**The International Journal of Biotechnology**
*2020 Vol. 9, No. 2, pp. 50-66.*
*ISSN(e): 2306-6148*
*ISSN(p): 2306-9864*
*DOI: 10.18488/journal.57.2020.92.50.66*


# PHYTOCHEMICALS OF *Senna auriculata* (L.) Roxb. (Fabaceae) FLOWERS AS POTENT ANTIBACTERIAL AND ANTIDIABETIC AGENTS

**Murugesan Sakthivadivel**[1+]
**Dhivya Bharathi**[2]
**Ganesan Rithika**[3]
**Jeyabharathi Sakthivadivel**[4]
**Samuel Tennyson**[5]

[1]*Department of Virology, King Institute of Preventive Medicine and Research, Chennai, Tamil Nadu, India; Aathia Green Care Technology, Chennai, Tamil Nadu, India.*
[1]*Email: msjk2004@gmail.com*
[2,3]*Department of Biotechnology, St. Joseph's College of Engineering, Chennai, Tamil Nadu, India.*
[3]*Email: grithika16@gmail.com*
[4]*Aathia Green Care Technology, Chennai, Tamil Nadu, India.*
[4]*Email: sjkeekaa19@gmail.com*
[5]*Department of Zoology, Madras Christian College, Chennai, Tamil Nadu, India.*
[5]*Email: samtennyson@gmail.com*


*(+ Corresponding author)*

**Article History**
Received: 19 March 2020
Revised: 23 April 2020
Accepted: 27 May 2020
Published: 30 June 2020

**Keywords**
Avaram tea
Antibacterial
Antidiabetic
Floral extracts
Phytochemicals
*Senna auriculata.*

## *ABSTRACT*

Contrary to the synthetic drugs, phytochemical constituents of plant origin possess an enormous therapeutic potential as antibacterial and antidiabetic agents. The phytochemicals of *Senna auriculata* floral extracts and avaram tea were screened and tested for antibacterial and antidiabetic properties respectively. Antibacterial activity was determined by disc diffusion method at 0.25, 0.50 and 1.00% concentrations against *Escherichia coli*, *Klebsiella pneumonia*, *Pseudomonas aeruginosa* and *Staphylococcus aureus*. Overall results indicated maximum antibacterial activity at the lowest concentration (0.25%) by the petroleum ether, acetone, ethyl acetate and methanol extracts against *Escherichia coli*, *Staphylococcus aureus*; *Escherichia coli* and *Staphylococcus aureus* and their respective zone of inhibition values were 32, 28, 22 and 15mm; at the highest concentration (1.00%) it was exhibited against *Staphylococcus aureus* for all extracts except for methanol against *Klebsiella pneumonia* and the values were 36, 34, 30 and 19mm respectively. Experiments were carried with male albino wistar mice treated with streptozotocin to study the antidiabetic property for a period of 21 days. The body weight of mice after treatment decreased on Day 7 when compared to Day 3 and then increased on Day 14 and 21. The blood glucose level decreased right from Day 3 to 21. Further, it is suggested that the molecular basis for the modes of action of plant-based antibiotics and antidiabetics be ascertained and determined.

**Contribution/Originality:** This study documents and highlights Avaram tea as a potential antidiabetic agent as the flowers of *Senna auriculata* is prescribed for diabetes in traditional practices in Siddha, besides its phytochemical compounds with proven antibacterial action.

## 1. INTRODUCTION

On one hand, infectious diseases are the leading cause of death throughout the world, and drug resistance to human pathogenic bacteria has been commonly reported from all over the world (Cohen, 1992; Piddock & Wise, 1989). Antibiotic resistance has become a global concern. Increasing development of drug resistance in human pathogens as well as the appearance of side effect of synthetic drugs need to develop new antimicrobial drugs from natural sources (Doshi, Shahare, Aggarwal, Pillai, & Desai, 2011; Tomoko, Takashi, & Hiromu, 2000). Though then

again, diabetes mellitus a metabolic issue of numerous etiologies portrayed by incessant hyperglycemia with unsettling influences in starch, fat and protein digestion coming about because of imperfections in insulin discharge, insulin activity, or both (WHO, 1999) is perhaps the most established illness influencing a large number of individuals everywhere throughout the world (Andallu, 2002). Controlling blood sugar levels by dietary modification, physical exercise, insulin therapy, and oral medications is strictly advised (Sona, 2010) inspite of drugs like sulfonylurea and metformin. Although numerous synthetic drugs are in use to control diabetes, many are found to have adverse drug reactions with side effects (Inas, Ekram, Hoda, Ibrahim, & Somaia, 2011).

India is a varietal emporium of therapeutic plants and is perhaps the most extravagant nation on the planet with respect to hereditary assets of restorative plants. Plants are viewed as dietary enhancement to living being as well as generally utilized for rewarding numerous medical issues. Since antiquity, plants have been used to treat common infectious diseases. In opposition to the manufactured medication, antimicrobials of plant cause are not related with symptoms and have a huge restorative potential to mend irresistible sicknesses (Iwu, Ducan, & Okungi, 1999). Reports have displayed the viability of customary herbs against microorganisms, subsequently, plants are one of the bedrocks for present day medication to accomplish new standards (Evans, Banso, & Samuel, 2002). Secondly, the pathogenesis of diabetes mellitus and the possibility of its management with existing therapeutic agents without any side effects has been the subject of great interest in recent years (Bailey, 1999). Many traditional plant treatments for diabetes mellitus are used throughout the world and few of them have received scientific scrutiny, and the World Health Organisation has recommended that this area warrants attention (WHO, 1980). Consequently, the promotion of medicinal plants as therapeutic agents requires systematic investigation in evaluating their efficacy using various *in vitro* systems, besides pharmacological and toxicological properties involving *in vivo* studies (Divya & Mini, 2011) has become the need of the hour. *Senna auriculata* known as 'Avaram' in Tamil is a shrub belonging to the family Fabaceae (Thulasi & Amsaveni, 2012) found throughout India in open forests. The flowers of this plant are used in preparation of tea, which is prescribed in diabetes. The plant possess antidiabetic (Latha & Pari, 2003; Pari & Latha, 2002) antioxidant (Kumaran & Karunakaran, 2007) hepatoprotective (Kumar & Pandey, 2013) antipyretic (Vedavathy & Rao, 1991) anti-inflammatory (Manogaran & Sulochana, 2004) and antimicrobial (Thambidurai, Rajesh, & Kannan, 2010) properties. Therefore, keeping in view of the above mentioned pharmacological properties, the phytochemicals of *Senna auriculata* floral extracts were screened and tested for antibacterial and antidiabetic properties.

## 2. MATERIALS AND METHODS

### *2.1. Plant Collection and Preparation of Floral Extracts and Avaram Tea*

Mature and healthy flowers of *Senna auriculata* were collected from Vellore, Tamil Nadu, India Figure 1. Taxonomical identity of the plant was verified and affirmed at King Institute of Preventive Medicine and Research, Chennai, Tamil Nadu, India. The flowers were then brought to the laboratory, washed in dechlorinated water, shade dried and powdered with the guide of an electric blender. The dried powdered botanical parts (250g) were extricated with petroleum ether, acetone, ethyl acetate and methanol (750mL) in a Soxhlet apparatus (Vogel, 1978) to acquire extracts from dried flowers. Each crude solvent floral extract thus obtained were then stored in air tight sterilized amber coloured bottles at 4°C for bioassay. For preparation of avaram tea, fresh flowers (250g) were added to distilled water (500mL) and boiled until the volume diminishes to half of its underlying volume. The decoction was then filtered to acquire avaram tea.

**Figure-1.** *Senna auriculata* flowers.

### *2.2. Qualitative Analysis of Phytochemicals*

Different qualitative chemical tests were carried out on the solvent extracts using standard procedures to identify the phytoconstituents, *viz.*, alkaloids, anthra-quinones, carbohydrates, cardiac-glycosides, coumarins, flavonoids, glycosides, phenols, phlobatannins, phytosteroids, saponins, steroids, tannins, terpenoids and triterpenoids (Harborne, 1998).

### *2.3. Antibacterial Assay*

The microorganisms utilized for this examination incorporates three Gram-negative strains, *viz.*, *Escherichia coli* (MTCC 1687), *Klebsiella pneumonia* (MTCC 618) and *Pseudomonas aeruginosa* (ATCC 27853), and one Gram-positive strain, *Staphylococcus aureus* (ATCC 25923). All the strains were acquired from Department of Virology, King Institute of Preventive Medicine and Research, Chennai, Tamil Nadu, India. The necessary quantity of each microbe was completely blended with distilled water for bioassay. All microbiological media were from Hi-Media research facilities private constrained, Mumbai, India. Essential amounts of media were prepared and autoclaved at 15lbs (121°C) for 15 minutes. Antibacterial action of *Senna auriculata* was determined by disc diffusion technique of Bauer, Kirby, Sherris, and Turck (1966) with minor modifications. Stock cultures were maintained at 4°C on petriplate of nutrient agar. Active cultures for experiments were prepared by transferring a loopful of colonies of each microbe from the stock culture to peptone water and incubated for 4 hours at 37°C. Petri plates were set up with 20mL of sterile Muller Hinton Agar (MHA). The test cultures was inoculated on the surface of MHA agar plates using sterile cotton swab and allowed to dry for 10 minutes. The crude extract impregnated discs were prepared and air dried well. The test was directed at three distinct groupings of the crude extract (0.25%, 0.50% and 1.00%). The antibiotic discs loaded with floral extracts were placed on the surface of the inoculated media plates and left for 30 minutes at room temperature for compound dissemination, and incubated at 37°C for 24 hours. The relative susceptibility of the microorganisms to the crude extract indicated by the clear zone of inhibition around the discs, were observed, measured and recorded in millimetres.

