

Traditional uses and anti-bacterial activity of *Opuntia ficus-indica* stem and fruit extracts in Kasese District, Western- Uganda

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Abstract

Opuntia ficus-indica (OFI), also known as prickly pear, has been used in traditional medicine. This is attributed to its medicinal properties that contribute to treatment of conditions including asthma, stomach ulceration, and diabetes. We carried out a cross-sectional study in 2018 in Kasese district, western Uganda, to determine the traditional uses of *O. ficus-indica* and the anti-bacterial activity of the stem and fruit extracts of the plant. We interviewed participants using questionnaires and obtained data for traditional uses. We also performed the Agar well diffusion test to measure the anti-bacterial activity of the fruit and stem extracts of OFI. Data was analysed using SPSS version 26.0, and a P value of less than 0.05 was considered statistically significant after performing the one-way ANOVA test. Out of the 56 respondents, results showed that all (100%) of the respondents used prickly pear as food, 90% as ornamental, 80% as an anti-ulcer, 60% as an anti-constipation herb, and 20% used the plant to cleanse the body. On the other hand, fruit and stem extracts exhibited anti-bacterial activity as determined by the diameters of inhibition zones: 27mm and 21mm, respectively, compared to ampicillin (28mm), which was our positive control. The fruit extracts showed a higher anti-bacterial activity against *E. coli* bacteria than the stem extract ($p < 0.05$), hence the rejection of the null hypothesis, which stated that there is no significant variation in the anti-bacterial activity of *Opuntia ficus-indica* extracts from the stem and fruit.

Introduction

Plants have been used to treat diseases from old ages (1). Manzano et al., 2020 reported how observations contribute to the disclosure of therapeutic properties of medicinal plants under human consumption (2). Nevertheless, medicinal plants represent a rich source of anti-microbial agents that are not limited to flavonoids, phenols, and fatty acids (3, 4). For a considerable amount of time, domesticated *Opuntia ficus-indica* has been a significant crop plant in agricultural economies in arid and semi-arid regions of the world (5).

Opuntia ficus-indica is also known as “prickly pear” and belongs to the *Cactaceae* family (6). This species is the most known species among the nearly 1500 cactus species. Cactus possesses tissue capable of conserving water. This tissue appears swollen with water and is used when no moisture is available to the plant. The vast majority of cacti do not have leaves (7). Matthaus and Ozcan, 2011 reported that prickly pears grow with flat, rounded cladodes (also called platyclades) armed with two kinds of spines: large, smooth, fixed spines and small, hairlike prickles called glochids. These penetrate the skin and detach from the plant, and in particular, *Opuntia ficus-indica* is polyploid, hermaphrodite and autogamous (8).

According to Avendano et al., 2021, the perennial shrub *Opuntia ficus-indica* can grow up to 3-5m in height, with thick, succulent and oblong to spatulate stems called cladodes. It has a water-repellent and sun-reflecting waxy epidermis. Cladodes that are 1–2 years old produce flowers, the fruit's colours ranging from pale green to deep red. The plants flower in three distinct colours: white, yellow, and red and the fruits are typically eaten, minus the thick outer skin, after chilling in a refrigerator for a few hours

(9). They are reported to have a taste similar to sweet watermelon. In addition, he makes it clear that the bright red or purple or, white or yellowish flesh contains many tiny hard seeds that are usually swallowed but should be avoided by those who have problems digesting seeds (9).

Prickly pear can survive in arid environments due to the possession of spinney leaves (7). Kirschner *et al.*, 2021 reported that the shallow and extensive root system promotes the plant to exploit scarce moisture in such environments. He further put it that in some countries, possessing this species is prohibited, and it is illegal to extract the active substance, mescaline. Further, unique to prickly pears are globular or columnar and sometimes segmented stems that bear specialized felted discs called areoles, which are the spines that develop (10).

Other succulent plants can be confused with prickly pear, such as the succulent *euphorbia*. What is distinct about *euphorbia* is that the spines appear in pairs, and their stems produce white latex, which is an irritant to the skin and eyes (11). According to Ramadan and Morsel (2003), prickly pear is a potential alternative crop for places with little to no moisture because it can withstand prolonged drought. The successful introduction of *Opuntia* in dry regions areas has been attributed to its Crassulacean Acid Metabolism (CAM). The CAM plants take up CO₂ primarily at night, leading to high water-use efficiency and high drought resistance, essential for arid regions with limited rainfall (12).

