Introduction

*Solanum xanthocarpum* Schrad. & Wendl. (Family: Solanaceae) are commonly known as the Indian nightshade or yellow berried night shade (English) and kantakari (Sanskrit). It is a prickly, sparse, bright green perennial herb, woody at the base, reaching 2–3 m in height, and...
found throughout India, mostly in dry places as a weed along roadsides and waste lands\(^1\). Aqueous extract of \(S.\) \(xanthocarpum\) (SXE) is an important medication in the Hindu \textit{Materia Medica}, primarily as an expectorant and antipyretic. Various medicinal properties are attributed to it, particularly in the treatment of asthma, chronic cough and catarhral fever\(^2\)-\(^3\). It is one of the members of the Dashamula (10 roots) of the Ayurveda. It generally grows in March and April, and bears fruit throughout May and June. The flowers are small, few in number, and in extra-axillary cymes. The corolla is purple, with deltoid lobes, and a hairy exterior. The fruits are yellow or white with green veins. \(S.\) \(xanthocarpum\) has been reported to be useful in the treatment of cough and bronchial asthma\(^4\). The root is one of the constituents of Dasamulasava, an Ayurvedic formulation\(^2\). Ayurveda specially mentions that the plant is useful in facilitating conception. Formulations containing \(S.\) \(xanthocarpum\) are being promoted for use in conditions like irregular menses, menopause, breast cancer and infertility\(^5\). Menopause is an event that typically occurs in a woman’s late 40s or early 50s, and it signals the end of her fertile phase of life. Many women use hormone replacement therapy (HRT) to alleviate menopausal symptoms of her fertile phase of life. Many women use hormone replacement therapy (HRT) to alleviate menopausal symptoms, osteoporosis, stress, depression, sexual dysfunction, and hot flushes. However, with the publication of the Women’s Health Initiative in 2002\(^6\), the findings suggest that long-term HRT use increases the risk of breast cancer, endometrial cancer, thromboembolic events and vaginal bleeding and thus HRT has become a less desirable option for many women\(^7\)-\(^8\); the number of women using HRT has decreased dramatically\(^9\). Given this decrease, there is scientific and clinical interest in finding compounds that exhibit optimal estrogenic activity, for example with positive effect on bone health while having little effect on the uterus or breast tissues. Thus evaluation of the effects of SXE in postmenopausal syndrome was carried out to test its effects in various gynecological conditions.

2 Materials and methods

2.1 Chemicals

\(\beta\) Estradiol (Himedia Laboratories, India), methylene blue (Thomas Baker Chemicals, India), ketamine (Aneket, Neon laboratories, India), xylazine (xylaxin, Indian Immunologicals Ltd, India) and anesthetic ether (Analab Fine Chemicals, India) were used in this study. All the chemicals were of analytical grade.

2.2 Plant collection, preparation of extract and thin layer chromatography identification of the bioactive components

The plant was collected from Moregaon, Baramati, Pune during December 2011 and January 2012. The plant was authenticated at the Botanical Survey of India, Pune where voucher specimens are preserved. The voucher number is MAGSOV1. The whole plant, including the roots, leaves and fruit, was taken and shade dried. The coarsely powdered plant of \(S.\) \(xanthocarpum\) (200 g) was extracted with distilled water (900 mL) at room temperature by maceration process for 48 h. The extract was concentrated to yield a reddish brown gummy solid (yield: 13\% (w/w) with respect to dried plant material). One gram of the extract was dissolved in methanol solvent and a few drops of distilled water were added for complete solubility, then the extract was subjected to different phytochemical tests according to that described by Khandelwal\(^10\). The aqueous extract was analyzed by thin layer chromatography (TLC) to detect the bioactive components. The solvent system used was \(n\)-BuOH, AcOH and \(H_2O\) at a ratio of 4:1:5. The spots obtained were detected using 10\% \(H_2SO_4\) reagent and heating at 105 °C for 3 min. A known volume of each extract was suspended in distilled water and was orally administered to the animals by gastric intubation using a force feeding needle during the experimental period.

2.3 Animals

Albino mice (20–25 g), immature female Wistar rats (40 to 50 g) and male Wistar rats (200–250 g) were selected for the study. The rats were housed in a room maintained at (23±1) °C, relative humidity 50%–55% and 12-hour light-dark cycle. The rats were fed with standard food pellets and water \textit{ad libitum} throughout the study. The study was conducted in accordance with the CPCSEA guidelines for animal experimentation and was approved by the Institutional Animal Ethics Committee (SIOP/IAEC/2012/32).