### *2.4. Antidiabetic Assay*

Tests were done with male albino wistar mice each weighing around 20-30g, obtained from animal section, King Institute of Preventive Medicine and Research, Chennai, Tamil Nadu, India. The animals utilized in the current investigation were endorsed by the Institutional Animal Ethics Committee of King Institute of Preventive Medicine and Research, Chennai, Tamil Nadu, India, which is enlisted with the CPCSEA, Government of India. The study was directed following Institutional Animal Ethical Committee clearance and all experiments were performed according to ethical guidelines. The animals were housed in polypropylene cages and kept under standard conditions (12 hours light/12 hours dark cycle; temperature 25 ±3°C; humidity 35-60%). The animals had free access to water constantly and was given standard mice feed. A freshly prepared solution of streptozotocin from Hi-Media (40mg/kg of body weight i.p.) in 0.1M citrate buffer with pH 4.5 was injected intraperitoneally to overnight fasted animals to prompt diabetes. The control mice received an equal volume of citrate buffer and was utilized alongside diabetic animals. One touch glucometer was utilized for quantitative *in vitro* determination of

glucose in different samples. Following 48 hours of streptozotocin administration, blood samples were drawn and serum glucose level was resolved to affirm the development of diabetes by utilizing one touch glucometer. Mice with moderate diabetes having glycosuria, weight reduction and hyperglycaemia (with a fasting plasma blood glucose level of 100-150mg/dL) were taken for the experiment and treated with doses of *Senna auriculata* avaram tea and metformin for 21 days. The experimental procedure for antidiabetic activity are as per the following. Normal healthy albino wistar mice housed under standard natural conditions were divided into 4 groups of 3 mice in each group namely Group 1 (normal untreated mice), Group 2 (diabetic control mice), Group 3 (diabetic mice given avaram tea using an intragastric tube for 21 days), and Group 4 (positive control: diabetic mice treated with standard drug metformin [90mg/Kg body weight] in 1mL of aqueous solution on a daily basis for 21 days with the aid of an intragastric tube). Parameters such as body weight, blood glucose level, intake of water are recorded. Mice were induced diabetes by the administration of simple intraperitoneal dose of streptozotocin (40mg/Kg of body weight) as reported elsewhere. Body weight, blood glucose level, intake of water were observed and estimated on Day 0, 3 and 14. Every diabetic mice was fasted, denied of nourishement for at least 16 hours, however were permitted free access to water before the test. Body weight, water intake and blood glucose levels was investigated each day for 21 days. The blood tests of every grouped animals were gathered from the terminal tail vein puncture and blood glucose levels were estimated utilizing one touch glucometer. The difference in the blood glucose levels at various time stretches between the experimental groups and diabetic control groups were analyzed for statistical significance.

### *2.5. Statistical Analysis*

Data of antibacterial and antidiabetic assays were subjected to statistical analysis. Two way Analysis of Variance (ANOVA) test was performed and the differences were considered as significant at $P<0.05$ level. All statistics was conducted in IBM SPSS Statistics v22 with significance set at 95% confidence (SPSS, 2010).

## 3. RESULTS

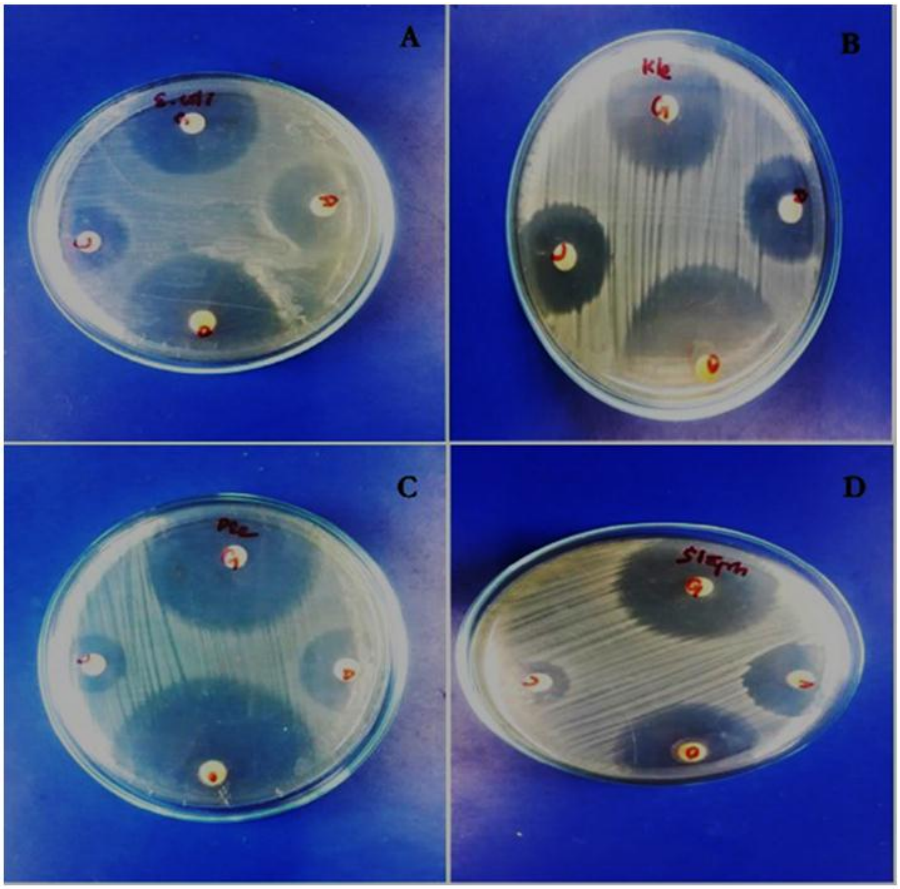
The subjective phytochemical analysis of *Senna auriculata* extracts and avaram tea tested positive for alkaloids, anthraquinones, carbohydrates, cardiac glycosides, coumarins, flavonoids, glycosides, phenols, phlobatannins, phytosteroids, saponins, steroids, tannins, terpenoids and triterpenoids Table 1.

**Table-1.** Phytochemical constituents of *Senna auriculata*.

| Phytochemicals | Solvent extracts | | | | Avaram tea |
|---|---|---|---|---|---|
| | Petroleum ether | Acetone | Ethyl acetate | Methanol | |
| Alkaloids | - | - | +++ | + | - |
| Anthraquinones | +++ | +++ | - | + | - |
| Carbohydrates | ++ | + | ++ | + | ++ |
| Cardiac glycosides | + | - | - | - | - |
| Coumarins | + | + | + | + | - |
| Flavonoids | +++ | +++ | - | +++ | - |
| Glycosides | + | - | - | - | ++ |
| Phenols | + | + | + | +++ | - |
| Phlobatannins | - | +++ | - | + | +++ |
| Phytosteroids | - | + | - | - | - |
| Saponins | + | - | - | - | + |
| Steroids | - | + | - | - | - |
| Tannins | - | + | ++ | - | + |
| Terpenoids | - | +++ | +++ | +++ | ++ |
| Triterpenoids | + | +++ | ++ | - | +++ |

**Note:** +++ Strongly present; ++ Present; + Weak; - Absent.

Among the extracts, the firmly present phytochemical constituents were the flavonoids and anthraquinones in petroleum ether; flavonoids, terpenoids, triterpenoids, phlobatannins and anthraquinones in acetone; alkaloids and terpenoids in ethyl acetate; and flavonoids, terpenoids and phenols in methanol. Avaram tea point out the solid presence of triterpenoids and phlobatannins. The antibacterial activity signifying the zone of inhibition by *Senna auriculata* floral extracts are presented in Figure 2. At concentration 0.25%, methanol extract was found to exhibit the maximum activity (32mm) against *Escherichia coli* followed by acetone (28mm) and petroleum ether (15mm) extracts in *Staphylococcus aureus*, and by both the microorganisms reported above (22mm) in the ethyl acetate extract. At 0.50% concentration, it was methanol, trailed by acetone, ethyl acetate and petroleum ether extracts which specified maximum activity by hindering the growth of *Staphylococcus aureus* and their respective values were 30, 28, 26 and 18mm, and acetone extract (28mm) against *Escherichia coli*. A similar pattern followed at 1.0% preventing the growth of *Staphylococcus aureus* and the values were 36, 34, 30 and 23mm respectively Figure 3; Table 2. Overall results indicated that among the bacterial strains tried, supreme antibacterial action at the lowest concentration (0.25%) was unveiled by the petroleum ether extract against *Escherichia coli*; acetone extract against *Staphylococcus aureus*; ethyl acetate extract against *Escherichia coli* and *Staphylococcus aureus*, and methanol extract against *Staphylococcus aureus*; and at the highest concentration (1.00%) it was displayed against *Staphylococcus aureus* for all the extracts except for methanol against *Klebsiella pneumonia*. The order of the antibacterial efficacy was petroleum ether>ethyl acetate>acetone>methanol extracts proving their efficacy against Gram positive and negative strain, i.e. *Staphylococcus aureus* and *Escherichia coli*.