The prickly pears have been found to contain phytochemicals. According to Nyero *et al.*, 2023, phytochemicals, also called phytonutrients, are any bioactive chemical compounds found in plants as antioxidants, considered beneficial to human health (13). The medicinal potential of prickly pear among humans depends on its tissue composition, as the fruit contains Sterols, Tannins, Anthraquinones, Alkaloids and Saponins (14).

Prickly pear organs like fruits and stems are being used for different reasons to treat certain diseases. Prickly pear fruit containing betalain pigments has a good potential for use as a natural food colourant as it has been reported to contain red-violet betacyanins and yellow betaxanthins (15).

Flavonoids and phenolic acids are the primary polyphenols of prickly pear, and flavonoids are known for their antioxidant activity (16) since they can interact with lipids, proteins, and carbohydrates to inhibit their oxidation.

The world today is threatened by climate change. This has a significant impact on the agricultural sector and the overall well-being of the human race. Prolonged droughts and desertification are among the issues many countries face, especially in Africa and Asia, where the rural poor and smallholders are most heavily affected (17). Plants that can withstand harsh conditions like drought must be cultivated if people are to survive in these ever-harsher conditions. *Opuntia ficus-indica* can grow on land where no other crops can (18). Nevertheless, it can potentially restore degraded land, and, in many countries, such as Ethiopia, it is a crop grown in severely long dry seasons.

Mexico is reported to be the largest country producing and consuming cacti in the world (19). Other countries, including Morocco, Ethiopia, South Africa, Kenya, Tanzania, India and Pakistan, are increasing their production and use.

Water is the main limiting factor in semi-arid environments where the prickly pears grow. They have developed several adaptations to dry conditions, notably succulence, and it is from this point that in Uganda, we have cactus pears growing in Katwe, Kasese district owing to its low acidity soils; however, its origin in Uganda is not known.

Problem Statement

There is very scanty literature on the uses of *Opuntia ficus-indica* in Uganda. Agro-climatic conditions can influence medicinal plant species' chemical composition and therapeutic properties (20). This was among the few studies that evaluated the anti-bacterial activity of *Opuntia ficus-indica* organs in Kasese. On the other hand, there is an observed reduction in the coverage of the species in Uganda as it is threatened with extinction (21).

There is scanty literature about *Opuntia ficus-indica* in Uganda, with reported uses for fencing and single medicinal uses that relieve brain damage and slow mind. However, researchers working on the same plant in other countries have documented many traditional uses of the plant, including fodder for animals. Phytochemical analyses of the different parts of the plant species have been done, including their anti-bacterial activities (6, 22).

The study determined and documented the traditional uses of *Opuntia ficus-indica*. In addition, it determined the anti-bacterial activity of fruit and stem to confidently give scientific evidence for the continued use of the plant as medicine in Uganda. The threatened status of *Opuntia ficus-indica* led to calls for its conservation.

Significance of the Study

The study documented the traditional uses of *Opuntia ficus-indica*. These would form the basis for bio-prospecting plant organs for developing the pharmacological industry. Results from the determination of the anti-bacterial activity of the extracts of stem and fruit provided scientific evidence for the traditional uses of *Opuntia ficus-indica*. Finally, the study provided confidence in using the plant as medicine and fostered its conservation.

Objectives

General objective

To determine traditional uses and anti-bacterial activity of *Opuntia ficus-indica* extracts from stem and fruit.

Specific objective

To document the traditional uses of *Opuntia ficus-indica* by the people of Kasese district.

To determine the anti-bacterial activity of *Opuntia ficus-indica* extracts of stem and fruit.

Hypotheses

Null: There is no significant variation in the anti-bacterial activity of *Opuntia ficus-indica* extracts from the stem and fruit.

Alternative: There is a significant variation in the anti-bacterial activity of *Opuntia ficus-indica* extracts from the stem and fruit.

Methodology

Description of Study Area

Katwe-Kabatoro Town Council is an enclave in the Queen Elizabeth National Park and located in Busongora Country, southwestern Uganda-Kasese district, at an elevation of 911 m with a total perimeter of 163 Km and has a population of 6000 people (23) at latitude of -0.1377° or 0°8'16" south and longitude of 29.883° or 29° 52' 59" east (24). The area has a mean temperature of 30°C high– 10°C low.