2.4 Acute oral toxicity studies

Adult albino mice of both sexes weighing between 20 and 25 g were used for acute oral toxicity study. The study was carried out according to the Organization for Economic Co-operation and Development (OECD) guideline No. AOT-425\(^11\). The mice were administered 2 000 mg/kg, p.o., of SXE solution prepared in distilled water. The mice were observed for 2 h for behavioral, neurological and autonomic profiles and for any lethality for the next 48 h.

2.5 Grouping of animals

Immature female Wistar rats underwent bilateral ovariectomy \((n=24)\) by the dorsolateral approach under ketamine \((80\text{ mg/kg body weight, i.p.})\) and xylazine \((20\text{ mg/kg, i.p.})\) anesthesia. The rats were allowed to recover for 3 d and then they were weighed and allocated to five groups \((n=6)\).

Sham: the animals underwent similar surgical procedure without ovariectomy and received distilled water daily orally.

Control: ovariectomized (OVX) rats were given distilled water daily orally.

\(\beta\) Estradiol \((1\text{ mg/kg})\): OVX rats received a suspension of \(\beta\) estradiol in olive oil \((1\text{ mg/kg, subcutaneously (s.c.), biweekly})\).
SXE (200 mg/kg): OVX rats received a suspension of SXE (200 mg/kg, per oral (p.o.))
SXE (400 mg/kg): OVX rats received a suspension of SXE (400 mg/kg, p.o.).

The treatment period was 90 d.

2.6 Screening for estrogenic activity

2.6.1 Sexual behavior study
A study was carried out at the end of 30, 60 and 90 d of treatment[12–13]. The male Wistar rats (200–250 g) were used for the study. A rectangular plastic box was used as an apparatus. One male rat was placed inside the box for 5 min before the introduction of a female. The observations were made for 30 min. The study was carried out at 22:00–24:00 under dim white light (300 lux). Sexual behaviors of female rats were studied using anogenital grooming, darting and lordosis as parameters of assessment.

2.6.2 Vaginal cornification
Vaginal smears were taken at the end of 30, 60 and 90 d of treatment for detecting vaginal cornification[14]. Samples of vaginal mucus were collected in the morning by flushing a few drops of saline solution into the vagina of the rat. The saline and its cellular contents were smeared and analyzed using an optical microscope to determine the estrous phase of the rat.

2.6.3 Serum estradiol estimation
On the last day of treatment, blood was withdrawn from the retro-orbital plexus. The serum estradiol level was analyzed by chemiluminescence immunoassay (Clia): immulite, fully automated immunoassay analyzer, USA[15].

2.6.4 Uterus weight to body weight
The method of Vijayanarayana et al[16] was followed. On the last day of treatment, animals were weighed and sacrificed by cervical dislocation. The uteri were dissected out. The uterine weight was then calculated by dividing the uterine weight in milligrams by body weights in grams.

2.7 Screening for antiosteoporotic activity

2.7.1 Biochemical evaluation
The method of Ko et al[17] was followed. After 90 d, the blood samples of rats were withdrawn from the retro-orbital plexus and the serum samples were analyzed for serum calcium and serum alkaline phosphatase (ALP) by an auto-analyzer of Hitachi, model No-912 using kits (Pathozyme Diagnostics, India).

2.7.2 Femur density
The method of Aswar et al[18] was followed. Freshly isolated left femurs were weighed using an electronic scale. Bone volume and density were measured by fluid displacement method using plethysmometer (VJ Instruments, India).

2.7.3 Fourth lumbar vertebral compression
The fourth lumbar vertebra was located and then it was isolated. The fresh vertebra was placed in a digital hardness tester (Electrolab, India), compressed until it fractured, and the reading was recorded in Newtons (N)[19].

2.7.4 Femoral ash calcium
After measuring the bone weight and volume of the left femur, it was dried in an oven at 100 °C for 24 h, then ashed in a furnace at 800 °C for 12 h. The ash was weighed and dissolved in 3 mL nitric acid and then diluted in lanthanum chloride. Calcium chloride was measured with an atomic absorption spectrophotometer (Shimadzu AA-680) at 422.7 nm[10,20].

2.7.5 Femoral histopathological evaluation.
The histopathological studies were carried out on sections of decalcified right femur (fixed in 10% neutral buffered formalin) embedded in paraffin wax. Sections stained with hematoxylin and eosin were observed under a microscope for the micro-architectural changes[21].

