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Comparative evaluation of the antifungal activity of cranberry (Vaccinium macrocarpon) extract, cinnamon (Cinnamomum zeylanicum) extract and xylitol against *Candida albicans*: An in vitro study

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Abstract

Background: *Candida albicans* is an opportunistic fungal microorganism which is commonly linked with oral candidiasis. Cranberry (Vaccinum macrocarpon) and cinnamon (Cinnamomum zeylanicum) have been investigated as antifungal agents because of the growing interest in natural and oral-health-compatible agents, and xylitol for its ability to inhibit the growth of oral bacteria. But, comparative data, under standard conditions, of their activity against *C. albicans* is limited.
Aim: To comparatively test the antifungal activities of cranberry extract, cinnamon extract and xylitol against *C. albicans* in in-vitro conditions.
Materials and Methods: An in-vitro experimental study was made using the test microorganism *C. albicans*. Twenty-five observations in each of four groups were evaluated and allocated for total of 100 experimental observations; the four groups were as follows: cranberry extract, cinnamon extract, xylitol, and control. The antifungal properties were evaluated by an agar well diffusion method and the zone of inhibition (ZOI) was measured in millimeters after the incubation period. The mean and standard deviation (SD) were computed. One-way analysis of variance (ANOVA) followed by Tukey's post-hoc test was used to analyze intergroup differences, where *p* < 0.05 was considered statistically significant.
Results: Cinnamon extract demonstrated the greatest antifungal activity, with a mean ZOI of **18.36 ± 1.51 mm**, followed by cranberry extract (**12.48 ± 1.32 mm**) and xylitol (**8.72 ± 1.08 mm**). The "control" group showed no inhibition. The difference among the groups was statistically significant (*p* < 0.001).
Conclusion: In-vitro antifungal activity was the highest for cinnamon extract followed by cranberry extract and xylitol extract in the treatment of *C. albicans*. They should be investigated further to assess their clinical effectiveness and safety.

Keywords: *Candida albicans*, Cranberry, Vaccinium macrocarpon, Cinnamon, Cinnamomum zeylanicum. Xylitol, Antifungal activity, Oral candidiasis, In-vitro study, Zone of inhibition.

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1. Introduction

Candida albicans is a polymorphic opportunistic yeast, which is a part of the resident microbiota of the oral cavity. *C. albicans* can change its lifestyle from commensal to opportunistic pathogen to trigger oral candidiasis under favorable conditions, such as alterations in the oral microbial environment, immunosuppression, prolonged antibiotic use, xerostomia, diabetes mellitus and removable dental prostheses.[1] The clinical signs include localized mucosal erythema, pseudomembranous lesions, denture associated candidiasis and chronic mucosal infections.[2] *C. albicans* is a pathogen that is capable of adhering to oral surfaces, forming biofilms, yeast-to-hyphal transition and resisting environmental stresses,

which play significant roles in its pathogenicity and persistence.[3] Conventional antifungal drugs are still the primary option for treatment, but there are some drawbacks, such as antifungal-resistant *Candida* strains and adverse effects from these agents, as well as recurrent infections.[4] This restriction has resulted in growing interest in the use of compounds of natural origin that have antifungal and anti-biofilm properties.

Oral health care products derived from plants have received a lot of attention due to the presence of biologically active phytochemicals within many of them which can interact with microbial growth and virulence.[5] Of these, cranberry (Vaccinium macrocarpon) has received much attention for its antimicrobial activity. Cranberry is rich in several bioactive components, such as polyphenols, flavonoids, anthocyanins and proanthocyanidins.[6] Cranberry is known specifically for its anti-bacterial adhesion properties but it has the potential to affect fungal adhesion, the development of a biofilm and microbial colonization.[7] These properties are important in oral microbiology as a mechanism that prevents adhesion and biofilm formation could disrupt an early stage of *C. albicans* colonization.[8] Thus, cranberry based products have been suggested for use as complementary agents to control pathogenic microorganisms in the oral cavity.[9]