Ethical consideration

Participants provided written informed consent to participate in the study following approval of the questionnaire by the ethics committee for the Department of Plant Sciences, Microbiology and Biotechnology.

Research Design

A cross-sectional and one-time data collection research design was used to collect data. The necessary data on traditional uses and a representative sample of *Opuntia ficus-indica* were collected while in the field. The representative sample was taken to the herbarium for identification and then to the laboratory. The sample was chopped into small pieces and then oven dried at 35°C. Finally, procedures for determination of the anti-bacterial activity followed.

Sampling procedure

A random sampling method was used to determine the respondents. This kind of sampling procedure does not call for the determination of the distance between the interviewees, and it was selected because the study site population was sparsely populated. The estimated area of the Kabatooro region, with a perimeter of 163 km, is approximately 2,114.3 square kilometres. Given a population of 6,000 people, the population density would be about 2.84 people per square kilometre. This is a low population density and, therefore, a low population. Individuals aged 18–35, 35–50 and > 50 were selected randomly based on the first identified willing respondent. Questionnaires were administered to them, and data was recorded.

Research Methods

Questionnaires were used as described by Seidman (2015). The number of people interviewed in the area was 60, and each received a questionnaire. The 60 questionnaires were collected from people aged 18–35, 35–50 and > 50. Data was collected for analysis.

Screening for anti-bacterial activity

Sample collection: the fresh stem and fruit of *Opuntia ficus-indica* were collected from Kabatooro town council. Each sample was stored in a plastic bag and then transported to the preparation laboratory at Makerere University.

Sample preparation: the collections were sorted to remove the thorns, cut into small pieces and oven-dried from the ethnobotany laboratory for three days at 35°C. This was followed by plant tissue homogenization; dried-fresh fruit and stem of *Opuntia ficus-indica* were ground in a blender to fine particles. About 2ml of ethanol was added, and the mixture was shaken vigorously for 5–10 min. After, the extract was filtered. The filtrate was dried under reduced pressure, and the residue was discarded. This was followed by soaking them in alcohol for three days in a dark room, filtering them, and discarding the residue. The filtrate was dried in the oven at room temperature for two days, and its weight was measured using a weighing scale.

Anti-bacterial analysis: Anti-bacterial activity for stem and fruit extracts was tested using the agar well diffusion method. About 0.1 ml of *Escherichia coli* bacterial culture obtained from the College of Veterinary Medicine, Animal Resources and Biosecurity, Makerere University, was aseptically inoculated by spreading it evenly into the surface of MacConkey agar plates. Three bores were made in the agar for each extract. Extracts were diluted with ethanol and 50% of each with water. For each extract solution, 2ml was filled in the bores, and the experiment was incubated at 37°C for 24 hours. The diameters of the zone of inhibition formed around the bores were measured and expressed in mm.

Data Analysis

Data from the anti-bacterial analysis was analysed using SPSS version 26.0, where the one-way ANOVA (Analysis of Variance) statistical test was performed to compare the mean data in terms of length obtained from the anti-bacterial activity of the extracts; stem and fruit of *Opuntia ficus-indica*. Statistical differences were deemed significant if the P value was less than 0.05 at a 95% confidence interval. On the other hand, data for traditional uses were cleaned and expressed as percentages using Excel.

Results

Demographic characteristics

From the 60 questionnaires, respondents were in the age ranges of 18–35, 35–50 and > 50. All the people knew at least a single traditional use of *Opuntia ficus indica*. From Fig. 1 below, the highest number of respondents was in the age range 35–50, followed by those aged 18–35 and those aged > 50.

Traditional Uses

Opuntia ficus indica is traditionally used as food; the plant's fruits are collected, peeled and taken when raw. As an anti-ulcer, the stem is collected, thorns are removed, and the cladode is sliced into medium sizes. Then, the soup is cooked, after which the soup is drunk as an anti-ulcer remedy. On the other hand, the fruit may be collected, prepared, and consumed raw, based on urgency, by the patient. For anti-constipation, the stem is cooked, and soup is consumed; however, the fruit is taken when raw. The plant stem is boiled for body cleansing, and the soup is consumed regularly. As an ornamental, almost all the households had *Opuntia ficus indica* in their compounds. Information about the number of respondents per use is presented in Fig. 2 below;

Anti-bacterial activity of stem and fruit extracts of *Opuntia ficus indica* against *E. coli* bacteria.