A: *Escherichia coli*; B: *Klebsiella pneumonia*; C: *Pseudomonas aeruginosa*; and D: *Staphylococcus aureus*.

**Figure-2.** Zone of inhibition for antibacterial activity of *Senna auriculata* floral extracts.

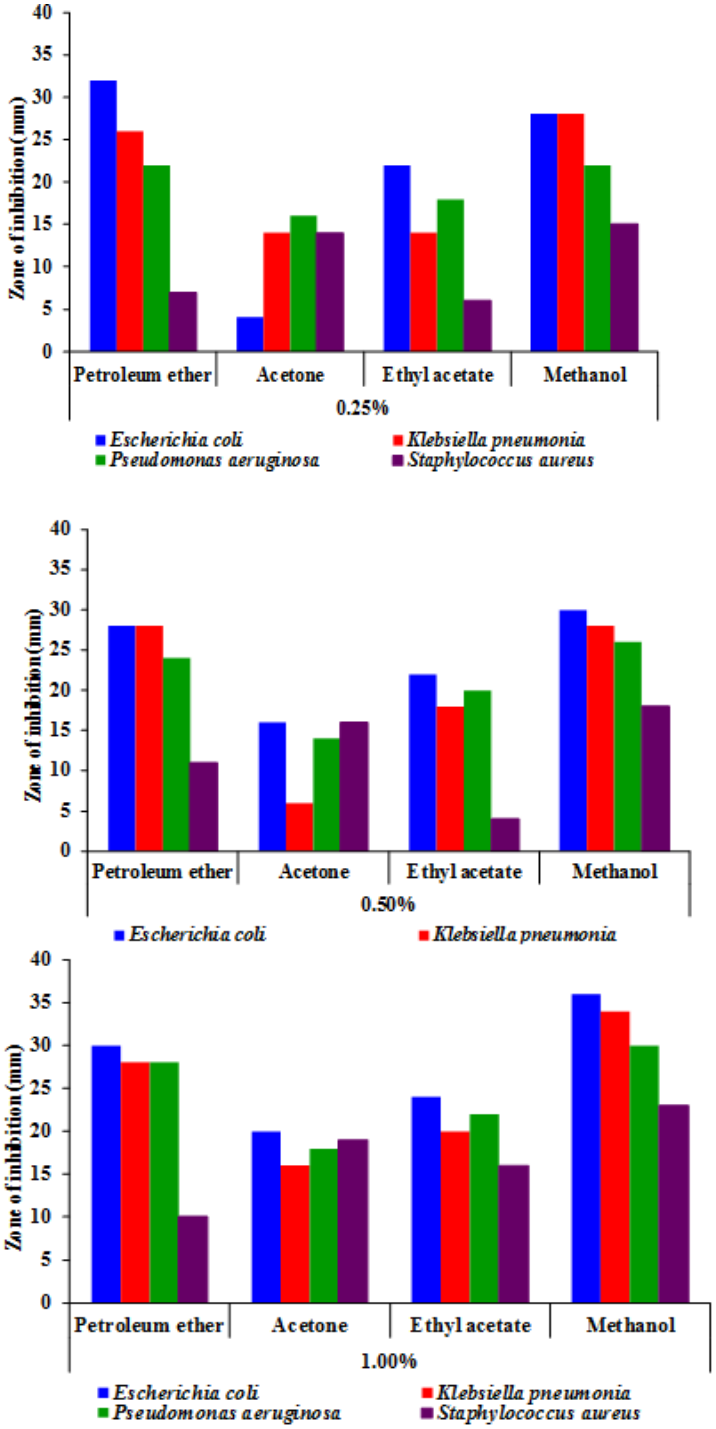


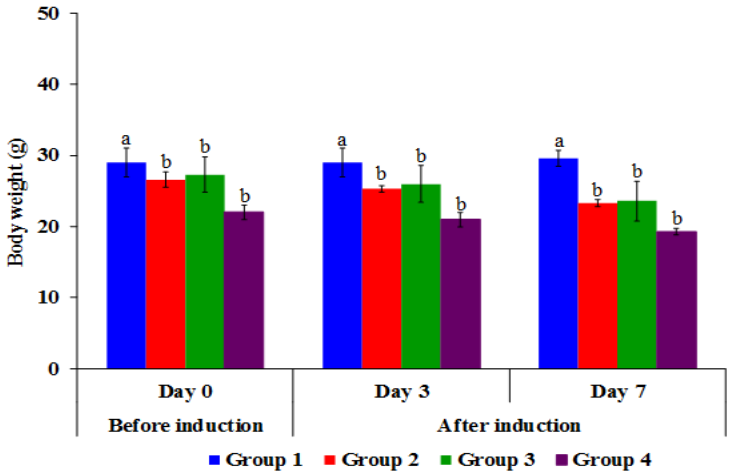

**Figure-3.** Antibacterial activity of *Senna auriculata* floral extracts.

**Table-2.** Two way ANOVA for antibacterial activity of *Senna auriculata* floral extracts.

| Source of variation | SS | df | MS | F | P value | F crit |
|---|---|---|---|---|---|---|
| 0.25% | | | | | | |
| Solvent extracts | 346.5 | 3 | 115.5 | 2.768309 | 0.103225 | 3.862548 |
| Bacteria | 308 | 3 | 102.6667 | 2.460719 | 0.129247 | 3.862548 |
| 0.50% | | | | | | |
| Solvent extracts | 403.6875 | 3 | 134.5625 | 4.941852 | 0.026887* | 3.862548 |
| Bacteria | 300.6875 | 3 | 100.2292 | 3.680949 | 0.055979 | 3.862548 |
| 1.00% | | | | | | |
| Solvent extracts | 357.25 | 3 | 119.0833 | 6.466063 | 0.012638* | 3.862548 |
| Bacteria | 240.75 | 3 | 80.25 | 4.357466 | 0.037236* | 3.862548 |

**Note:** *$P<0.05$.

As for the antidiabetic activity, Figure 4 displayed the initial and final body weight of diabetic rats treated with streptozotocin. The final body weight of rats in all the groups significantly decreased ($P$<0.05) with the exception of Group 1 which showed a mild increase Table 3. Considering the body weight of mice after treatment, it was found that Group 1, 3 and 4 demonstrated a reduction in their body weight on Day 7 when compared to Day 3 and thereafter an increase on Day 14 and 21 and the values were 30.0, 27.3, 30.3 and 30.3; 27.3, 23.3, 27.6 and 28.0; 26.3, 22.2, 23.0 and 25.5g respectively Figure 5; Table 3. Figure 6 presented the initial and final level of blood glucose of rats. Group 2, 3 and 4 recorded a critical increase ($P$<0.05) in their final blood glucose level on Day 7, whereas in Group 1 it was vice-versa Table 3. While observing the level of blood glucose after treatment, it was observed that there was an increase in blood glucose level in Group 2 and their respective values were 115.6, 120.0, 121.3, and 126.0mg/dL. Group 3 and 4 indicated a decrease in blood glucose level right from Day 3 to 21 and their respective values were 120.0, 118.6, 118.3 and 115.6; 103.6, 101.0, 96.6 and 92.0mg/dL. While Group 1 exhibited an increase in blood glucose level from Day 7 when compared to Day 3 and from there on a slight reduction and increase on Day 14 and Day 21 and their respective values were 102.6, 103.6, 102.3 and 103.3mg/dL Figure 7; Table 3.




Similarity in superscript alphabets indicate no variation

**Figure-4.** Body weight variation in mice before and after induction of diabetes.

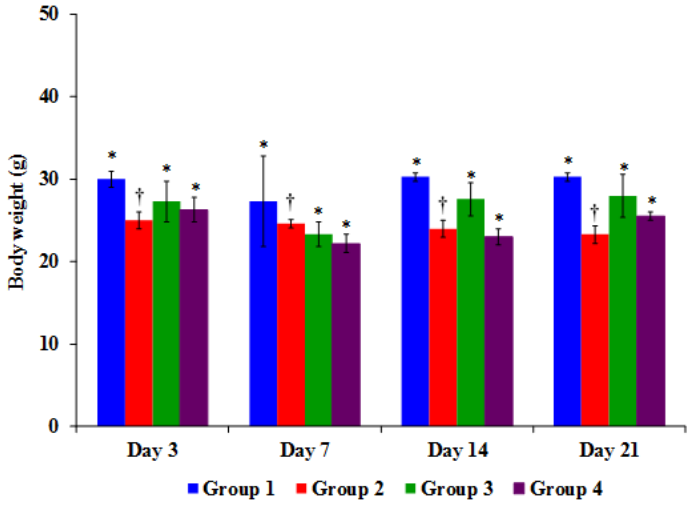



**Figure-5.** Body weight of mice after treatment.

**Note:** *P<0.05; †Not significant.

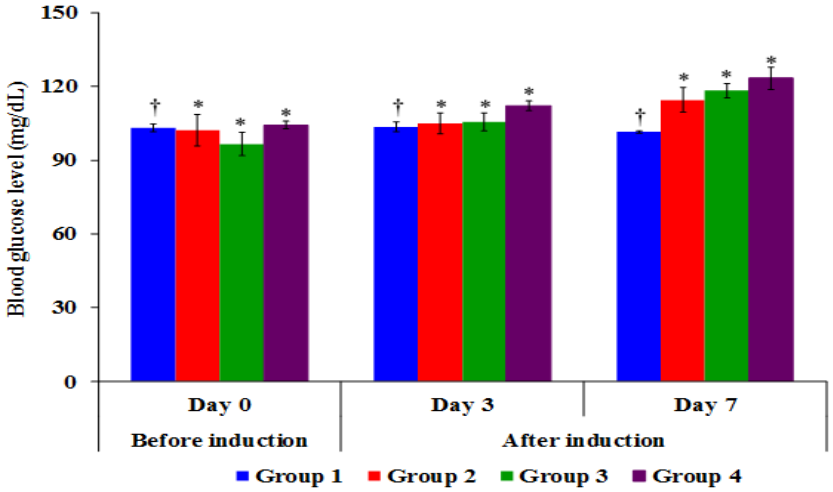



**Figure-6.** Blood glucose level variation in mice before and after induction of diabetes.
**Note:** *P<0.05; †Not significant.