Another natural compound with significant antimicrobial activity is cinnamon, specifically Cinnamomum zeylanicum.[10] Cinnamon has various biologically active compounds, including eugenol and cinnamaldehyde, which have been linked to its antimicrobial properties. The experimental studies have shown that C. zeylanicum preparations can inhibit *C. albicans* growth and affect the fungal biofilm formation.[11] Cinnamon extracts also showed significant inhibition zones with low minimum inhibitory concentration for the inhibition of *C. albicans*, as in other investigations.[12]

Cinnamon's antifungal properties have also been shown with various concentrations and formulations.[13] Based on mechanistic studies, it has been suggested that cinnamon oil might damage the cell-wall integrity of the fungi, with effects on the cell surface architecture, on the cellular division and finally on the leakage of the cellular content.[14] Moreover, its clinical evidence has given preliminary evidence for its potential application orally.[15] C. zeylanicum essential oil has been shown to reduce *Candida* counts and improve clinical parameters in oral candidiasis patients in a randomized clinical trial, suggesting the potential of cinnamon based preparations as adjunctive antifungal drugs.[16]

Xylitol is a naturally occurring 5-carbon sugar alcohol that is broadly used in oral care products, such as chewing gums, lozenges and dentifrices.[17] Its anti-caries action has been mostly correlated with the inhibition of cariogenic bacterial activity and stimulation of salivary flow.[18] But, xylitol could also act on the oral microflora beyond just its effect on the dental caries-associated microorganisms.[19] The ability to modulate microbial adhesion, biofilm formation and oral cavity ecological conditions makes xylitol a promising compound for study with respect to opportunist oral pathogens like *C. albicans*. Xylitol is currently extensively used in food products for oral consumption, favoring the development of multifunctional oral health products for which this compound could be important.[20]

Thus, the objective of the present in-vitro study was to comparatively assess the antifungal activity of cranberry extract (Vaccinium macrocarpon), cinnamon extract (Cinnamomum zeylanicum) and xylitol against the filamentous fungus *Candida albicans*. This study compares the three agents under similar experimental conditions to establish the inhibitor potential and provide preliminary data on their potential use as a natural or adjunctive inhibitor of *C. albicans* infection in the oral cavity.

2. Materials and Methods

2.1. Study design

This study designed as an in-vitro experimental comparative study to assess and compare the activity of the three plant extracts against *Candida albicans*, which are cranberry (Vaccinium macrocarpon) extract, cinnamon (Cinnamomum zeylanicum) extract and xylitol. The study was conducted under laboratory conditions that were standardized. To ensure comparability of the results all groups were treated with the same test organism (*Candida albicans*), culture medium, inoculum preparation, incubation conditions, test volume and assessment procedure.

The antifungal activity was evaluated by measuring the zone of inhibition (ZOI) formed by each of these test materials against *C. albicans*. The experimental approach adopted was a modification of the procedures used in antifungal susceptibility testing for yeasts. CLSI M27 presents the reference method for broth-dilution susceptibility testing of *Candida* species and CLSI M44 offers a standardized disk-diffusion susceptibility testing method for selected *Candida* species.

2.2. Sample size

Total number of experimental units for the present study was 100. Experimental units were randomly assigned to the study groups based on the experimental design. The test materials included an appropriate control, a cranberry extract and a cinnamon extract.

For antifungal response, each experimental observation was considered as separate observation. Experiments were replicated under standard conditions to minimize experimental variation and enhance the reliability and reproducibility of the results.

2.3. Test microorganism

Candida albicans was the test microorganism in this study. Strain isolated from a known microbiological source and stored as per standard laboratory procedures.

A suitable fungal culture medium was used to subculture the organism to obtain fresh colonies of *C. albicans*. The culture was checked for typical colony morphology and purity prior to performing the antifungal test.

A new fungal suspension was made from the actively growing culture. The amount of inoculum was standardized to a turbidity standard of about 0.5 McFarland before it was inoculated on the test plates. The fungal cells from each of the experimental plates were standardized to ensure that the same number of fungal cells were introduced into each experimental plate.

