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Comparative Study on the Antimicrobial Activity in Various Solvent Extracts of *Garcinia gummi-gutta* (L.) Roxb and *Solanum betaceum* Cav. Fruits Against Major Fish Pathogens

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Abstract: The present study aimed to evaluate the antimicrobial activity of the extracts from the fruits of *Garcinia gummi-gutta* and *Solanum betaceum* using the standard Agar well diffusion method. Three concentrations (25, 50,and 75 µl/ml) of various extracts such as aqueous, ethanol, petroleum ether, and chloroform were tested against six fish pathogens such as *Aeromonas hydrophila, Vibrio cholerae, Streptococcus agalactia, Streptococcus iniae Pseudomonas aeruginosa,* and *Klebsiella pneumoniae*. Amoxiclav 10 mcg was used as the positive control (Disc). Three major fungal species *Aspergillus niger, Aspergillus flavus*, and *Candida albicans* were used to determine the fruit extracts' antifungal activity at three different concentrations (25, 50, 100 µl/ml). Amphotericin B (100 units) was used as a positive control. Both plant extracts showed dose-dependent antimicrobial activity against the tested pathogens. The crude ethanol and petroleum ether extracts of *G. gummi-gutta* and *S. betaceum* displayed more potential against all strains at higher concentrations. However, *G. gummi-gutta* showed better efficacy against microbes when compared to *S. betaceum*. The findings of present study will be valuable for future identification, quality control, and pharmacological studies of natural chemicals derived from these plants especially in aquaculture.

Keywords: Medicinal plants, Anti-microbial activity, Dose-dependent, Zone of inhibition, Therapeutic effects, Aquaculture

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Introduction

Aquaculture is the world's fastest-growing food sector, and it aids in food security. Farmed fishes are vulnerable to a variety of illnesses as a result of the rapid emergence of various pathogenic microbes, weakening the aquaculture industry. The research on antimicrobial constituents should be sustained, and all possible approaches and techniques should be investigated for the prevention and control of various diseases caused by microbes. Medicinal plants seem to be a suitable alternative for this purpose.

Since prehistoric times, medicinal plants have been identified and used in traditional medicine. Plants produce a variety of chemical substances to

protect themselves from fungus, insects, and mammals. A variety of phytoconstituents have been closely associated with biological activity (Thenmozhi *et al.,* 2021)

Infectious disease remains the leading cause of morbidity and mortality around the world. The emergence of multidrug-resistant microbial strains, as well as strains with lower antibiotic susceptibility, are on the rise. The situation fuelled the search for new antimicrobial substances from a variety of sources, including medicinal plants (Selvamohan *et al.,* 2012).

Since modern treatment is limited and costly, a huge part of the world's population relies on traditional medicine. Medicinal plants have contributed various plant-derived medicines to modern medicine. Various plants contain phytopharmaceuticals, which also have found significant applications in agriculture, clinical and veterinary medicine. Herbal compounds have a key role in the evolution of new drugs necessary for the prevention and treatment of diseases (Sandosh *et al.,* 2013).

Plant phytochemicals having antimicrobial properties are employed in the formulation of novel antimicrobial drugs (Nascimento *et al.,* 2000). Considering the hazardous side effects of modern synthetic drugs, the search for alternative medicine for the treatment with potential anti-inflammatory, antibacterial, and other properties has gained importance (Akharayi *et al.,* 2012).

For the treatment of fungal diseases in plants, animals, and humans, only a few effective antifungal drugs are available. As a result, it is critical to create new sources of antifungal drugs. Due to the alarming rise in the incidence of new and re-emerging infectious diseases, as well as resistance to currently used drugs, more antifungal compounds with diverse chemical structures and novel mechanisms of action are needed (Mahlo *et al.,* 2016).

Garcinia gummi-gutta, an ethnomedicinal plant, has traditionally been used to cure respiratory problems such as sore throats, coughs, and colds (Oluyemi *et al.,* 2007). *Garcinia gummi-gutta* extract was revealed to have anti-inflammatory activity, which could lead to the discovery of new anti-inflammatory compounds useful in the treatment of inflammatory bowel disease (Dos Reis *et al.,* 2009).