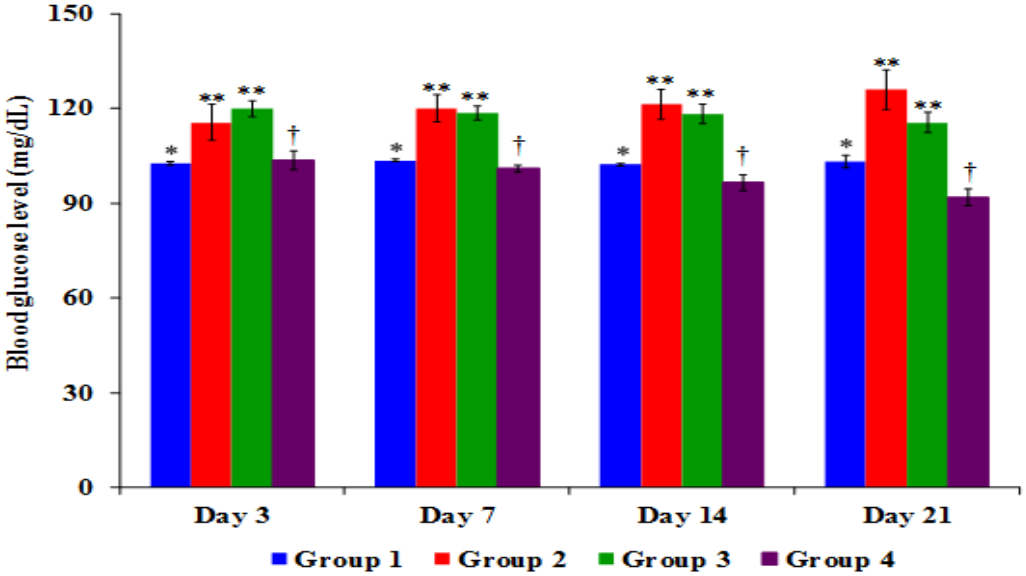



**Figure-7.** Blood glucose level of mice after treatment.
**Note:** **P<0.001; *P<0.05; †Not significant.

**Table-3.** Two way ANOVA for antidiabetic activity of avaram tea on mice

| Source of variation | SS | df | MS | F | *P* value | F crit |
|---|---|---|---|---|---|---|
| Body weight variation before and after induction of diabetes | | | | | | |
| Groups | 107.5667 | 3 | 35.85556 | 35.62793 | 0.000322* | 4.757063 |
| Days | 10.50167 | 2 | 5.250833 | 5.217499 | 0.048657* | 5.143253 |
| Body weight after treatment | | | | | | |
| Groups | 74.115 | 3 | 24.705 | 14.49446 | 0.000859* | 3.862548 |
| Days | 18.535 | 3 | 6.178333 | 3.624837 | 0.057999† | 3.862548 |
| Blood glucose level variation before and after induction of diabetes | | | | | | |
| Groups | 167.6533 | 3 | 55.88444 | 1.956833 | 0.221933† | 4.757063 |
| Days | 334.2817 | 2 | 167.1408 | 5.852555 | 0.038919* | 5.143253 |
| Blood glucose level after treatment | | | | | | |
| Groups | 1470.525 | 3 | 490.175 | 32.00969 | 3.94E-05* | 3.862548 |
| Days | 6.325 | 3 | 2.108333 | 0.13768 | 0.934987† | 3.862548 |

**Note:** *P<0.05; †Not significant.

## 4. DISCUSSION

Researches grounded on the screening of phytochemical constituents of various medicinal plants as new wellsprings of natural antibiotics are done in different parts of the world. Customarily, since the old time frame,

*Senna auriculata* has been utilized as a medicinal plant and in the current investigation, the floral extracts of this plant had antibacterial action. Of all the extracts tested, the methanol extract was found to have the robust antibacterial activity against *Escherichia coli* and *Staphylococcus aureus*. The order of the antibacterial efficacy was petroleum ether>ethyl acetate>acetone>methanol extracts. This plant prior has been reported for antibacterial activity by different researchers. Yet, arbitrary screening of plants for dynamic phytocompounds is as significant as the screening of ethnobotanically targeted species (Godstime, Felix, Augustina, & Christopher, 2014) on the grounds that the antibacterial action consequences of a similar plant part tested more often than not differed. This is conceivable in light of the fact that grouping of plant constituents of a similar plant part can shift starting with one geological area then onto the next, relying upon the age of the plant, contrasts in geographical variables, and extraction strategy technique utilized for the investigation (Rajasekaran & Gebrekidan, 2018).

Antibacterial action of diverse plant extracts have been reported for inhibitory effects against pathogenic microorganisms (Alviano & Alviano, 2009; Burt, 2004; Reichling, Schnitzler, Suschke, & Saller, 2009; Solórzano-Santos & Miranda-Novales, 2012). The results of the current investigation were tantamount with the reports of prior studies. Doshi et al. (2011) examined methanolic extract of dry flowers of *Cassia auriculata* utilizing agar disc diffusion method and observed extreme activity against *Staphylococcus aureus* followed by *Bacillus subtilis*, *Escherichia coli* and *Salmonella typhi*. Sujith and Senthilkumar (2012) analysed the different flowering stages of the *Cassia auriculata* bud, before seedling and dried stages after extraction with various solvents and found the methanol extract of the fresh flowers with 19 and 18mm of inhibition zone against *Proteus mirabilis* and *Staphylococcus aureus* respectively. Murugan, Wins, and Murugan (2013) in their examination tried chloroform, methanol and aqueous leaf extracts of *Cassia auriculata* by well diffusion method against *Bacillus cereus*, *Staphylococcus aureus*, *Escherichia coli*, *Klebsiella pneumonia* and *Pseudomonas aeruginosa* and revealed the chloroform and methanol extracts to display strong inhibitory action against all the tested micoorganisms aside from *Pseudomonas aeruginosa* with a 12-20mm zone of inhibition. Sumathy et al. (2013) assessed *Cassia auriculata* petals by disc diffusion method against *Staphylococcus aureus*, *Escherichia coli*, *Bacillus subtilis*, *Pseudomonas aeruginosa* and *Proteus vulgaris* with a zone of inhibition percentage of 18.73, 20.03, 17.84, 16.00 and 21.17mm respectively.

Members of the plant families Fabaceae, Lamiaceae, Lauraceae And Zingiberaceae have exhibited the capacity to disrupt the bacterial cell wall/membrane (Prasad, Zolnik, & Molina, 2019) and their phytochemical constituents influence the integrity of the cell wall/membrane, with Gram-positive bacteria progressively vulnerable, though a few species have been conveyed to permeabilize outer membranes of Gram-negative bacteria. Fabaceae, the Bean Family, to which *Senna auriculata* belongs possess a variety of chemically active constituents, *viz*., alkaloids, phenolics, saponins and terpenoids (Wink, 2013) and any of these may be contributing to bacterial cell wall/membrane disruption. The chromone derivative, acthaside isolated from dried bark of *Acacia ataxacantha* displayed antibacterial activity against both Gram-positive and Gram-negative microorganisms, though Gram-positive bacteria showed a greater susceptibility overall (Amoussa, Bourjot, Lagnika, Vonthron-Sénécheau, & Sanni, 2016). In *Dolichos kilimandscharicus*, saponins were found to hinder Gram-positive bacteria (Shava et al., 2016). Gram-positive bacteria likewise surrendered to the cell wall destabilizing effects of terpenoids and flavonoids in extracts of *Cassia abbreviata*, *Senna didymobotrya* and *Parkinsonia aculeata* (Madureira, Ramalhete, Mulhovo, Duarte, & Ferreira, 2012) polyphenolic extracts from *Vicia faba*, *Cajanus indica* (Chanda, Dudhatra, & Kaneria, 2010) *Arachis hypogea* (Tamura, Ozawa, Tanaka, Arai, & Mura, 2016) and other legume species rich in isoflavonoids (Araya-Cloutier, Den Besten, Aisyah, Gruppen, & Vincken, 2017) had intense antibacterial activity against Gram-positive bacteria. Despite the fact, that Fabaceae species possess phytochemical diversity that may be synergistically damaging the cell wall, flavonoids could be one of the primary phytochemicals responsible as they form complexes with soluble proteins on bacterial cell walls (Yahaya & Idris, 2017). The antibacterial impact of flavonoids might be ascribed to different causes such as hindrance of bacterial proteins, DNA amalgamation, membrane formation and/or energy metabolism (Kumar & Pandey, 2013). This unequivocally demonstrates Fabaceae family as

pharmacologically significant attributable to its relic of its colossal species decent variety, making it imperative that phytochemicals inside this family are reliably connected with cell wall interuption in Gram-positive bacteria, thereby affirming the antibacterial potential of *Senna auriculata*.