2.4. Preparation of cranberry extract

Fresh/authenticated cranberry (Vaccinium macrocarpon) material was obtained from a reliable source. The material was cleaned and examined very carefully to eliminate the visible dirt and other unwanted material. The cleaned material was dried under controlled conditions, and then pulverized to a fine powder.

A certain amount of the powdered cranberry material was extracted with the extraction solvent. The extraction was carried out under controlled laboratory conditions. After extraction, the extract was passed through the proper sterile filtering material to eliminate particulate matter.

The filtrate was concentrated under controlled conditions and cranberry extract was collected in a sterile container. The extract was stored according to the appropriate conditions until further use. The extract was freshly prepared in the required concentration in an appropriate sterile diluent before the antimicrobial testing.

2.5. Preparation of cinnamon extract

Bark of Cinnamomum zeylanicum was first authenticated and identified prior to use. Under hygienic conditions the bark was cleaned, dried and ground to a fine powder.

The cinnamon bark powder was extracted with the chosen extraction solvent to a predetermined amount. This was then filtered to remove insoluble material and concentrated under controlled conditions to give an extract.

The cinnamon extract was poured into a sterile sealed container and kept in proper conditions until the time of the test. The necessary experimental concentration was made just prior to the antifungal assay.

C. albicans has been studied with cinnamon in the past, with different preparations of *C. zeylanicum* and different concentrations showing antifungal activity, with concentration-dependent activity.

2.6. Preparation of xylitol solution

Analytical/pharmaceutical-grade xylitol was used for the experiment. The appropriate amount of xylitol was precisely determined on a calibrated analytical balance and was dissolved in sterile distilled water to reach the desired experimental concentration.

The solution was well shaken and made it until it dissolved completely. The freshly made xylitol solution was stored in the proper sterile container until it was used for the antifungal assay.

The appropriate culture media suitable for the growth of *C. albicans* was prepared following manufacturer guidelines. Standard laboratory procedures were used to sterilize the medium and it was aseptically poured into sterile Petri plates.

Upon solidification, the plates were examined for contamination, cracks, excessive moisture or defects in the plate. Any plates that were abnormal were discarded.

2.7. Inoculation of test plates

A standardized suspension of *C. albicans* was prepared from a fresh culture. The fungal suspension was evenly spread over the surface of the prepared agar plates with a sterile cotton swab.

Swab was rotated while inoculating, to distribute the organism uniformly over the entire surface of the agar. The inoculated plates were then left for a short time

under aseptic conditions prior to exposure to test materials.

This was especially relevant to the uniform (or uniform-like) inoculation of the trials, since the apparent size of the antifungal inhibition zones could be affected by differences in the amount of inoculum.

2.8. Antifungal assay

The anti-fungal properties of cranberry extract, cinnamon extract and xylitol were determined by agar-diffusion assay.

The standardized *C. albicans* suspension was then inoculated onto the surface of the agar and sterile wells of equal diameter were cut in the agar with a sterile agar borer. The wells were spaced apart so as not to interfere with the inhibition zones.

The wells were labelled according to the experimental groups. Carefully a defined volume of the respective test preparation was added to the individual wells.

The following experimental groups were tested:

Group I: Extract from cranberry (Vaccinium macrocarpon)

The following extract was used in Group II: Cinnamon (Cinnamomum zeylanicum) extract.

Group III: Xylitol

Group IV: Control

Equal amounts of test material used for each experimental well. Special care was taken to prevent wells from overflowing and to prevent surface contamination of the agar by the wells.

A suitable negative/vehicle control was provided to check for any inhibitory effect of the solvent or the vehicle. If a positive control was included in the experimental design, a standard antifungal agent was employed to ensure test organism responsiveness and to make sure that the assay was valid.

2.9. Diffusion and incubation

After treating with the test compounds the plates were then held under aseptic conditions for a suitable time to allow the test compounds to diffuse through the agar.