Tamarillo (*Solanum betaceum* Cav.) fruit has been shown to have potential health benefits such as anti-oxidant, anti-obesity, anticancer, and prebiotic properties (Diep *et al.* 2020a, b). Tamarillo contains phenolics and anthocyanins that have high antioxidant activity.

Given these plants' importance, identifying the bioactive compounds responsible for their pharmacological activity is critical. The purpose of this research was to assess theanti-microbial effect of various solvent extracts of *Garcinia gummi-gutta* and *Solanum betaceum* fruits against major bacterial and fungal fish pathogens.

Materials and Methods

Sample collection and Preparation of the extract:

The fruits of *Garcinia gummi-gutta* were collected from Thrissur district, Kerala, India and the fruits tree of *Solanum betaceum* was collected from Nilgiris district, Tamil Nadu, India. The collected fruits were identified at the Botanical Survey of India, Southern Region Centre, Tamil Nadu Agricultural University campus (TNAU), Lawley Road, Coimbatore, India.The voucher specimen was kept in our lab for future reference.

Fresh and tender fruits of the selected plants were collected and washed well with distilled water. The fruits were then cut into small pieces and dried under shade at room temperature for about two weeks. 50 g of ground sample of *Garcinia gummi-gutta* and *Solanum betaceum* were extracted by Soxhlet apparatus using 200 ml of each -- ethanol, petroleum ether, chloroform, and distilled water. The sample was then filtered to obtain the extract.

Collection of bacterial culture:

Six major fish pathogen cultures such as Gram-negative-- *Pseudomonas aeruginosa, Aeromonas*

hydrophila, Vibrio cholerae, Klebsiella pneumoniae, and Gram-positive-- *Streptococcus agalactiae, Streptococcus iniae* were obtained from the Microbiology Laboratory at CMFRI, Cochin, India.

Antibacterial activity:

Antibacterial activity of the sample was done by using the standard agar well diffusion method. For the antibacterial activity nutrient agar was prepared by dissolving 28 g in 1000 ml of distilled water and sterilized under autoclave at 121 C for 15 min, the media were poured into a sterilized Petri plate and allowed for solidification. After solidification 70 µl of the bacterial suspension of *Pseudomonas aeruginosa, Aeromonas hydrophila, Vibrio cholerae, Streptococcus agalactiae, Streptococcus iniae,* and *Klebsiella pneumonia* were swabbed. Cork borer was used to make a well, and in each well sample was poured (25, 50, 75 µl), amoxiclav (10mcg) was used as a positive control (disc). After placing the samples, plates were incubated at 37 C for 24 h, and the zone of inhibition was measured in mm (Johney *et al.,* 2017)

Collection of fungal culture:

Three major fungal cultures such as *Aspergillus niger, Aspergillus flavus,* and *Candida albicans* were obtained from the TRI-Biotech Laboratory, Trichy, India.

Antifungal activity:

Antifungal activity of the sample was done by using the standard agar well diffusion method. For the antifungal activity, the potato dextrose agar medium was prepared by dissolving 40 g of potato infusion, 4 g of dextrose, and 3.5 g of agar in 200 ml of distilled water. The dissolved medium was autoclaved at 15 lbs pressure at 121 C for 15 min. The autoclaved medium was mixed well and poured onto 100 mm Petri plates (25-30 ml/plate) while still molten. Petri plates containing 20 ml potato dextrose agar medium was seeded with 72 h culture of fungal strain, wells were cut and different concentration of samples (25, 50, and 100 µl) were added. The plates were then incubated at 37 C for 48-72 h. The anti-fungal activity was assayed by measuring the diameter of the inhibition zone formed around the wells. Amphotericin B (100 units) was used as a positive control (disc).

Results

Antibacterial study:

The antibacterial activity of aqueous, ethanol, petroleum ether, and chloroform extract of *G. gummi-gutta* at 25, 50, and 75 µl concentrations were assayed *in vitro* by agar well diffusion method against 6 fish pathogens. The significant antibacterial activity of the active plant extracts was compared to amoxiclav (10 mcg). Antibacterial activities of all the four extracts of *Garcinia gummi-gutta* fruits have been evaluated by measuring the diameters of zones of inhibition on bacterial strain and the results are presented in Table 1.