Phytochemical compounds influence multiple target sites against the bacterial cells (Burt, 2004; Oonmetta-aree, Suzuki, Gasaluck, & Eumkeb, 2006). Flavonoids and terpenoids gets implicated in bacterial cell wall/membrane of Gram-positive bacteria leading to its disruption, and studies have demonstrated that terpenoids permeabilize external layers of Gram-negative bacteria (Prasad et al., 2019). Flavones action is because of their capacity to frame edifices with extracellular and dissolvable proteins as well as the complexation with bacterial cell walls, thereby instigating bacterial cell membrane annoyances (Moyo, Masika, & Muchenje, 2012). Quinones render substrates inaccessible to the bacterium. Kazmi, Malik, Hameed, Akhtar, and Ali (1994) labelled an anthraquinone from *Cassia italica*, which represses *Bacillus anthracis*, *Corynebacterium pseudodiphthericum*, and *Pseudomonas aeruginosa* and goes about as a bactericidal for *Pseudomonas pseudomalliae*. Saponins act by modifying the porousness of cell walls and hence exercise toxicity on organized tissues by combining with cell membranes to evoke changes in cell morphology prompting cell lysis (Moyo et al., 2012). Tannins are polyphenols with articulated capacity to smother bacterial cell proliferation by blocking vital enzymes of microbial metabolism such as the proteolytic macerating enzymes (Moyo et al., 2012). They additionally inactivate microbial catalysts and transport of cell envelope proteins and muddle to the cell walls of ruminal bacteria, thus bringing bacterial stasis and protease activity (Jones, McAllister, Muir, & Cheng, 1994).

It is fundamental to develop a superior comprehension of the antibacterial mechanism of plant crude extracts against Gram-positive and Gram-negative strains. Numerous mechanisms of antibacterial action of phytochemicals recommended by different researchers, opined that phytochemicals may act by restraining microbial development, prompting cellular membrane perturbations, impedence with certain microbial metabolic processes, regulation of signal transduction or gene expression pathways. Plant-based constituents may display various modes of action against enterotoxigenic bacterial strains which range from snooping with the phospholipoidal cell membranes, which has an outcome of expanding the porousness profile and loss of cell constituents, damage of the enzymes engaged in the production of cellular energy and blend of structural components, and obliteration or inactivation of genetic material (Kotzekidou, Giannakidis, & Boulamatsis, 2008). Hence, the key factors in finding the antibacterial activity of an agent is mainly attributed to two mechanisms, which incorporate meddling chemically with the synthesis or function of vital components of bacteria, and additionally evading the ordinary components of antibacterial obstruction which includes various focuses for the antibacterial operators that contain (i) bacterial protein biosynthesis; (ii) bacterial cell-wall biosynthesis; (iii) bacterial cell membrane destruction; (iv) bacterial DNA replication and repair, and (v) inhibition of a metabolic pathway (Khameneh, Iranshahy, Soheili, & Bazzaz, 2019).

Despite the fact that components by which phytochemicals inspire these activities are indistinct, it is recommended that the dynamic principles from these plants hamper with the transcriptional and translational processes of the bacterial cellular membranes (Trease & Evans, 1989). Phytochemicals resembling phenolics and polyphenolics, terpenoids, and other essential oils constituents, alkaloids, lectins, peptides, and polyacetylenes block bacterial growth by various mechanisms and no confirmations on the rise of its resistance has been accounted (Stavri, Piddock, & Gibbons, 2007). Conversely, action of phytochemicals with regard to antibacterial mechanism is completely silent (Simoes, Bennett, & Rosa, 2009). In conjoint, phytochemicals have diverse antimicrobial mechanisms including damage of cell wall and cytoplasmic membrane, membrane permeabilization by pore formation or disrupting membrane integrity and cell wall lysis. The mechanism of action is viewed as the disturbance of the cytoplasmic membrane, disrupting the proton motive force, electron flow, active transport, and coagulation of cell substances (Kotzekidou et al., 2008). Dilapidation of the cell wall, disruption of cytoplasmatic membrane, damage of membrane proteins, spillage of intracellular substances, coagulation of cytoplasm, and proton

depletion have been as of now detailed accountable for cell death (Borges, Ferreira, Saavedra, & Simoes, 2013; Cowan, 1999; Perumal Samy & Gopalakrishnakone, 2010; Saleem et al., 2010; Savoia, 2012).

Controlling diabetes involves alteration of diet, change of lifestyle, intake of oral hypoglycemic, administration of exogenous insulin and herbal remedies (Venkatesh, Reddy, Reddy, Mullangi, & Lakshman, 2010). Plants and herbs have the ability to lessen blood glucose values and improve diabetes with less side effects (Venkatesh et al., 2010). Plants have consistently been a decent wellspring of medications and the ethnobotanical data reports about plants that have hostile to diabetic potential. The development of herbal research in the administration of diabetes has expanded from the recent decades, and Asia stands first followed by Africa. A scientific authentication of several plant species has ascertained the efficacy of the botanicals in reducing the sugar level. In the current investigation, scientifically validated experimental animal models utilized to investigate the *Senna auriculata* floral extracts in the form of Avaram tea against diabetic through its blood glucose lowering activity reported no abnormal symptoms when administered orally, and reflected therapeutically acceptable safety profile. The oral administration of Avaram tea revealed a noteworthy reduction in the glucose level of oral administration. The mechanism of avaram tea to bring about hypoglycemic action is still to be explored, and might be due to the increase in pheripheral utilization of glucose or by exciting the secretion of insulin by the remaining intact β-cells that may certainly be available and potentiation of its effect. In this perspective, a number of plants have likewise been seen to have hypoglycemic and insulin discharge stimulatory impacts. Thus, further examination utilizing biochemical methods are sought to ascertain the scrupulous mechanism of action of this decoction.

Plant extracts can change the structure and function of affected parts *viz.*, renewal of β-cells of pancreas, commencement of receptor and ligand interactions in productions of insulin, activation of signal transduction for creation of insulin and decrease of blood glucose level, initiation of number of liver enzymes for conversion of sugar into various products or limiting the production of byproducts. Some of the extracts have gone about as insulin like action or prompt the activity of insulin, and some hindered the activity of enzymes, *viz.*, α-amylase, α-glucosidase (Govindappa, 2015). Streptozotocin is notable for its particular pancreatic islet β-cell cytotoxicity and has been broadly utilized to incite diabetes mellitus in animals. It impedes with cellular metabolic oxidative mechanisms. Intraperitoneal administration of streptozotocin effectively induced diabetes in normal mice as reflected by glycosuria, hyperglycaemia and bodyweight loss when compared with normal mice. In the current investigation, there was a noteworthy rise in blood glucose in streptozotocin diabetic mice when contrasted with normal mice. Administration of avaram tea and metformin brought the parameter altogether towards the normal glucose level. The maximum percent reduction of serum glucose was perceived with the standard drug metformin, while with avaram tea, reduction of serum glucose was observed too simultaneously. Both avaram tea and metformin reduced the blood glucose level, and the impact of avaram tea was huge about equivalent to that of standard metformin, and can be utilized for further biochemical examinations. Likewise, a rise in total blood glucose level after induction of diabetes due to improper secretion of insulin caused by damage of pancreatic cells was additionally watched. Decline in the degree of blood glucose in animals given avaram tea might be because of recovery of harmed pancreatic cells bringing about proper insulin secretion. The body weight of normal and experimental mice, streptozotocin induced diabetic mice when compared with normal mice indicated noteworthy lessening in body weight. Avaram tea directed to streptozotocin dosed animals turned around the weight reduction. The maximum body weight reinstated was witnessed with the standard drug metformin while avaram tea restored body weight at the same time interval. The impact of avaram tea and metformin was comparative in body weight re-established and the capacity of avaram tea to recoup body weight reduction was because of its antihyperglycemic impact. Avaram tea results recommend that *Senna auriculata* can be a potential substitute for standard metformin due to its noteworthy action equivalent to metformin with no symptoms. It is discovered that, the extract of *Senna auriculata* flowers was worthwhile to develop the bioactive principle for diabetes mellitus and it is also clinched that the phytochemical compounds present could be attributed for antidiabetic action too.