2.8 Screening for the antidepressant activity of SXE
Rats of either sex were individually forced to swim in an open cylindrical container (20 cm in diameter, 40 cm in height), containing 38 cm of water at (25±1) °C. The total duration of immobility was recorded during the last 6 min of the 10-minute period. Each rat was judged to be immobile when it ceased struggling and remained floating motionless in the water, making only those movements to keep its head above water[22]. A decrease in the duration of immobility is indicative of an antidepressant-like effect.

2.9 Statistical analysis
Data for each parameter were analyzed by one-way analysis of variance (ANOVA) followed by Bonferroni post hoc test except for sexual behavior parameters which were analyzed by two-way ANOVA followed by Bonferroni post hoc test using Graph Pad, Prism software, version 5.02.

3 Results

3.1 Phytochemical analysis and TLC identification of the bioactive components
Phytochemical studies revealed the presence of carbohydrates, flavonoids, alkaloids, sterols, saponins, tannins (condensed and hydrolyzable), and coumarins. TLC of the extract showed four major spots in the solvent system, where three spots gave a faint red color that indicated steroid compounds.

3.2 Acute oral toxicity
Acute toxicity studies were carried out to evaluate toxicity and to determine the minimum lethal dose of the drug extracts, using three swiss albino mice. At a dose level of 2 000 mg/kg, neither mortality nor any clinical signs of toxicity were observed.

3.3 Estrogenic activity
3.3.1 Effect on sexual behavior
The results indicated that anogenital grooming, darting, and lordosis frequency were significantly decreased in the control group as compared with the sham group ($F_{(4,20)}=294.4$, $F_{(4,20)}=199.6$, $F_{(4,20)}=157.9$, $P<0.01$). The
sexual behavior parameters were significantly increased in the β estradiol (1 mg/kg) group ($P<0.01$). SXE (200 mg/kg) made significant increase in the parameters from day 30 onwards as compared to the control group ($P<0.01$). SXE (400 mg/kg) did not have any significant effects (Figure 1).

3.3.2 Effect on vaginal cornification

The score was given according to the maximum number of animals in a given phase. β Estradiol (1 mg/kg) and SXE (200 mg/kg) showed the maximum number of animals in estrous phase and proestrous phase respectively (Table 1).

3.3.3 Effect on serum estradiol

The results showed significant ($P<0.01$) decrease in serum estradiol level in the control group as compared to the sham group. Significant rises in serum estradiol expression were observed in the β estradiol (1 mg/kg) group and SXE (200 mg/kg) ($F_{1,8}=192.3$, $P<0.01$) group as compared to the control group. No significant effect was observed in the SXE (400 mg/kg) group (Table 1).

3.3.4 Effect on uterine weight to body weight ratio

The results showed significant decrease in mean uterine weight to body weight ratio in the control group as compared to the sham group ($F_{1,12}=368.5$, $P<0.01$), and significant increase in the β estradiol (1 mg/kg) group as compared to the control group ($P<0.01$). No significant effect was observed in uterine weight to body weight ratios in the SXE-treated groups as compared to the control group (Table 1).

3.4 Antiosteoporotic effect

3.4.1 Effect on biochemical parameters

The results of biochemical parameters in animals of different groups are shown in Table 2. The results indicate that the serum calcium concentration was significantly decreased in the control group as compared to the sham group ($F_{1,12}=4.95$, $P<0.01$) and significantly increased in the β estradiol group (1 mg/kg) and SXE (200 mg/kg) group as compared to the control group ($P<0.05$).

Serum ALP levels were significantly increased in the control group as compared to the sham group ($F_{1,12}=7.163$, $P<0.05$), but significantly reduced in the β estradiol (1 mg/kg) ($P<0.01$) and SXE (200 mg/kg) ($P<0.05$) groups (Table 2).

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Vaginal cornification</th>
<th>Serum estradiol (ng/L)</th>
<th>Uterine weight (mg/kg body weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>30th day 60th day 90th day</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sham</td>
<td>6</td>
<td>Positive Negative Positive</td>
<td>2 900.0±172.5</td>
<td>347.1±23.1</td>
</tr>
<tr>
<td>Control</td>
<td>6</td>
<td>Negative Negative Negative</td>
<td>31.9±6.7</td>
<td>33.1±4.4</td>
</tr>
<tr>
<td>β Estradiol (1 mg/kg)</td>
<td>6</td>
<td>Positive Positive Positive</td>
<td>4 173.0±95.0 △△</td>
<td>834.8±38.9 △△</td>
</tr>
<tr>
<td>SXE (200 mg/kg)</td>
<td>6</td>
<td>Positive Positive Positive</td>
<td>1 312.0±42.5 △△</td>
<td>53.2±7.1</td>
</tr>
<tr>
<td>SXE (400 mg/kg)</td>
<td>6</td>
<td>Negative Negative Negative</td>
<td>143.7±45.0</td>
<td>48.2±10.1</td>
</tr>
</tbody>
</table>

All values are expressed as mean ± standard error of mean. △△$P<0.01$, vs sham group; △$P<0.01$, vs control group.