G. gummi-gutta extracts showed dose-dependent antibacterial activity against the tested pathogens. The crude ethanol extracts displayed more potential against *S. iniae* (32±0.17), *S. agalactiae* (22.5±0.25), *A. hydrophila* (24±0.20), *and P. aeruginosa* (25±0.4). Whereas petroleum ether extract showed a maximum zone of inhibition against *V. cholerae* (21±0.26) and *K. pneumonia* (25±0.4) at 75 µl concentration as shown in Figure 1. All other extracts showed comparatively less activity than ethanol and petroleum ether extracts in the decreasing order -- ethanol > petroleum ether > aqueous > chloroform. However, their maximum zone of inhibition was higher than Disc (Amoxiclav 10 mcg).

The antibacterial report of the medicinal fruit *S. betaceum* fractionation extracts is summarized in Table 2 and Figure 2. *S. betaceum* also exhibited dose-dependent potential against microbial strains. The petroleum ether extracts presented more antibacterial activity against *Streptococcus agalactiae* (30±0.22), *Aeromonas hydrophila* (24±0.20), *Klebsiella pneumonia* (24±0.17), and *Pseudomonas eruginosa* (28±0.15) at the same concentration. While ethanol extracts

Table 1: Zone of inhibition (mm in diameter) against different bacterial strains by *Garcinia gummi-gutta* fruit extracts

Extract	Conc. (µl)	Bacterial Strains Used					
		Gram-positive		Gram-negative			
		Si	***Sa***	***Ah***	***Vc***	***Kp***	***Pa***
Aqueous	**25 µl**	12±0.12**	12.5±0.03**	16.5±0.26**	13±0.21**	8.5±0.26**	8±0.25**
	50 µl	15±0.15**	15±0.25**	22±0.30**	17±0.35**	14±0.25**	12±0.2**
	75 µl	22±0.25**	22±0.30**	25±0.46**	20.5±0.26**	20±0.1**	21.5±0.3**
	Disc	10±0.28**	10±0.25**	12±0.30**	11±0.26**	9±0.3**	14±0.25**
Ethanol	**25 µl**	20±0.23**	14.5±0.20**	16±0.15**	12±0.3**	8.5±0.25**	20±0.25**
	50 µl	26±0.37**	18±0.4**	21.5±0.15**	14.5±0.23**	6±0.15**	22±0.6**
	75 µl	32±0.17**	22.5±0.25**	24±0.20**	20±0.20**	22.5±0.26**	25±0.4**
	Disc	12±0.26**	11.5±0.20**	14±0.25**	11.5±0.15**	12.5±0.4**	10±0.26**
Petroleum ether	**25 µl**	14±0.20**	10±0.26**	12.5±0.26**	10±0.28**	16±0.25**	10±0.20**
	50 µl	20±0.23**	14±0.23**	15±0.15**	13.5±0.2**	20±0.23**	16±0.1**
	75 µl	23.5±0.5**	21.5±0.28**	23±0.1**	21±0.26**	25±0.15**	24±0.4**
	Disc	12±0.26**	11±0.17**	14±0.23**	10.5±0.11**	13.5±0.1**	14±0.3**
Chloroform	**25 µl**	18±0.11**	13.5±0.32**	10.5±0.25**	8.5±0.25**	6±0.25**	8±0.17**
	50 µl	24±0.32**	18±0.20**	13±0.11**	12±0.16**	15±0.20**	10±0.2**
	75 µl	27±0.2**	21.5±0.26**	19.5±0.2**	18±0.21**	21.5±0.17**	12.5±0.4**
	Disc	12±0.17**	10±0.20**	6.5±0.25**	10.5±0.23**	11±0.25**	9±0.3**

Si- Streptococcus iniae, Sa- Streptococcus agalactiae, Ah- Aeromonas hydrophila, Vc- Vibrio cholerae, Kp- Klebsiella pneumonia, Pa- Pseudomonas aeruginosa, Disc-amoxiclav, Values are Mean ± standard error; ** indicates significance at P<0.01