Researchers have documented that plant extracts are safe and effective in bringing down the glucose level. It has been accounted that the utilization of plant parts as follows, leaves (35%) followed by fruits (13%), whole plant (12%), seed (12%), root (9%), stem (8%), aerial (7%) and flower parts (2%). In spite of the fact that the minimal percentage of plant parts stated are the flowers, and *Senna* species antidiabetic property is ascribed to its floral extracts which has been by and by affirmed in the current investigation. This has been matched with the further reports. A blend of roots, leaves, flowers, barks and unique fruits of *Cassia auriculata* shrub is utilized in Avarai panchaga chooranam which controls the blood sugar level (Brahmachari & Augusti, 1961). Pari and Latha (2002) proved that the aqueous extract of *Cassia auriculata* flowers smothered the raised blood glucose and lipid levels in diabetic rats when administered orally at doses of 0.15, 0.30 and 0.45g/Kg body weight for 30 days. Hatapakki, Suresh, Bhoomannavar, and Shivkumar (2005) stated extreme decrease of serum glucose (29.09%) by ethanol extract (250mg/kg, p.o) of *Cassia auriculata* flowers which revealed the presence of sterols, triterpenoids, flavanoids and tannins against alloxan induced diabetes in rat at 4 hours. Hakkim, Girija, Kumar, and Jalaludeen (2007) exposed the antidiabetic potential of aqueous and ethanol extract of *Cassia auriculata* flowers in alloxan-induced diabetic rats which indicated noteworthy reduction in the blood glucose level and an exceptional increase in plasma insulin level after 48 hours at a dose of 0.25 and 0.5g/kg of body of weight, for 30 days. Surana, Gokhale, Jadhav, Sawant, and Wadekar (2008) portrayed the strong antidiabetic part from *Cassia auriculata* flowers at a dose of 0.20 g/kg body weight in alloxan-instigated diabetes in rats, when its methanolic extract which specified the presence of phenolic compounds, carbohydrates, tannins, steroids and amino acids showed a huge reduction in blood glucose levels and was additionally seen as viable in reestablishing the blood lipids and proteins to typical level and its action was discovered practically identical with the standard medication phenformin. Shanmugasundaram, Devi, Soris, Maruthupandian, and Mohan (2011) demonstrated that the ethanol extract of *Senna auriculata* for its antidiabetic impact in diabetes instigated wistar albino rats by administration of alloxan monohydrate (150mg/Kg, i.p) evoked a huge decrease in blood glucose. *Cassia auriculata* treated animals displayed amplified serum insulin levels in streptozotocin treated diabetic animals when compared to diabetic control and the β cells regeneration substantiate with expanded degree of insulin (Daisy, Feril, & Kani, 2012). Administration of *Cassia auriculata* leaf and flower extracts stimulated the insulin discharge by recovering β cells in alloxan-induced diabetic rats (Kalaivani, Umamaheswari, Vinayagam, & Kalaivani, 2008). *Cassia auriculata* leaf extract additionally controlled the raised blood glucose by stopping the activity of α-amylase and α-glucosidase by which it suggests the postprandial hypoglycemic control in diabetes (Jyothi, Chavan, & Somashekaraiah, 2012).

Similarly remaining then again close to its antibacterial property, Fabaceae family have solid antidiabetic property detailed by *Cassia auriculata*, *Cassia fistula*, *Dolichos biflorus*, *Galega officinalis*, *Glycine soja*, *Hedysarum polybotrys*, *Lathyrus sativus*, *Mucuna pruriens* and *Securigera securidaca* (Qais, Jahan, & Shajib, 2018) in genereal. Likewise, the extracts of *Lupinus albus*, *Lupinus perennis*, *Securigera securidaca*, *Tamarindus indica*, *Trigonella foenum*, *Trigonella foenum graecum* seed; *Pterocarpus marsupium* bark; *Acacia catechu*, *Acacia tetragonophylla*, *Bauhinia forficata*, *Cyamposis tertragonoloba*, *Medicago sativa*, *Pterocarpus marsupium* whole plant; leaf and flower of *Clitoria ternatea*; and *Cajanus cajan* root are additionally archived for antidiabetic property (Govindappa, 2015). Phytoconstituents of Fabaceae family such as alkaloids, glycosides, flavonoids, saponins, polysaccharides, glycolipids, peptidoglycans and amino acids have been accounted as strong potent hypoglycemic representatives (Mukherjee, Maiti, Mukherjee, & Houghton, 2006). Alkaloids from *Lupinus perennis* upgraded glucose-instigated insulin discharge from isolated rat islet cells. Nonetheless, their impact on insulin discharge was reliant on the glucose concentration in the incubation media (López et al., 2004). *Trigonella foenum-graecum* seeds exerted a brief hypoglycemic outcome accredited to an uncharacterized alkaloid, trigonelline, albeit other probable hypoglycemic agents such as nicotinic acid (Mishkinsky, Joseph, Sulman, & Goldschmied, 1967; Mishkinsky, Goldschmied, Joseph, Ahronson, & Sulman, 1974) in sound and somewhat diabetic animals yet were not effective in severely diabetic animals. Baldeón, Castro, Villacrés, Narváez, and Fornasini (2012) detailed that *Lupinus mutabilis* legumes rich in proteins decrease blood glucose and improve

insulin sensitivity in animals and humans. Flavonoids have hypoglycemic properties and they improve altered glucose and oxidative metabolisms of diabetic states. *Bauhinia forficata* leaves exercised a long term effect on glycaemia in diabetic rats and suggests that blood glucose lowering activity was owed to the flavonoid compound which credited to changed intrinsic activity of the glucose transporter (Jorge, Horst, de Sousa, Pizzolatti, & Silva, 2004).

In view of the potential viability reports against diabetes, it is expected that the bioactive antidiabetic principles of plant origin are mainly phytochemicals like flavonoids, saponins, alkaloids, tannins, glycosides, terpenes (Dewanjee, Das, Sahu, & Gangopadhyay, 2009) have a significant part in the management of diabetes, which needs further investigation for the essential development of drugs and nutraceuticals from natural resources (Gaikwad, Mohan, & Rani, 2014). Alkaloids have been embroiled as the active principles in antidiabetic medicinal plants owing to their mechanisms which embrace reduction in total cholesterol, triglyceride, diminution of glucose-6-phosphatase activity and enhancement in the hepatic glycogen content (Sharma, Salunke, Balomajumder, Daniel, & Roy, 2009). Flavonoids go about as insulin secretagogues/mimetics, by afffecting the pleiotropic mechanisms to constrict diabetic intricacies (Gupta, Sharma, Dobhal, Sharma, & Gupta, 2011). Saponins incite insulin production and several antidiabetic medicinal plants owe their activities to saponins (Riguera, 1997). Tannins are accounted as the bioactive antidiabetic standards of medicinal plants as tannic acid excites glucose transportation and inhibition of differentiation in adipocytes accomplished by phosphorylation of insulin receptor and translocation of glucose transporter 4, besides, inhibition of the genes for adipogenesis (Liu et al., 2005). By and large, as a rule, these phytochemical constituents, surges insulin discharge, drops hepatic glucose output, controls enzymes involved in carbohydrate metabolism such as α-glucosidase inhibitors, moderates hypolipidaemic activities and antioxidant effects, impedes with activity of glycolytic enzymes such as phosphoenolpyruvate carboxykinase, ameliorates glycosylated haemoglobin, and boosts the expression of glucose transporters (Aba & Asuzu, 2018).

## 5. CONCLUSION

In spite of the fact that this is a primer research, it is proposed that the atomic reason for the methods of activity of plant-based anti-infection agents and antidiabetics be learned and decided whether these phytochemicals would display these systems *in vitro* and *in vivo*. While many plant species have been approved for their antibacterial and antidiabetic properties, there is a requirement for current research in the distinguishing proof of phytochemical compound(s), their target(s) and their methods of activity and mix treatment of plant items with manufactured drugs.

**Funding:** This study received no specific financial support.
**Competing Interests:** The authors declare that they have no competing interests.
**Acknowledgement:** All authors contributed equally to the conception and design of the study.

## REFERENCES

Aba, P. E., & Asuzu, I. U. (2018). Mechanisms of actions of some bioactive anti-diabetic principles from phytochemicals of medicinal plants: A review. *Indian Journal of Natural Products and Resources*, *9*(2), 85-96.

Alviano, D., & Alviano, C. (2009). Plant extracts: Search for new alternatives to treat microbial diseases. *Current Pharmaceutical Biotechnology*, *10*(1), 106-121.Available at: https://doi.org/10.2174/138920109787048607.

Amoussa, A., Bourjot, M., Lagnika, L., Vonthron-Sénécheau, C., & Sanni, A. (2016). Acthaside: A new chromone derivative from Acacia ataxacantha and its biological activities. *BMC Complementary and Alternative Medicine*, *16*(1), 506-506.Available at: https://doi.org/10.1186/s12906-016-1489-y.

Andallu, B. (2002). Control of hyperglycemic and retardation of cataract by mulberry (Morus indica. L) leaves in streptozotocin diabetic rats. *Indian Journal of Experimental Biology*, *40*(7), 791-795.

Araya-Cloutier, C., Den Besten, H. M., Aisyah, S., Gruppen, H., & Vincken, J.-P. (2017). The position of prenylation of isoflavonoids and stilbenoids from legumes (Fabaceae) modulates the antimicrobial activity against gram positive pathogens. *Food Chemistry*, *226*, 193-201.Available at: https://doi.org/10.1016/j.foodchem.2017.01.026.

Bailey, C. J. (1999). New pharmacological approaches to glycemic control. *Diabetes Reviews*, *7*(2), 94-113.

Baldeón, M. E., Castro, J., Villacrés, E., Narváez, L., & Fornasini, M. (2012). Hypoglycemic effect of cooked Lupinus mutabilis and its purified alkaloids in subjects with type-2 diabetes. *Nutricion Hospitalaria*, *27*(4), 1261-1266.

Bauer, A. W., Kirby, W. M. M., Sherris, J. C., & Turck, M. (1966). Antibiotic susceptibility testing by a standardized single disk method. *American Journal of Clinical Pathology*, *45*, 493-496.Available at: https://doi.org/10.1093/ajcp/45.4_ts.493.

Borges, A., Ferreira, C., Saavedra, M. J., & Simoes, M. (2013). Antibacterial activity and mode of action of ferulic and gallic acids against pathogenic bacteria. *Microbial Drug Resistance*, *19*(4), 256-265.Available at: https://doi.org/10.1089/mdr.2012.0244.