The diameter of inhibition zones for each well of the setup experiment for the stem and fruit extracts plus positive control experiment were measured, and their mean was estimated. Figure 3 below shows that *E. coli* was highly sensitive to the fruit extract, evident in the higher mean diameter of the zone of inhibition, 27mm.

Table 1
Treatments and mean diameter of zones of inhibition

Treatments	Diameter of zones of inhibition (mm)
Fruit	27.10 ± 0.17 ^b
Stem	21.23 ± 0.06 ^a
Positive control	28.00 ± 0.00 ^c

Discussion

Demographic characteristics

Individuals with an age range of greater than 50 years were found to be heavily distant from the area where *Opuntia* is common, and these were busy with other work. On the other hand, individuals in the age range of 35 to 50 years of age were found to know significantly the uses of *Opuntia ficus indica*. This is attributed to their most considerable percentage being involved in trade. This exposes them to several places, encompassing interactions and their knowledge of plant uses. Also, Kabatooro town council has the highest population under this age range, so their awareness about the traditional uses of *Opuntia ficus indica* was high.

Traditional uses

Food, anti-constipation, anti-ulcer, ornamental and body cleansing were the reported uses of *Opuntia ficus indica*. Its cladodes are used for the treatment of gastric ulcers (25). Pre-treatment tests in rats revealed a protective action against ethanol-induced ulcers. The mucilage may prevent penetration of the necrotizing agent into the gastric mucosa. The major components of *Opuntia ficus indica* stems consist of a mixture of mucilage and pectin (26). The pectin polysaccharides from *Opuntia ficus indica* stem affect gastrointestinal mucosa regeneration. Preventive treatment with *Opuntia ficus indica* stems can stop the ulcerogenic agent from preventing damage (25).

The plant is used as an ornamental because of its lovely, appealing flowers. On the other hand, the cladodes or fruits of *Opuntia ficus indica* are taken as food. This is because the fruit tastes like a watermelon, and it gives a nice colour before ripening, and when ripe, it also contains a higher nutritional fibre (27). The reason for consumption of the plant for ulcer treatment is that *Opuntia* contains bioactive compounds, such as phenols, flavonoids and fatty acids, polyphenols, vitamins and other specific compounds, and anti-inflammatory abilities (4). Nevertheless, the plant is used against constipation because of its richness in fibre content.

Anti-bacterial analysis

The anti-bacterial activity of fruit and stem extracts was quantitatively assessed by the diameter of inhibition zones, as shown in Fig. 3. Both fruit and stem extracts showed positive results from anti-

bacterial activity against *E. coli* bacteria. These results are in agreement with the results of Aruwa et al., 2019 (28). The fruit showed a higher anti-bacterial activity than the stem extracts. These results agree with Iftikhar et al., 2023 (16).

Opuntia ficus indica is known for its high content of polyphenols exhibiting antioxidant and anti-inflammatory properties (6). Interestingly, alkaloids, indicaxanthin, neobetanin, and various flavonoids have been isolated from the cactus, along with polysaccharides, which are abundant in cladode extracts and endowed with antidiabetic and anti-glycation effects (6).

The cactus cladodes contain vitamins, antioxidants and various flavonoids, particularly quercetin 3-methyl ether, a highly efficient radical scavenger (29). Cladodes of *Opuntia ficus-indica* extracts may lower cholesterol levels and convey anti-ulcer and anti-inflammatory mechanisms, and the water extract remarkably improves wound healing (6).

Cactus fruit contains substantial amounts of ascorbic acid, vitamin E, carotenoids, fibres, amino acids and antioxidant compounds (phenols, flavonoids, betaxanthin and betacyanin), which have been put forward to account for its health benefits such as hypoglycemic and hypolipidemic action, and antioxidant properties (6). Several reports have documented cacti's abundance of vitamins and minerals (30). In this respect, the fruit of *O. ficus indica* is a valuable source of nutrients and anti-ulcerogenic, antioxidant, anticancer, and anti-proliferative compounds (6, 22, 31).