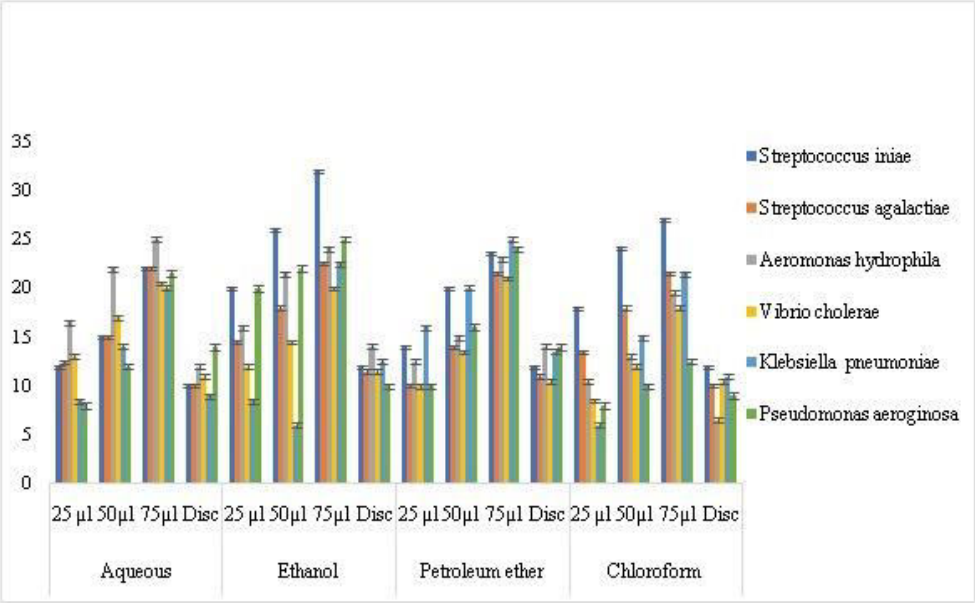

Fig. 1: Zone of inhibition (mm in diameter) against different bacterial strains by *Garcinia gummi-gutta fruit extracts.*

Table 2: Zone of inhibition (mm in diameter) against different bacterial strains by *Solanum betaceum* fruit extracts

Extracts	Conc. (µl)	Bacterial Strains Used					
		Gram-Positive		Gram-Negative			
		Si	***Sa***	***Ah***	***Vc***	***Kp***	***Pa***
Aqueous	**25 µl**	10±0.26**	10±0.05**	8±0.34**	7±0.2**	8±0.21**	11±0.3**
	50 µl	12.5±0.21**	14±0.38**	15±0.31**	13.5±0.26**	11±0.28**	12.5±0.2**
	100 µl	20±0.26**	20±0.17**	21.5±0.20**	20±0.21**	18±0.15**	13±0.26**
	Disc	10±0.17**	11±0.2**	4±0.32**	5±0.3**	6±0.3**	7±0.21**
Ethanol	**25 µl**	10±0.32**	14±0.36**	14±0.36**	11.5±0.25**	10±0.4**	14±0.42**
	50 µl	12.5±0.23**	16.5±0.23**	18±0.25**	16±0.17**	13.5±0.20**	18±0.21**
	100 µl	26±0.38**	25±0.55**	22±0.23**	20.5±0.51**	21±0.2**	21.5±0.45**
	Disc	15±0.20**	12±0.23**	7±0.44**	10±0.23**	8.5±0.26**	11±0.25**
Petroleum ether	**25 µl**	8.5±0.26**	22±0.18**	14±0.21**	9.5±0.1**	11.5±0.15**	16±0.3**
	50 µl	15±0.2**	26±0.11**	17.5±0.45**	12±0.20**	16±0.21**	20±0.15**
	100 µl	19±0.32**	30±0.22**	24±0.20**	18±0.25**	24±0.17**	28±0.15**
	Disc	17±0.46**	18±0.12**	12±0.25**	8±0.21**	10±0.3**	8.5±0.17**
Chloroform	**25 µl**	15±0.25**	16±0.15**	7±0.15**	6.5±0.11**	8±0.20**	9.5±0.26**
	50 µl	18±0.15**	20±0.7**	12.5±0.26**	10±0.2**	13.5±0.31**	11±0.15**
	100 µl	25±0.4**	23.5±0.21**	16±0.40**	15±0.21**	15±0.15**	18±0.2**
	Disc	8±0.25**	14±0.26**	6±0.26**	8±0.06**	7±0.1**	13±0.1**