The vaginal smear test score report: 0, Di estrus smear, mainly leukocytes; 1, Mixture of leukocytes and epithelial cells; 2, Pro estrus smear, few cornified cells; 3, Estrus smear, cornified cells only. Animals showing the score 2 or 3 were considered to be positive (+). SXE: aqueous extract of Solanum xanthocarpum.
3.4.2 Effect on fourth lumbar vertebral compression
Significant decrease in the biomechanical strength was observed in the control group as compared to the sham group ($P<0.01$). Treatment with β estradiol (1 mg/kg) ($P<0.05$) and SXE (200 mg/kg) ($P<0.05$) significantly increased the biomechanical strength as compared to the control group (Table 2).

3.4.3 Effect on femur density
Femur density was significantly decreased in the control group as compared to the sham group ($F(3,12)=0.396$, $P<0.05$). Femur density was not increased significantly in any of the treatment groups as compared to the control group (Table 2).

3.4.4 Effect on femoral ash calcium
Significant decrease in ash calcium was observed in the control group as compared to the sham group ($F(3,8)=15.07$, $P<0.01$), whereas significant increase was observed in the β estradiol (1 mg/kg) ($P<0.01$) and SXE (200 mg/kg) ($P<0.01$) groups as compared to the control group. SXE (400 mg/kg) did not show any significant increase in femoral ash calcium as compared to the control (Table 2).

3.4.5 Effect on femoral histopathological evaluation
The rats in the sham group showed normal, dense and uniform trabeculae (Figure 2A); the control group showed fragility with disruptive, lytic changes, thinning of the trabecule resulting in intertrabecular spaces widening (Figure 2B). β Estradiol (1 mg/kg) (Figure 2C) and SXE (200 and 400 mg/kg) (Figure 2D-E) groups exhibited restorative progress as observed by thickening of trabecule and reduced intertrabecular spaces as compared to the control group.

### Table 2 Effect of SXE on serum alkaline phosphatase, serum calcium, femur density, lumbar hardness and ash content

<table>
<thead>
<tr>
<th>Treatment</th>
<th>n</th>
<th>ALP (U/L)</th>
<th>Calcium (mg/dL)</th>
<th>Femur density (g/mL)</th>
<th>Fourth lumbar hardness (N)</th>
<th>Femoral ash calcium (1/million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sham</td>
<td>6</td>
<td>487.10±18.40</td>
<td>12.23±0.23</td>
<td>1 475.0±2.9</td>
<td>319.80±13.12</td>
<td>8.31±0.32</td>
</tr>
<tr>
<td>Control</td>
<td>6</td>
<td>750.60±61.50</td>
<td>9.10±0.30</td>
<td>1 142.0±47.4</td>
<td>173.00±8.52</td>
<td>5.93±0.23</td>
</tr>
<tr>
<td>β Estradiol (1 mg/kg)</td>
<td>6</td>
<td>400.80±52.30</td>
<td>11.60±0.30</td>
<td>1 332.0±73.4</td>
<td>307.40±31.86</td>
<td>8.84±0.32</td>
</tr>
<tr>
<td>SXE (200 mg/kg)</td>
<td>6</td>
<td>476.00±92.95</td>
<td>11.45±0.30</td>
<td>1 281.0±89.6</td>
<td>290.80±31.13</td>
<td>7.85±0.47</td>
</tr>
<tr>
<td>SXE (400 mg/kg)</td>
<td>6</td>
<td>725.60±45.47</td>
<td>10.90±0.91</td>
<td>1 185.0±67.2</td>
<td>222.00±32.75</td>
<td>6.70±0.22</td>
</tr>
</tbody>
</table>

All values are expressed as mean ± standard error of mean. *$P<0.05$, **$P<0.01$, vs sham group; △$P<0.05$, △△$P<0.01$, vs control group. ALP: alkaline phosphatase; SXE: aqueous extract of Solanum xanthocarpum.