Conclusions

Opuntia ficus indica is an advantageous plant, and conservation is needed. Fruits from *Opuntia ficus indica* are an effective source of anti-biotics compared to the stem, and both of these extracts are worth exploring for potential anti-bacterial activity against other infectious bacteria to relieve the ever-growing anti-microbial resistance (AMR) burden.

Recommendations

We recommend that similar research is done using fruit extracts of *Opuntia ficus indica* collected from other places and evaluate their anti-bacterial activity against several common infectious bacteria to further determine their capacity to contribute to the growing threat of anti-microbial and drug resistance. We also recommend screening these collected samples for their phytochemical composition to identify the elements contributing to their anti-microbial activity.

Declarations

Data availability

The corresponding author will make raw data that guided these conclusions available upon request.

Conflict of interest

The authors declared no conflict of interest.

Funding

This study was self-funded.

Author contribution

DS collected the samples and field data, performed laboratory experiments, analyzed data, and drafted the pre-print. AG supervised this work and reviewed the pre-print while EKK offered direction for this work.

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Figures

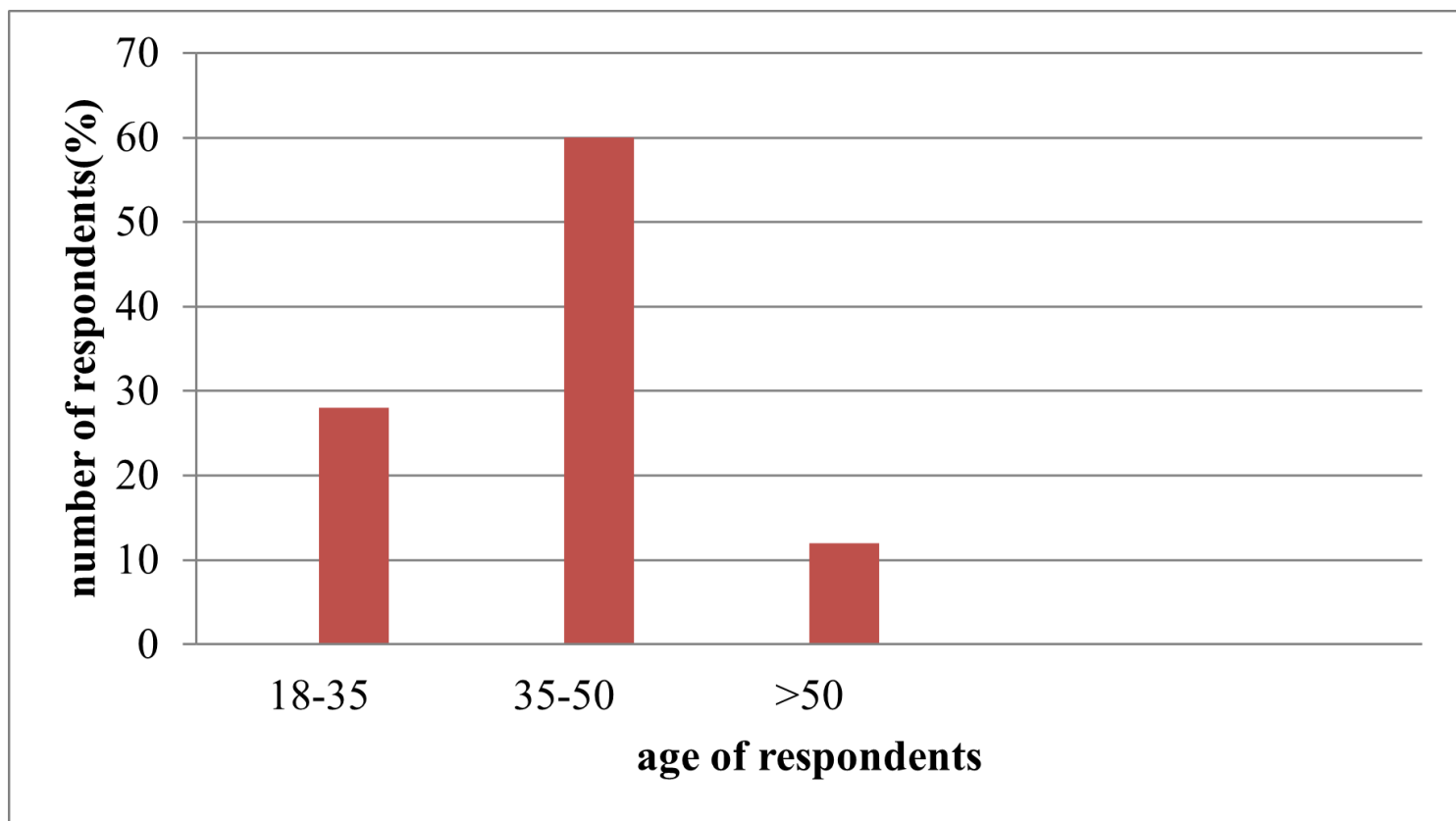


Figure 1

Percentages of traditional usage of *Opuntia ficus indica* versus age of respondents. *The number of respondents was expressed as percentages, and their age was expressed in years.*

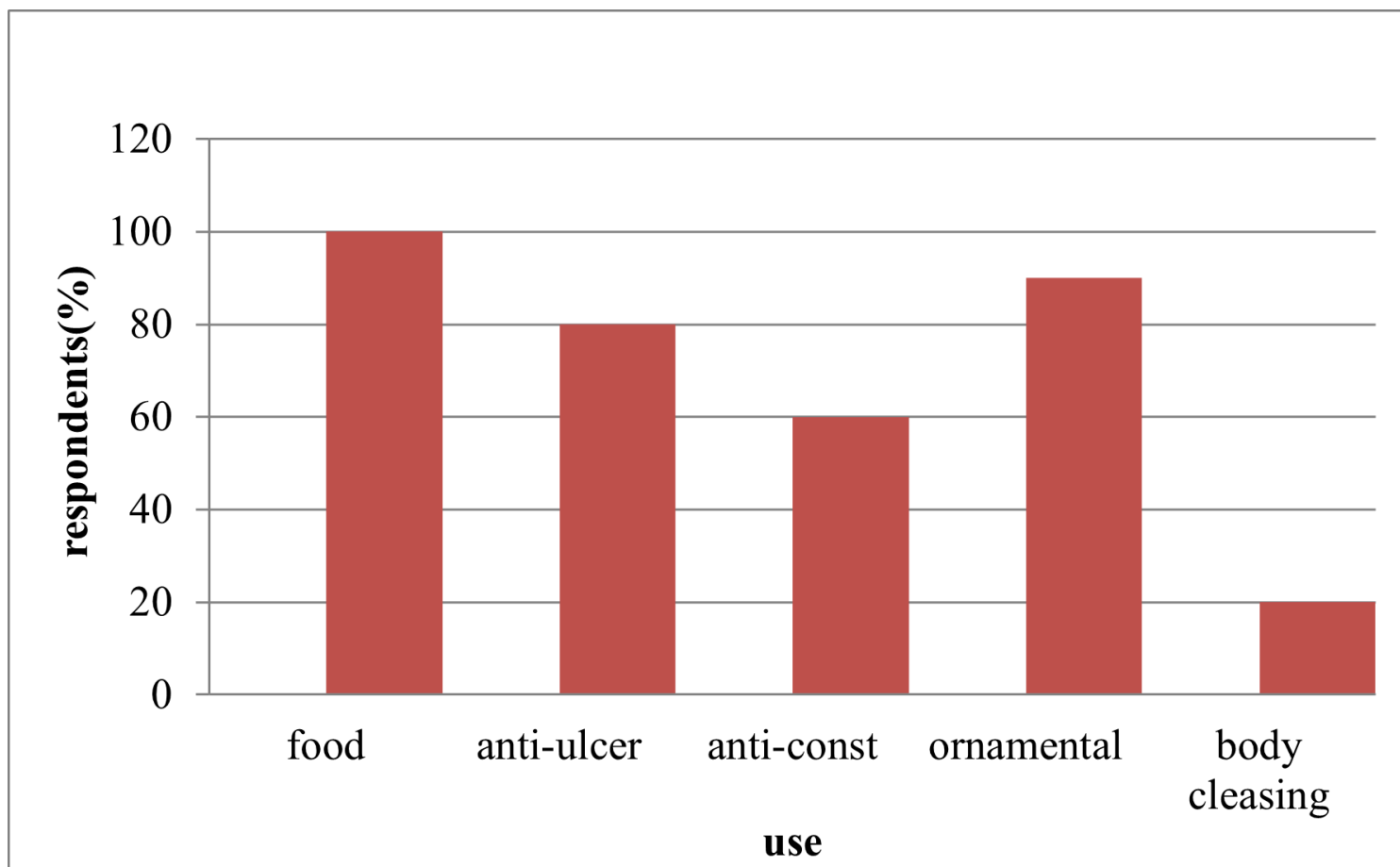


Figure 2

Percentages of respondents versus usage of *Opuntia ficus indica*.