Si- Streptococcus iniae, Sa- Streptococcus agalactiae, Ah- Aeromonas hydrophila, Vc- Vibrio cholerae, Kp- Klebsiella pneumonia, Pa- Pseudomonas aeruginosa, Disc-amoxiclay, Values are Mean ± standard error; **-indicates significance at P<0.01

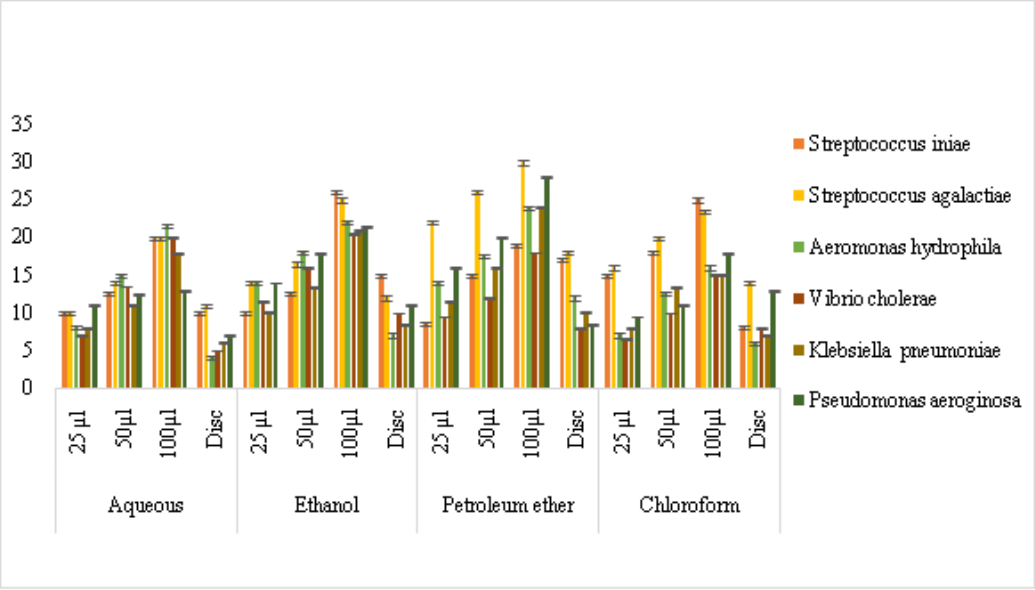

Fig. 2: Zone of inhibition (mm in diameter) against different bacterial strains by *Solanum betaceum* fruit extracts.

Table 3: Zone of inhibition (mm in diameter) against different fungal strains by *Garcinia gummi-gutta* fruit extracts

Fungal strains used	Extracts	Concentration (µl)			
		25 µl	50 µl	100 µl	Disc
Aspergillus flavus	**A**	7.5±0.12**	9.5±0.23**	14.5±0.12**	20±0.25**
	E	11±0.21**	13±0.2**	15.5±0.1**	17.5±0.07**
	P. E	10.5±0.18**	12.5±0.09**	13.5±0.08**	18±0.18**
	C	10.5±0.15**	12.5±0.17**	13.5±0.19**	18.5±0.12**
Aspergillus niger	**A**	7.5±0.40**	9±0.15**	13±0.20**	16.5±0.05**
	E	9±0.20**	11.5±0.06**	15±0.15**	15.7±0.29**
	P. E	9.5±0.06**	10.5±0.12**	14.5±0.14**	14±0.07**
	C	9±0.14**	11±0.24**	12.5±0.08**	14±0.14**
Candida albicans	**A**	6.5±0.14**	12±0.26**	12.5±0.17**	11.5±0.20**
	E	8±0.15**	11±0.13**	13.5±0.08**	11.5 ±0.14**
	P.E	7.5±0.17**	10±0.13**	12±0.19**	11= 0.21**
	C	7.5±0.18**	10=0.21**	12=0.23**	11.5±0.2**

A – Aqueous, E- Ethanol, P.E – Petroleum ether, C- Chloroform, Values are Mean ± standard error; ** indicates significant at P<0.01

demonstrated a greater zone of inhibition against *Streptococcus iniae* (26±0.38). All other extracts showed relatively lower activity than petroleum ether and ethanol extracts in the decreasing order -- petroleum ether > ethanol > aqueous > chloroform. However, their maximum zone of inhibition was greater than the positive control (disc).