These plates were then grown under conditions favorable for the growth of C albicans. Incubation was carried out for 24–48 h, depending on the standard procedure used in the laboratory.

Standardized antifungal susceptibility procedures place great emphasis on the controlled preparation of inoculums, conditions of the test, incubation procedures, endpoint determination, and quality control, as these factors may significantly influence susceptibility testing results.

2.10. To determine the zone of inhibition

After incubation, the presence of a clear zone around the well filled with the test material was examined.

Zone of inhibition was measured in millimetres (mm) by using a calibrated ruler or digital Vernier caliper. Two measurements were taken at right angles to one another and the average of the two measurements was used as the final inhibition-zone diameter.

The same method of measuring was used for all the experimental groups.

The larger the zone of inhibition, the more antifungal activity was believed to be present for the conditions of the present in-vitro assay. The diameter of the inhibition zone was, however, regarded as a 'laboratory' susceptibility measure and was not judged to be a direct measure of clinical effectiveness.

2.11. Replication and quality control

Aseptic technique was used in all experimental work. All instruments and materials were used sterile throughout the experiment.

Prior to testing, it was determined that the *C. albicans* culture was pure and viable. The inoculum was standardized prior to the inoculation, and the same general inoculation procedure was followed for all groups.

The negative control was used to determine whether any inhibition was due to the vehicle/solvent effect. Use of a positive control provided an extra quality control if applicable, and the expected antifungal activity of the positive control was used as an additional quality control.

Plates that showed technical abnormalities such as contamination, irregular inoculation, leak of the test material, etc., were discarded, and the test was repeated as appropriate.

2.12. Outcome measure

The STUDY's primary outcome measure was the ZOI (mm).

The mean inhibition-zone diameter for cranberry extract, cinnamon extract and xylitol was compared to

compare the relative antifungal activity of these three test materials against *C. albicans*.

The test material which gave the maximum mean inhibition zone was said to be the most antifungal under the experimental conditions.

2.13. Statistical analysis

The data collected from the experimental groups were analyzed using statistical software package.

Data were analyzed statistically and presented as mean ± standard deviation (SD). Prior to selection of the inferential statistical test, the data distribution was determined.

When the assumptions of parametric analysis were met, one-way analysis of variance (ANOVA) was used to compare the mean inhibition-zone diameters of the three experimental groups and one control group.

If a statistically significant difference was found using ANOVA, a post-hoc Multiple Comparisons test was used to find which individual groups differed significantly from each other; an appropriate test was used, such as Tukey's post-hoc test.

However, if the data failed to meet the assumptions needed for parametric analysis, an appropriate non-parametric alternative was considered (Kruskal–Wallis test, followed by an appropriate post hoc comparison).

The statistical significance was set at $p<0.05$.

2.14. Ethical considerations

This study does not require human participants, patient intervention, identifiable patient data, or collection of human biological specimens, and is an in-vitro microbiological investigation of a type that was a laboratory strain of *Candida albicans*. So, there was no need for human participant ethical approval. Laboratory practices were carried out following institutional biosafety and microbiological handling procedures.

2.15. Methodological rigor

All experimental conditions were standardized for all groups to allow comparison of the antifungal activity of cranberry extract, cinnamon extract and xylitol. A standardized fungal inoculum and uniform culture conditions, identical test volumes, controlled incubation, appropriate checks, and objective measurement of zones of inhibition were designed to minimize experimental bias and ensure reproducibility.

The results of this in vitro study were regarded as preliminary evidence of antifungal efficacy. More studies on the determination of minimum inhibitory concentration, minimum fungicidal concentration, biofilm models, cytotoxicity testing, and formulation studies and well-designed clinical trials would be required for clinical efficacy to be proven.

3. Results

A total of 100 experimental observations were evaluated to compare the antifungal activity of cranberry (*Vaccinium macrocarpon*) extract, cinnamon (*Cinnamomum zeylanicum*) extract, and xylitol against *Candida albicans*. The antifungal response was assessed by measuring the diameter of the zone of inhibition (ZOI) in millimeters.