The uses of *Opuntia-ficus indica* were listed by the respondents, who were expressed as percentages. Anti-const means anti-constipation.

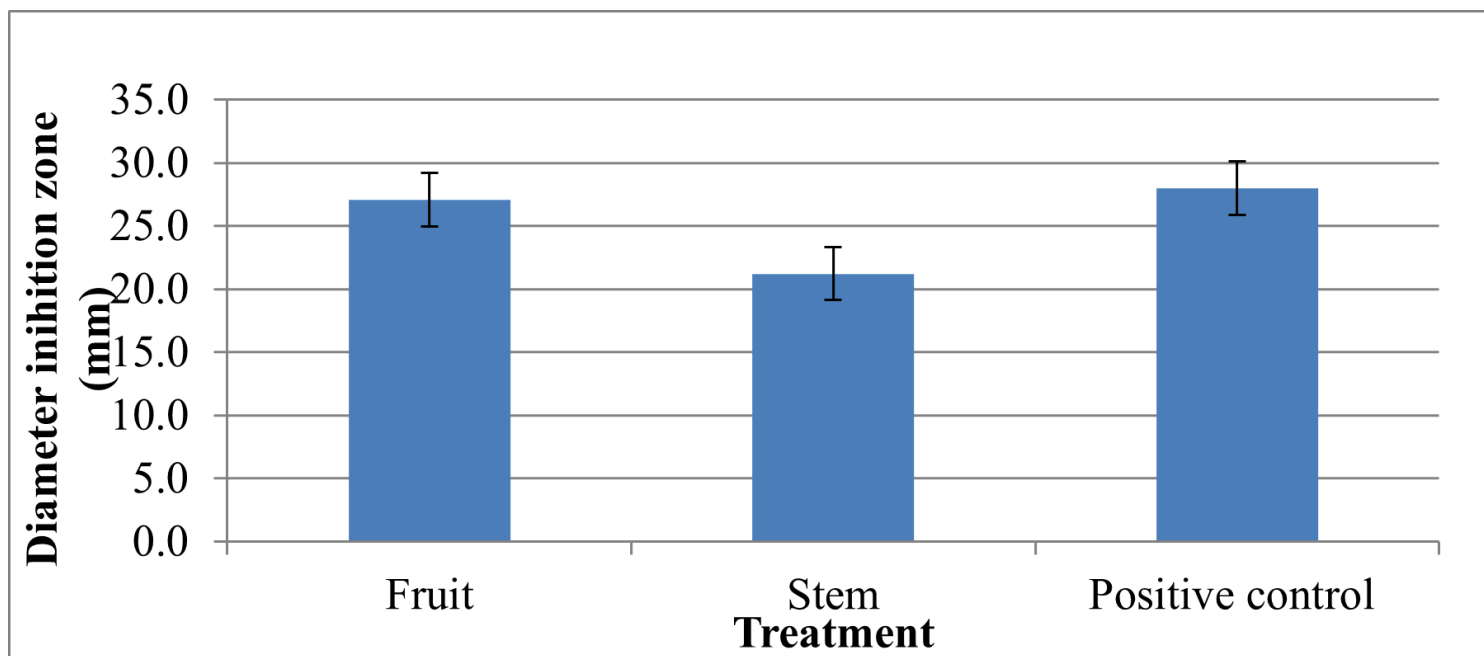


Figure 3

Diameter of zones of inhibition and treatment

*The difference in length of the positive test and that of the fruit extract is not statistically significant (**Table 1**). *E. coli* was moderately sensitive to the stem extract, evident in the moderate mean diameter of zones of inhibition, 21mm. On the other hand, the difference in length of the positive test and that of the stem extract is statistically significant (28-21) mm.*