Antifungal study:

The antifungal assay result of *Garcinia gummi-gutta* fruits is illustrated in Table 3. The ethanol extract of *Garcinia gummi-gutta* strongly inhibited the fungus *Aspergillus flavus* (15.5±0.1), *Aspergillus niger* (15±0.15), and *Candida albicans* (13.5±0.08) at 100 µl concentration. The maximum inhibition was shown by ethanol extract followed by petroleum ether extract, aqueous, and chloroform extract (Fig. 3). All the extracts displayed comparatively lower activity than the disc (Amphotericin B 100 units). However, there were no substantial variances between them.

The antifungal activity of *Solanum betaceum* fruits extracts is shown in Table 4 and Figure 4. The petroleum ether extract showed a maximum zone of inhibition against *Aspergillus niger* (14±0.15) and *Candida albicans* (13±0.34) at 100 µl concentration. On the other hand, ethanol extract showed a greater inhibition against *Aspergillus flavus* (13.5±0.06). Petroleum ether exhibited potential activity followed by ethanol, aqueous, and chloroform extracts. All the extracts showed less activity when compared to the positive control (disc). Nevertheless, there were no significant differences between them.

Discussion

Antibiotic resistance is a dilemma that tends to affect the healthcare system in both developing and developed countries around the world. The increasing prevalence of multidrug-resistant pathogens has significantly jeopardized current antimicrobial therapy. This has entailed the search for new antimicrobial sources, such as plants,

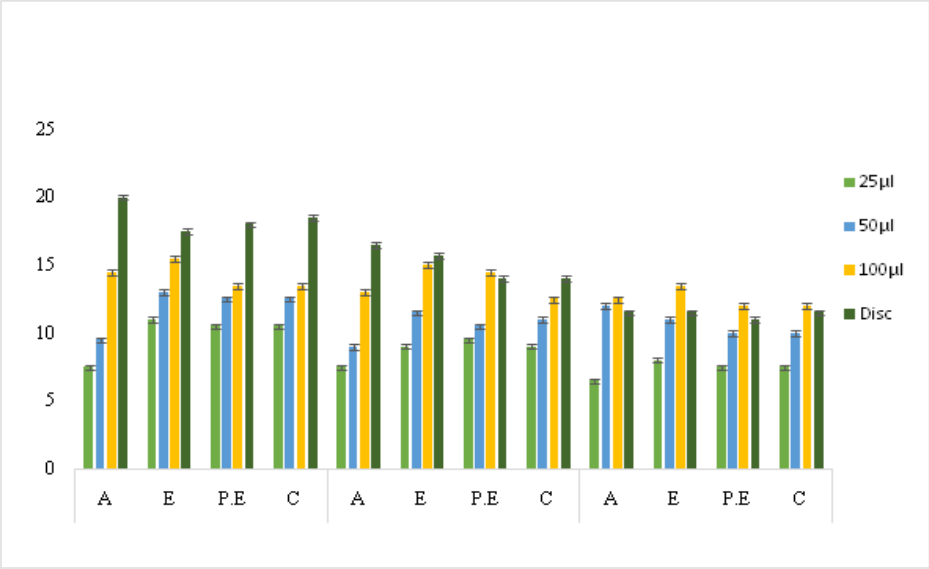

Fig. 3: Zone of inhibition (mm in diameter) against different fungal strains by *Garcinia gummi-gutta* fruit extracts.