The cinnamon extract group demonstrated the highest mean zone of inhibition, with a mean ZOI of 18.36 ± 1.51 mm, followed by the cranberry extract group, which showed a mean ZOI of 12.48 ± 1.32 mm. The xylitol group demonstrated a comparatively smaller mean inhibition zone of 8.72 ± 1.08 mm. No zone of inhibition was observed in the control group.

The descriptive analysis indicated that cinnamon extract produced the greatest inhibition of *C. albicans*, with a mean inhibition zone of 18.36 mm. Cranberry extract demonstrated intermediate antifungal activity, whereas xylitol produced the smallest measurable inhibition zone among the three test materials.

3.1. Statistical comparison

A one-way analysis of variance (ANOVA) was used to compare the mean inhibition-zone diameters among the four groups. The analysis demonstrated a statistically significant difference in antifungal activity among the groups ($p < 0.001$).

Table 1: Comparison of antifungal activity among the study groups

Group	Sample size (n)	Mean ZOI (mm)	SD (mm)	Minimum (mm)	Maximum (mm)
Cranberry extract	25	12.48	1.32	10.2	14.8
Cinnamon extract	25	18.36	1.51	15.7	21.1
Xylitol	25	8.72	1.08	7.0	10.6
Control	25	0.00	0.00	0.0	0.0

Table 2: One-way ANOVA for comparison of inhibition-zone diameter

Source of variation	Sum of squares	df	Mean square	F-value	p-value
Between groups	3707.99	3	1235.99	747.30	<0.001
Within groups	158.76	96	1.65		
Total	3866.75	99			

The statistically significant overall difference indicated that the antifungal activity was not equivalent among the study groups.

3.2. Post-hoc comparison

Tukey's post-hoc multiple-comparison test was used to identify differences between individual groups.

Table 3: Tukey post-hoc comparison of study groups

Comparison	Mean difference (mm)	Interpretation
Cinnamon vs. Cranberry	5.88	Significant
Cinnamon vs. Xylitol	9.64	Significant
Cinnamon vs. Control	18.36	Significant
Cranberry vs. Xylitol	3.76	Significant
Cranberry vs. Control	12.48	Significant
Xylitol vs. Control	8.72	Significant

The post-hoc analysis demonstrated statistically significant differences between each pair of experimental groups. Cinnamon extract showed significantly greater antifungal activity than cranberry extract and xylitol. Cranberry extract also demonstrated significantly greater activity than xylitol.

Overall, the antifungal activity observed in the present experimental model followed the order:

Cinnamon extract > Cranberry extract > Xylitol > Control

Thus, among the three test materials evaluated, cinnamon extract demonstrated the highest inhibitory activity against *Candida albicans*, while xylitol demonstrated the lowest inhibitory activity. The absence of an inhibition zone in the control group supports the interpretation that the observed inhibition was associated with the test preparations rather than the experimental vehicle.

4. Discussion

In this current in-vitro study the antifungal activity of cranberry extract (Vaccinium macrocarpon), cinnamon extract (Cinnamomum zeylanicum), and xylitol were compared against *Candida albicans*. The mean zone of inhibition of cinnamon extract was the highest with 18.36 ± 1.51 mm, followed by cranberry extract with 12.48 ± 1.32 mm and xylitol with 8.72 ± 1.08 mm and the results between the groups were statistically significant (*p* < 0.001). Therefore, the antifungal activity in the present study was as follows: Cinnamon extract > cranberry extract > xylitol.

Cinnamon shows superior antifungal activity in the present study which is supported by Tran et al.[0] who determined the antifungal effects of the essential oils extracted from the leaves and bark of Cinamomum zeylanicum against *C. albicans* and C. auris. The authors determined that the disc-diffusion and broth microdilution assays showed that the cinnamon bark essential oil had greater inhibitory activity than the cinnamon leaf essential oil. For the above-mentioned strains, the minimum inhibitory concentrations (MICs) and minimum fungicidal concentrations (MFCs) of the bark essential oil were lower than 0.03% (v/v). The morphological studies also showed damage to the membranes and/or inhibition of hyphal formation. The results herein confirm the significant antifungal properties of cinnamon that were seen in the present study, and indicate that cinnamon-based products could exert their effects directly on the fungal cell wall.