Brahmachari, H., & Augusti, K. (1961). Hypoglycaemic agents from Indian indigenous plants. *Journal of Pharmacy and Pharmacology*, *13*(1), 381-382.Available at: https://doi.org/10.1111/j.2042-7158.1961.tb11839.x.

Burt, S. (2004). Essential oils: Their antibacterial properties and potential applications in foods—a review. *International Journal of Food Microbiology*, *94*(3), 223-253.Available at: https://doi.org/10.1016/j.ijfoodmicro.2004.03.022.

Chanda, S., Dudhatra, S., & Kaneria, M. (2010). Antioxidative and antibacterial effects of seeds and fruit rind of nutraceutical plants belonging to the fabaceae family. *Food & Function*, *1*(3), 308-315.Available at: https://doi.org/10.1039/c0fo00028k.

Cohen, M. L. (1992). Epidemiology of drug resistance: Implications for a post—antimicrobial era. *Science*, *257*(5073), 1050-1055.Available at: https://doi.org/10.1126/science.257.5073.1050.

Cowan, M. M. (1999). Plant products as antimicrobial agents. *Clinical Microbiology Reviews*, *12*(4), 564-582.Available at: https://doi.org/10.1128/cmr.12.4.564.

Daisy, P., Feril, G., & Kani, J. (2012). Evaluation of antidiabetic activity of various extracts of cassia auriculata linn. Bark on streptozotocin-induced diabetic wistar rats. *International Journal of Pharmacy and Pharmaceutical Sciences*, *4*(4), 312-318.

Dewanjee, S., Das, A. K., Sahu, R., & Gangopadhyay, M. (2009). Antidiabetic activity of Diospyros peregrina fruit: Effect on hyperglycemia, hyperlipidemia and augmented oxidative stress in experimental type 2 diabetes. *Food and Chemical Toxicology*, *47*(10), 2679-2685.Available at: https://doi.org/10.1016/j.fct.2009.07.038.

Divya, B., & Mini, S. (2011). In vitro radical scavenging activity of different extracts of butea monosperma bark. *International Journal of Current Pharmaceutical Research*, *3*(3), 114-116.

Doshi, G. M., Shahare, M. D., Aggarwal, G. V., Pillai, P. G., & Desai, S. K. (2011). Evaluation of in vitro antioxidant methods of cassia auriculata. *Der Pharmacia Lettre*, *3*, 297-305.

Evans, C. E., Banso, A., & Samuel, O. A. (2002). Efficacy of some nupe medicinal plants against Salmonella typhi: An in vitro study. *Journal of Ethnopharmacology*, *80*(1), 21-24.Available at: https://doi.org/10.1016/s0378-8741(01)00378-6.

Gaikwad, S. B., Mohan, G. K., & Rani, M. S. (2014). Phytochemicals for diabetes management. *Pharmaceutical Crops*, *5*(1), 11-28.

Godstime, O. C., Felix, E. O., Augustina, J. O., & Christopher, E. O. (2014). Mechanisms of antimicrobial actions of phytochemicals against enteric pathogens – a review. *Journal of Pharmaceutical, Chemical and Biological Sciences*, *2*(2), 77-85.

Govindappa, M. (2015). A review on role of plant (s) extracts and its phytochemicals for the management of diabetes. *J Diabetes Metab*, *6*(7), 1-38.Available at: https://doi.org/10.4172/2155-6156.1000565.

Gupta, R., Sharma, A. K., Dobhal, M., Sharma, M., & Gupta, R. (2011). Antidiabetic and antioxidant potential of β-sitosterol in streptozotocin-induced experimental hyperglycemia. *Journal of Diabetes*, *3*(1), 29-37.Available at: https://doi.org/10.1111/j.1753-0407.2010.00107.x.

Hakkim, F. L., Girija, S., Kumar, R. S., & Jalaludeen, M. (2007). Effect of aqueous and ethanol extracts of cassia auriculata L. flowers on diabetes using alloxan induced diabetic rats. *International Journal of Diabetes and Metabolism*, *15*, 100-106.

Harborne, J. B. (1998). Phytochemical methods, a guide to modern techniques of plant analysis (3rd ed., pp. 279). London: Chapman and Hill Ltd.

Hatapakki, B., Suresh, H., Bhoomannavar, V., & Shivkumar, S. (2005). Effect of cassia auriculata linn flowers against alloxan-induced diabetes in rats. *Journal of Natural Remedies*, *5*(2), 132-136.

Inas, S. G., Ekram, S. A., Hoda, F. B., Ibrahim, M. F., & Somaia, A. N. (2011). Evaluation of antihyperglycemic action of oyster mushroom (Pleurotus ostreatus) and its effect on DNA damage, chromosome aberrations and sperm abnormalities in streptozotocin-induced diabetic rats. *Global Veterinaria*, *7*(6), 532-544.

Iwu, M. W., Ducan, A. R., & Okungi, C. O. (1999). New antimicrobials of plant origin. In: Perspectives on new crops and new uses. Janik, J. (Ed.). (pp. 457-462). Alexandria: ASHS press.

Jones, G., McAllister, T., Muir, A., & Cheng, K.-J. (1994). Effects of sainfoin (Onobrychis viciifolia Scop.) condensed tannins on growth and proteolysis by four strains of ruminal bacteria. *Appl. Environ. Microbiol*, *60*(4), 1374-1378.Available at: https://doi.org/10.1128/aem.60.4.1374-1378.1994.

Jorge, A. P., Horst, H., de Sousa, E., Pizzolatti, M. G., & Silva, F. R. M. B. (2004). Insulinomimetic effects of kaempferitrin on glycaemia and on 14C-glucose uptake in rat soleus muscle. *Chemico-Biological Interactions*, *149*(2-3), 89-96.Available at: https://doi.org/10.1016/j.cbi.2004.07.001.

Jyothi, S., Chavan, S. C., & Somashekaraiah, B. (2012). In vitro and in vivo antioxidant and antidiabetic efficacy of cassia auriculata L. flowers. *Global Journal of Pharmacology*, *6*(1), 33-40.

Kalaivani, A., Umamaheswari, A., Vinayagam, A., & Kalaivani, K. (2008). Anti-hyperglycemic and antioxidant properties of cassia auriculata leaves and flowers on alloxan induced diabetic rats. *Pharmacologyonline*, *1*, 204-217.

Kazmi, M. H., Malik, A., Hameed, S., Akhtar, N., & Ali, S. N. (1994). An anthraquinone derivative from cassia Italica. *Phytochemistry*, *36*(3), 761-763.Available at: https://doi.org/10.1016/s0031-9422(00)89812-x.

Khameneh, B., Iranshahy, M., Soheili, V., & Bazzaz, B. S. F. (2019). Review on plant antimicrobials: A mechanistic viewpoint. *Antimicrobial Resistance & Infection Control*, *8*(1), 118.Available at: https://doi.org/10.1186/s13756-019-0559-6.

Kotzekidou, P., Giannakidis, P., & Boulamatsis, A. (2008). Antimicrobial activity of some plant extracts and essential oils against foodborne pathogens in vitro and on the fate of inoculated pathogens in chocolate. *LWT-Food Science and Technology*, *41*(1), 119-127.Available at: https://doi.org/10.1016/j.lwt.2007.01.016.

Kumar, S., & Pandey, A. K. (2013). Chemistry and biological activities of flavonoids: An overview. *Scientific World Journal*, *1*(1), 1-16.

Kumaran, A., & Karunakaran, R. J. (2007). Antioxidant activity of cassia auriculata flowers. *Fitoterapia*, *78*(1), 46-47.Available at: https://doi.org/10.1016/j.fitote.2006.09.031.

Latha, M., & Pari, L. (2003). Antihyperglycaemic effect of cassia auriculata in experimental diabetes and its effects on key metabolic enzymes involved in carbohydrate metabolism. *Clinical and Experimental Pharmacology and Physiology*, *30*(1-2), 38-43.Available at: https://doi.org/10.1046/j.1440-1681.2003.03785.x.

Liu, X., Kim, J.-k., Li, Y., Li, J., Liu, F., & Chen, X. (2005). Tannic acid stimulates glucose transport and inhibits adipocyte differentiation in 3T3-L1 cells. *The Journal of Nutrition*, *135*(2), 165-171.Available at: https://doi.org/10.1093/jn/135.2.165.

López, P. M. G., De La Mora, P. G., Wysocka, W., Maiztegui, B., Alzugaray, M. E., Del Zotto, H., & Borelli, M. I. (2004). Quinolizidine alkaloids isolated from lupinus species enhance insulin secretion. *European Journal of Pharmacology*, *504*(1-2), 139-142.Available at: https://doi.org/10.1016/j.ejphar.2004.09.008.

Madureira, A. M., Ramalhete, C., Mulhovo, S., Duarte, A., & Ferreira, M.-J. U. (2012). Antibacterial activity of some African medicinal plants used traditionally against infectious diseases. *Pharmaceutical Biology*, *50*(4), 481-489.Available at: https://doi.org/10.3109/13880209.2011.615841.

Manogaran, S., & Sulochana, N. (2004). Anti-inflammatory activity of cassia aauriculata. *Ancient Science of Life*, *24*(2), 65-67.

Mishkinsky, J., Joseph, B., Sulman, F., & Goldschmied, A. (1967). Hypoglycaemic effect of trigonelline. *The Lancet*, *290*(7529), 1311-1312.Available at: https://doi.org/10.1016/s0140-6736(67)90428-x.