![Figure 2](image-url) Femoral histopathological changes stained by hematoxylin and eosin
(A) Sham group epiphyseal femoral region showed normal, dense and uniform trabeculae; (B) Control group epiphyseal femoral region showed sparse thinning of trabeculae, loss of interconnectivity and widening of intertrabecular spaces, and trabeculae showed marked disruptive and lytic changes; (C) β Estradiol (1 mg/kg) group epiphyseal femoral region showed complete restoration of normal architecture; (D) Aqueous extract of Solanum xanthocarpum (SXE, 200 mg/kg) showed normal, dense and uniform trabeculae; (E) SXE (400 mg/kg) showed trabecular restoration (40×).
3.5 Effect of SXE on immobility time in forced swim test

Significant increase in immobility time was observed in the control group as compared to the sham group \((P<0.01)\). Significant reduction in the immobility time was observed in the \(\beta\) estradiol \((1 \text{ mg/kg})\) \((P<0.05)\) and SXE \((200 \text{ mg/kg})\), \((P<0.01)\) groups as compared to the control group. SXE \((400 \text{ mg/kg})\) significantly increased the immobility time as compared to the control \((F_{(3,12)}=31.94, P<0.01)\) (Table 3).

### Table 3 Effect of SXE on immobility period in forced swim test

<table>
<thead>
<tr>
<th>Treatment</th>
<th>(n)</th>
<th>Immobility period (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sham</td>
<td>6</td>
<td>18.50±2.99</td>
</tr>
<tr>
<td>Control</td>
<td>6</td>
<td>78.67±13.53**</td>
</tr>
<tr>
<td>(\beta) Estradiol (1 mg/kg)</td>
<td>6</td>
<td>36.50±9.18(\triangle)</td>
</tr>
<tr>
<td>SXE (200 mg/kg)</td>
<td>6</td>
<td>13.75±2.28(\triangle\triangle)</td>
</tr>
<tr>
<td>SXE (400 mg/kg)</td>
<td>6</td>
<td>142.80±7.36(\triangle\triangle)</td>
</tr>
</tbody>
</table>

All values are expressed as mean ± standard error of mean. \(\ast P<0.01\), vs sham group; \(\triangle P<0.05\), \(\triangle\triangle P<0.01\), vs control group. SXE: aqueous extract of Solanum xanthocarpum.

4 Discussion

The phytochemical analysis of SXE showed the presence of carbohydrates, alkaloids, flavonoids, sterols, and tannins. TLC analysis confirmed the presence of steroids as the major constituents. A pilot study carried out in our lab indicated the estrogenic activity of SXE. Therefore SXE was studied in detail for postmenopausal syndrome in the present study. Postmenopausal syndrome is characterized by low estrogen levels leading to sexual dysfunction, vaginal atrophy, depression and osteoporosis. The ovariectomized rats were used in order to avoid interference of endogenous estrogen. Estrogen deficiency in animals causes neuropathy in the distribution of the pudendal nerve. The same changes may occur in estrogen-deficient women, causing decreased sensation in the clitoral and vulvar area, vaginal dryness and dyspareunia which are responsive to estrogen replacement therapy via restoration of vaginal cells, pH and blood flow\(^{23}\).

Ovariectomy in rats declines all parameters of sexual behavior in female rats\(^{25}\). Our study confirmed the previous reports. Treatment with \(\beta\) estradiol \((1 \text{ mg/kg})\) as well as SXE \((200 \text{ mg/kg})\) showed marked improvement in sexual behavior parameters. SXE \((400 \text{ mg/kg})\) did not improve sexual behavior parameters. A possible explanation could be the negative feedback mechanism observed with hormones. The ventral medial nuclei (VMN) and medial preoptic area (MPOA) of the brain are responsible for eliciting lordosis\(^{24}\). The VMN is rich in estrogen receptor (ER) \(\alpha\) subtype, which plays an important role in lordosis. Our study suggests SXE may be acting via a central nervous system mechanism as that observed in the case of estrogen treatment. The vaginal cytology assay was used to determine estrogen activity\(^{25}\). The vagina is covered by a mucosa layer with stratified epithelium comprised of ER-\(\alpha\) and ER-\(\beta\). Ovariectomy results in diestrous phase while treatment with estrogen produces estrous phase in ovariectomized rats, due to increased vaginal cytological maturation\(^{24}\). In our study, treatment with \(\beta\) estradiol \((1 \text{ mg/kg})\) and SXE \((200 \text{ mg/kg})\) showed estrous and proestrous phases respectively. The findings indicate that SXE exhibits estrogenic activity. A similar pattern of results was obtained when serum from the rats was measured for estradiol concentration. Serum estradiol was significantly high in the \(\beta\) estradiol \((1 \text{ mg/kg})\) group and SXE \((200 \text{ mg/kg})\) group. On the other hand, SXE \((400 \text{ mg/kg})\)-treated animals showed lower serum estradiol content. This study confirms that SXE at a lower dose has potent estrogenic activity, but induces negative feedback inhibition at the higher dose of \(400 \text{ mg/kg}\). It would be interesting to study SXE further at more dose ranges in order to understand clearly dose-dependent effects of SXE. The uteri of estradiol \((1 \text{ mg/kg})\) treatment group rats were significantly heavier than those of the control and SXE treatment groups. Increased uterine weight is consistent with the idea that estradiol \((1 \text{ mg/kg})\) has uterotrophic effects. SXE was devoid of uterotrophic activity. Many of the effects of estrogen in the uterus are mediated by ER-\(\alpha\)\(^{26}\). ER-\(\alpha\) is predominantly present in the uterus. From the results of uterotrophic activities, it can be hypothesized that SXE might be acting on ER-\(\beta\) and has no measurable activity on ER-\(\alpha\) in the uterus. Thus, our studies show that SXE’s estrogenic activity improves sexual behavior and attenuates vaginal atrophy.