Table 4: Zone of inhibition (mm in diameter) against different fungal strains by *Solanum betaceum* fruit extracts

Fungal strains used	**Extracts**	**Concentration (µl)**			
		25 µl	**50 µl**	**100 µl**	**Disc**
Aspergillus flavus	**A**	6±0.15**	8.5±0.17**	10.5=0.11**	13.5±0.09**
	E	8±0.21**	10±0.12**	13.5±0.06**	14=0.13**
	P.E	8.5±0.06**	10.5±0.11**	12±0.46**	11±0.32**
	C	8.5±0.11**	13±0.13**	10.5±0.19**	13.5±0.35**
Aspergillus niger	**A**	6±0.14**	7.5±0.07**	10.5±0.12**	11.5±0.03**
	E	8.5±0.09**	10±0.12**	12.5±0.08**	13.5±0.05**
	P.E	6.5±0.05**	10.5±0.08**	14±0.15**	13±0.21**
	C	7±0.23**	8.5±0.08**	12±0.48**	13.5±0.12**
Candida albicans	**A**	5.5±0.02**	8.5±0.07**	12±0.25**	13±0.26**
	E	7.5±0.05**	9±0.18**	12.5±0.09**	12±0.2**
	P.E	7±0.13**	9.5±0.12**	13 ±0.34**	11.5±0.25**
	C	6±0.12**	8±0.21**	12±0.21**	13±0.42**

A – Aqueous, E- Ethanol, P.E – Petroleum ether, C- Chloroform, Values are Mean ± standard error; ** indicates significant at P<0.01

which contain a wide range of bioactive components with established medicinal benefits (Manandhar *et al.,* 2019).

Garcinia gummi-gutta L. provides a good source of bioactive compounds, making it a promising source of herbal medicine. Antioxidant, antiobesity, antihelminthic, antidiabetic, anti-microbial, and hyperlipidaemic properties are some of their health benefits.

The present study aimed at elucidating the antibacterial and antifungal activity of fruit extracts of *G. gummi-gutta* and *S. betaceum* against six bacterial species majorly affecting fishes viz, *Pseudomonas aeruginosa, Aeromonas hydrophila*

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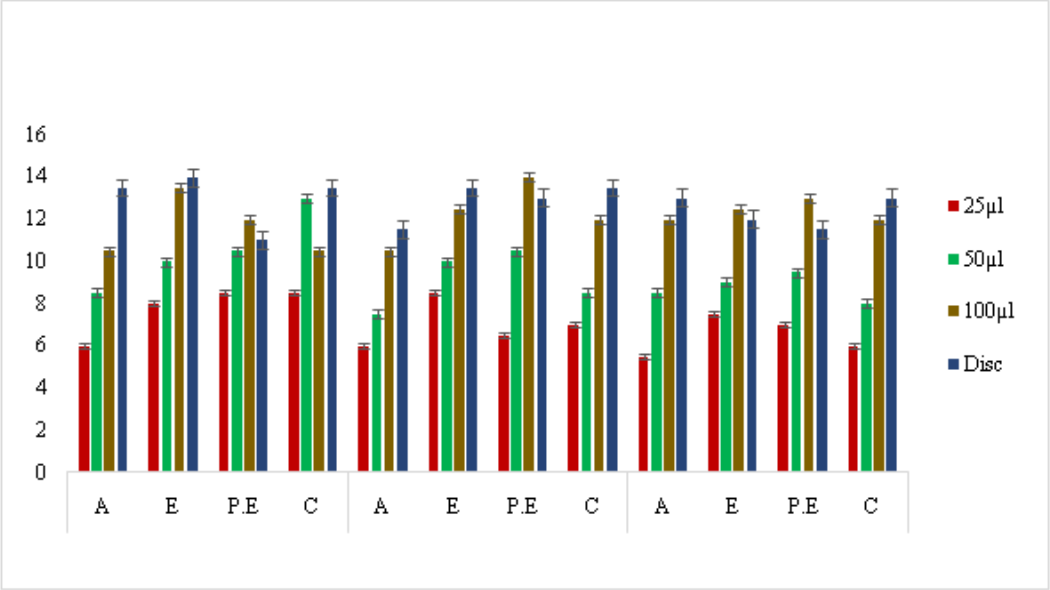

Fig. 4: Zone of inhibition (mm in diameter) against different fungal strains by *Solanum betaceum* fruit extracts.

Vibrio cholerae, Streptococcus agalactiae, Streptococcus iniae, and *Klebsiella pneumonia* and two fungal species viz. *Aspergillus niger, Aspergillus flavus* and *Candida albicans*. The extracts inhibited the growth of all the test bacteria with wider zones of growth inhibition when compared to the control (Tables 1, 2).