Mishkinsky, J., Goldschmied, A., Joseph, B., Ahronson, Z., & Sulman, F. (1974). Hypoglycaemic effect of trigonella foenum graecum and lupinus termis (leguminosae) seeds and their major alkaloids in alloxan-diabetic and normal rats. *International Pharmacodynamics and Therapy Archives*, *210*(1), 27-37.

Moyo, B., Masika, P. J., & Muchenje, V. (2012). Antimicrobial activities of moringa oleifera lam extracts. *African Journal of Biotechnology*, *11*(11), 2797-2802.

Mukherjee, P. K., Maiti, K., Mukherjee, K., & Houghton, P. J. (2006). Leads from Indian medicinal plants with hypoglycemic potentials. *Journal of Ethnopharmacology*, *106*(1), 1-28.

Murugan, T., Wins, J., & Murugan, M. (2013). Antimicrobial activity and phytochemical constituents of leaf extracts of cassia auriculata. *Indian Journal of Pharmaceutical Sciences*, *75*(1), 122-125.Available at: https://doi.org/10.4103/0250-474x.113546.

Oonmetta-aree, J., Suzuki, T., Gasaluck, P., & Eumkeb, G. (2006). Antimicrobial properties and action of galangal (Alpinia galanga linn.) on staphylococcus aureus. *LWT-Food Science and Technology*, *39*(10), 1214-1220.Available at: https://doi.org/10.1016/j.lwt.2005.06.015.

Pari, L., & Latha, M. (2002). Effect of cassia auriculata flowers on blood sugar levels, serum and tissue lipids in streptozotocin diabetic rats. *Singapore Medical Journal*, *43*(12), 617-621.

Perumal Samy, R., & Gopalakrishnakone, P. (2010). Therapeutic potential of plants as anti-microbials for drug discovery. *Evidence-Based Complementary and Alternative Medicine*, *7*(3), 283-294.Available at: https://doi.org/10.1093/ecam/nen036.

Piddock, L., & Wise, R. (1989). Mechanisms of resistance to quinolones and clinical perspectives. *Journal of Antimicrobial Chemotherapy*, *23*(4), 475-480.

Prasad, M. A., Zolnik, C. P., & Molina, J. (2019). Leveraging phytochemicals: The plant phylogeny predicts sources of novel antibacterial compounds. *Future Science OA*, *5*(7), FSO407.Available at: https://doi.org/10.2144/fsoa-2018-0124.

Qais, N., Jahan, S., & Shajib, M. S. (2018). A review on anti-diabetic plants. *Dhaka University Journal of Pharmaceutical Sciences*, *17*(1), 139-152.

Rajasekaran, R., & Gebrekidan, Y. (2018). A review on antibacterial phytochemical constitutions present in aerva lanata and their mode of action against bacterial biofilm. *International Journal of Pharmaceutical & Biological Archives*, *9*(1), 16-30.

Reichling, J., Schnitzler, P., Suschke, U., & Saller, R. (2009). Essential oils of aromatic plants with antibacterial, antifungal, antiviral, and cytotoxic properties–an overview. *Complementary Medicine Research*, *16*(2), 79-90.Available at: https://doi.org/10.1159/000207196.

Riguera, R. (1997). Isolating bioactive compounds from marine organisms. *Journal of Marine Biotechnology*, *5*, 187-193.

Saleem, M., Nazir, M., Ali, M. S., Hussain, H., Lee, Y. S., Riaz, N., & Jabbar, A. (2010). Antimicrobial natural products: An update on future antibiotic drug candidates. *Natural Product Reports*, *27*(2), 238-254.

Savoia, D. (2012). Plant-derived antimicrobial compounds: Alternatives to antibiotics. *Future Microbiology*, *7*(8), 979-990.Available at: https://doi.org/10.2217/fmb.12.68.

Shanmugasundaram, R., Devi, K., Soris, T., Maruthupandian, A., & Mohan, V. (2011). Antidiabetic, antihyperlipidaemic and antioxidant activity of senna auriculata (L.) Roxb. Leaves in alloxan induced diabetic rats. *International Journal of PharmTech Research*, *3*(2), 747-756.

Sharma, B., Salunke, R., Balomajumder, C., Daniel, S., & Roy, P. (2009). Anti-diabetic potential of alkaloid rich fraction from capparis decidua on diabetic mice. *Journal of Ethnopharmacology*, *127*(2), 457-462.

Shava, C., Mutsaka, P., Moyo, B., Sithole, S., Chitemerere, T., & Mukanganyama, S. (2016). Antibacterial and anticancer properties of dolichos kilimandscharicus (Fabaceae). *Journal of Biologically Active Products from Nature*, *6*(2), 112-135.Available at: https://doi.org/10.1080/22311866.2016.1184990.

Simoes, M., Bennett, R. N., & Rosa, E. A. (2009). Understanding antimicrobial activities of phytochemicals against multidrug resistant bacteria and biofilms. *Natural Product Reports*, *26*(6), 746-757.Available at: https://doi.org/10.1039/b821648g.

Solórzano-Santos, F., & Miranda-Novales, M. G. (2012). Essential oils from aromatic herbs as antimicrobial agents. *Current Opinion in Biotechnology*, *23*(2), 136-141.Available at: https://doi.org/10.1016/j.copbio.2011.08.005.

Sona, P. S. (2010). Nanoparticulate drug delivery system for the treatment of diabetes. *Digest Journal of Nanomaterials and Biostructures*, *5*(2), 411-418.

SPSS. (2010). *IBM SPSS statistics for windows, version 22.0.* Armonk, NY: IBM Corp.

Stavri, M., Piddock, L. J., & Gibbons, S. (2007). Bacterial efflux pump inhibitors from natural sources. *Journal of Antimicrobial Chemotherapy*, *59*(6), 1247-1260.Available at: https://doi.org/10.1093/jac/dkl460.

Sujith, P., & Senthilkumar, P. K. (2012). Bactericidal activity of extracts of different flowering stages of cassia auriculata and screening of its amino acids. *International Journal of Microbiological Research*, *3*(2), 144-148.

Sumathy, R., Sankaranarayanan, S., Bama, P., Ramachandran, J., Vijayalakshmi, M., & Deecaraman, M. (2013). Antibacterial & antioxidant activity of flavanoid rich fraction from the petals of cassia auriculata–an in-vitro study. *International Journal of Pharmacy and Pharmaceutical Sciences*, *5*(3), 492-497.

Surana, S., Gokhale, S., Jadhav, R., Sawant, R., & Wadekar, J. B. (2008). Antihyperglycemic activity of various fractions of cassia auriculata linn. in alloxan diabetic rats. *Indian Journal of Pharmaceutical Sciences*, *70*(2), 227-229.Available at: https://doi.org/10.4103/0250-474x.41461.

Tamura, T., Ozawa, M., Tanaka, N., Arai, S., & Mura, K. (2016). Bacillus cereus response to a proanthocyanidin trimer, a transcriptional and functional analysis. *Current Microbiology*, *73*(1), 115-123.Available at: https://doi.org/10.1007/s00284-016-1032-x.

Thambidurai, M., Rajesh, P., & Kannan, V. R. (2010). In-vitro anti-oxidant and anti-microbial study on cassia auriculata linn. *International Journal of Pharma and Bio Sciences*, *1*(2), 1-7.

Thulasi, G., & Amsaveni, V. (2012). Antibacterial activity of Cassia auriculata against ESBL producing E. coli from UTI patients. *International Journal of Microbiological Research*, *3*(1), 24-29.

Tomoko, N., Takashi, A., & Hiromu, Y. (2000). Antibacterial activity of extracts prepared from tropical and subtropical plants on methicillin resistant staphylococcus aureus. *Journal of Health Sciences*, *48*(3), 273-276.

Trease, G., & Evans, W. (1989). Pharmacognosy (pp. 161-163). Aberdeen, Great Britain: University Press.

Vedavathy, S., & Rao, K. (1991). Antipyretic activity of six indigenous medicinal plants of Tirumala Hills, Andhra Pradesh, India. *Journal of Ethnopharmacology*, *33*(1-2), 193-196.Available at: https://doi.org/10.1016/0378-8741(91)90178-g.

Venkatesh, S., Reddy, B. M., Reddy, G. D., Mullangi, R., & Lakshman, M. (2010). Antihyperglycemic and hypolipidemic effects of helicteres isora roots in alloxan-induced diabetic rats: A possible mechanism of action. *Journal of Natural Medicines*, *64*(3), 295-304.Available at: https://doi.org/10.1007/s11418-010-0406-9.

Vogel, A. L. (1978). Text book of practical organic chemistry (pp. 1363). London: The English Language Book Society and Longman

WHO. (1980). Expert committee on diabetes mellitus second report (Vol. 61). Technical Report Series 646. World Health Organization. Geneva.

WHO. (1999). Definition, diagnosis and classification of diabetes mellitus and its complications. Report of a WHO Consultation. Part 1: Diagnosis and classification of diabetes mellitus. Geneva: World Health Organization.

Wink, M. (2013). Evolution of secondary metabolites in legumes (Fabaceae). *South African Journal of Botany*, *89*, 164-175.Available at: https://doi.org/10.1016/j.sajb.2013.06.006.

Yahaya, A., & Idris, A. (2017). Antibacterial activity and phytochemical screening of carica papaya on some enteric bacterial isolates of public health importance. *Greener Journal of Biological Sciences*, *7*(1), 1-7.