As the compound SXE was shown to have estrogenic properties, we further studied it for antiosteoporotic effects. Ovariectomy in rats resulted in deprivation of estrogen. Deficiency of estrogen is also responsible for a decrease in bone density and hardness\(^{26}\). Bone loss in ovariectomized rats mimics that of postmenopausal bone loss in women. The present study showed significant reduction in serum calcium in ovariectomized animals. \(\beta\) Estradiol \((1 \text{ mg/kg})\) and SXE \((200 \text{ mg/kg})\) significantly increased serum calcium. A study by Garnero and Delmas\(^{27}\) indicated that with regard to bone metabolic markers, the serum ALP level associated with bone formation is increased in osteoporosis. In our study, the level of ALP in the control group was significantly increased as compared to the sham group, while treatment with \(\beta\) estradiol \((1 \text{ mg/kg})\) and SXE \((200 \text{ mg/kg})\) significantly decreased ALP level as compared to the control group. The results indicate that SXE may be effective in preventing bone loss due to estrogen deficiency for treatment of osteoporosis. Further, calcium was estimated in bone ash and it was observed that the calcium content was significantly
reduced in the control group as compared to the sham group while the β estradiol (1 mg/kg) and SXE (200 mg/kg) increased bone calcium content as compared to the control. Bone is metabolically active tissue with constant turnover, and calcium balance generally reflects the degree of coupling of bone formation and resorption processes. Ninety-nine percent of the body’s calcium is in bone, and calcium balance depends upon a number of factors, including amount of calcium in the diet, rates of calcium absorption by the intestines and excretion of calcium. In the present study, we found that there was an increase in bone calcium and increased level of serum estradiol in the SXE (200 mg/kg) group. Our study corroborates findings of earlier reports that estrogen is required for absorption of calcium from the intestines. SXE’s estrogenic activity protects bones, which can be seen in the histopathology of femur bones; this aids in the prevention of osteoporosis.

Depression is another consequence of estrogen deficiency. Depressive disorders were characterized by increased immobility time in the ovariectomized animals. Treatment with β estradiol and SXE (200 mg/kg) significantly reduced the immobility duration in forced swim test. On the other hand SXE (400 mg/kg) significantly increased immobility duration as compared to the control indicating severe depression. Estradiol has been shown to reduce anxiety and depression-like activity in several tasks, via activation of ER-β. The antidepressant effect of SXE may be attributed to its involvement in modulating β estrogenic receptors present in brain. The beneficial effect of SXE in treating sexual behavior, osteoporosis and depression could be attributed to its steroidal, alkaloid or flavonoid content. Bector and Pur have reported the presence of solasodine alkaloid in S. xanthocarpum which is the starting material for the production of cortisol and sex hormones. Solanidine, a glycoalkaloid, is found to be the precursor molecule for estrogen and androgen; moreover, it is found to be estrogenic. Further studies are required to carry out the fractionation, isolation and characterization of the active moiety responsible for estrogenic activity. The present study confirms estrogen activity of SXE and its role in preventing postmenopausal symptoms associated with estrogen deficiency.

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6 Competing interests

The authors declare that they have no competing interests.

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Submission Guide

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