The results are comparable to those of Varghese *et al.* (2016) who have investigated the antibacterial and antifungal activity of *G. gummi-gutta* leaf extracts against eight bacterial strains and two fungal species. All the test bacteria were inhibited by the extracts, with larger zones of inhibition. Kumar *et al.* (2021) confirmed that the fruit rind aqueous extract of *G. gummi-gutta* possessed better antimicrobial activity against the selective bacterial cultures. Al-Askalany (2018) also concluded that aqueous *G. gummi-gutta* extracts were a good antibacterial and antifungal activity. According to Naveen and Krishna Kumar (2013), Philip Jacob *et al.* (2015) and Jayasudha *et al.* (2016), *G. gummi-gutta* possesses numerous antimicrobial properties. The antimicrobial activity of *G. gummi-gutta* fruit rind aqueous extract on test microorganisms could be due to the nature of the antimicrobial matters present in the extracts and their mode of mechanisms (Shan *et al.,* 2007).

Tamarillo is high in vitamins, bioactive components (phenolics and anthocyanins), and amino acids like aspartic acid, glutamic acid, and GABA (Diep *et al.,* 2020a). *S. betaceum* fruit extracts are known for their antimicrobial efficacy (Gonçalves *et al.,* 2021). At a concentration of 100 mg. ml^{-1}, the methanol extract of tamarillo peel inhibited *E. coli* better than the methanol extract of feijoa peel, with an inhibition zone of 14.7 mm (Phan *et al.,* 2019). Tamarillo extracts (invertase inhibitory protein) have been shown to inhibit the growth of xylophagous and phytopathogenic fungi and phytopathogenic bacteria (Ordonez *et al.,* 2006). According to Diep *et al.* (2021), water and methanol extracts from the peel and pulp of *S. betaceum* fruits were more effective against Gram-negative bacteria than Gram-positive bacteria. One reason for these phytochemicals' bactericidal activity could be membrane permeability, which allows intracellular materials to leak out and cause cell death (Karsha and Lakshmi, 2010). These results are similar to the antibacterial results of *S. betaceum* in the present study.

There were not many antifungal studies conducted for *G. gummi-gutta* and *S. betaceum*. However, the fruit extracts of both plants exhibited significant activity against all three fungal species viz., *Aspergillus flavus, Aspergillus niger,* and *Candida albicans*. Other investigators have also reported on the variable antifungal activity of plant extracts. The flower of *Acacia auriculiformis* was analyzed against *Aspergillus niger* and *Candida tropicallis* and its antifungal activity was confirmed at 1000 ppm concentration (Samling *et al.,* 2018). Kim *et al.* (2004) testified that 33 (18%) out of 183 plant species displayed strong *in vivo* antifungal properties against at least one of six plant pathogenic fungi. Earlier studies have revealed that the antimicrobial effect of medicinal plants might be due to the presence and synergistic action of diverse bioactive compounds (Manilal and Idhayadhulla, 2014).

Conclusion

The current study examined the antibacterial and antifungal activity of fruit extracts of *G. gummi-gutta* and *S. betaceum*. The extracts prevented the growth of all the tested bacterial strains with wider growth inhibition zones, in the decreasing order -- ethanol, petroleum ether, aqueous, and chloroform. In *G. gummi-gutta* the ethanol extract was superior in inhibiting the growth of test bacteria with wider zones of growth inhibition whereas, in *S. betaceum* petroleum ether extract was superior. The aqueous extract exhibited only minimal growth inhibition when compared to other extracts. In the antifungal study, the aqueous extract exhibited minimal antifungal activity against *Aspergillus flavus, Aspergillus niger,* and *Candida albicans*when compared to positive control. However, there were no significant differences between them. It is evident from the results of the present study that the fruits of *Garcinia gummi-gutta* and *Solanum betaceum* have immense potential as an ethnomedicinal plants, rich in bioactive compounds, and have significant levels of antibacterial and antifungal activity. Since the fruits showed potential anti-microbial activities against fish pathogens, these plants have scope for future identification, quality control, and pharmacological studies of natural chemicals derived from these plants. It may also help in developing antimicrobial drugs in the treatment of fish diseases. Further research on various pathogenic bacteria and fungi is recommended. More research is necessary to confirm the percentage of toxicity, mechanism of action, and dose-dependent activity against diverse species of bacteria and fungi.

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