be linked to its antioxidant potential (Liao et al., 2002).

Another finding of this study is that cigarette smoke exposure adversely affected the serum levels of corticosterone and testosterone (Figs. 1 and 2). Corticosterone is released in response to the stress condition while testosterone is associated with libido in both males and females (Jdls and Kloet, 1994). The increased level of corticosterone indicated the stress the animals might experience during their exposure to cigarette smoke (Fig. 1). A relationship has been reported in the literature about the level of corticosterone and testosterone (Rivier and Rivest, 1991). According to these studies, an elevation in the level of corticosterone is known to suppress the serum levels of testosterone. The alterations in the level of these hormones have been reported to affect the libido and sexual activity in experimental rats (Jdls and Kloet, 1994). Studies in the past have also reported that the degree of sexual arousal is sensitive to a reduction in testosterone levels. Apart from physical strength, testosterone is known to be involved in the emotional aspect of the body. The hormone prime the body to respond to sexual stimulation and trigger the arousal centers in the brain (Gunnels and Bloomer, 2014). This can be confirmed from the present data where chronic cigarette smoke reduced sexual behavior and altered the levels of stress and libido hormones. The administration of *S. persica* (200 mg/kg) and ginseng (100 mg/kg) reversed these changes induced by tobacco smoke exposure. A dose-dependent libido protective activity was

observed for *S. persica*, where highest tested dose produced the significant ( $p < 0.05$ ) effect compared to control group (Table 1 and 2 and Figs. 1–2). The reduction in the serum corticosterone levels could have improved the orientation behavior of cigarette smoke-exposed rats before sexual activity and could have elevated the testosterone levels thus protecting the libido in cigarette-smoke exposed rats (Retana-Marquez et al., 2003).

Studies conducted in the past indicated that the phytochemical constituents of natural products play an important role in improving sexual activity. The alkaloidal components were found to produce estrogenic activity by causing vasodilation of sexual organs, while flavonoids and phytosterols can modify the neurotransmitter levels such as testosterone and dopamine both peripherally and centrally and can also modulate the levels of libido hormone (Gunnels and Bloomer, 2014; Njila et al., 2018). Further, dietary phytosterols are reported to act as precursors for the synthesis of several endogenous hormones such as testosterone (Tarkowska, 2019). The phytochemical analysis done on the decoction of *S. persica* indicated the presence of alkaloids, flavonoids, sterols, phenols, and tannins (Table 3). The findings suggest that at 200 mg/kg, *S. persica* contained those essential phytoconstituents in the required concentration that is needed for protecting the libido activity. In this dose, the phytoconstituents might have induced multiple activity such as alteration of hormonal levels, antioxidant property, and vasodilation of sensitive sexual organs that is reported to suppress the adverse effects of cigarette smoke-induced loss of libido in rats. The findings revealed intriguing information that, in addition to providing numerous health benefits, using a toothbrush tree regularly could protect cigarette smokers' libido.

## 5. Conclusions

The results of this study showed that chronic cigarette smoke exposure to rats harmed sexual activity by increasing serum corticosterone and decreasing testosterone levels. *S. persica* at 200 mg/kg and ginseng at 100 mg/kg reversed these changes induced by cigarette smoke. Multiple pathways such as alteration of hormonal levels and antioxidant property due to presence of alkaloids, flavonoids and phytosterols might be related for this activity. More research into the sub-cellular parameters can reveal the precise mechanism of *S. persica's* libido-protective action.

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## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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