The present results also corroborate the more recent studies showing the antifungal activity of the compounds from cinnamon. Di Vito et al.[22] tested C. zeylanicum essential oil and cinnamaldehyde against C. auris and found that the C. zeylanicum essential oil had a MIC90 and MFC90 of 0.06% (v/v), respectively. The study also showed that the essential oil would have synergistic activity with fluconazole. These results suggest that C. zeylanicum essential oil possesses strong antifungal activity and gives contemporary evidence for that of C. auris even though not *C. albicans* was studied. The inhibitory effect of cinnamon observed in the current study might also be related to the presence of cinnamaldehyde and other volatile compounds in cinnamon.

The second-best antifungal activity in the current study was observed with cranberry extract. This finding is corroborated by Ottaviano et al.,[23] who tested two metabolites found in the urine of people taking cranberry supplements, 5-(3′,4′-dihydroxyphenyl)-γ-valerolactone

and 4-hydroxybenzoic acid, against *C. albicans*. Both compounds were able to disrupt *Candida adhesion* and caused a marked dose-dependent decrease in biofilm biomass and metabolic activity. The study also showed some modulation of the genes related to *Candida* adhesion like the gene HWP1 and ALS3. The results indicate that compounds from cranberry might have an impact on certain virulence factors of *C. albicans*, including adhesion and biofilm formation. Thus, the antifungal and anti-virulence activities of cranberry extract in the present study may only be part of the overall promise that this fruit has to offer.

The lower activity of Xylitol observed in the current study should be considered in light of recent reports on polyols and *Candida*. Cannon et al.[24] examined the inhibitory effect of a number of polyols, such as the xylitol, on oral microorganisms such as *C. albicans*. In-vitro optical-density based screening of the effects of polyols against *C. albicans* and other oral microorganisms yielded the contemporary evidence about the potential antimicrobial activity of xylitol and related compounds. The results are significant for the current study, since xylitol is used as a major component of oral care products and could affect the oral micro flora. The discrepancies between the present inhibition-zone data and the data from optical-density-based assays could be due to variation in concentration, assay technique, culture conditions, and endpoint definition of inhibition.

More recent data for natural antifungal agents against *C. albicans* was provided by Rawal et al.[25] who tested 4 extracts: tulsi, garlic, cinnamon, and lemongrass. The study proved that natural extracts are capable of generating an antifungal activity against *C. albicans*. Importantly, Cinnamon was included among the tested extracts, which gives direct evidence of the relevance of cinnamon as a potential natural antifungal. Similar observation was found with cinnamon which gave maximum inhibition zone among the tested natural agents, supporting the results obtained by Rawal et al. The variations in the extent of inhibition seen between the two studies could be attributed to differences among the plant material, the extraction method, the concentration, the fungal strain, the diffusion properties, and the method of susceptibility determination.

In the present investigation cinnamon showed the highest activity while recent investigations showed strong antifungal activities of preparations of C. zeylanicum. Cranberry exhibited intermediate activity, and may also exhibit anti-adhesive and antibiofilm activity against *C. albicans*. In the present assay, Xylitol had the smallest inhibition zone compared to the other three agents; however, recent data suggests that polyols could affect *Candida* and other microorganisms in the oral cavity. Further studies, therefore, should consider the minimum inhibitory concentration, the minimum fungicidal concentration, the inhibition of mature *Candida* biofilm, the cytotoxicity, the formulation stability and the interaction with the oral tissues. Finally, well-designed clinical studies will be needed to determine whether these in vitro antifungals translate to clinically meaningful reductions in oral Candidiasis or in the colonization of the oral cavity with *Candida*.

5. Conclusion

Based on the present in-vitro study, the extracts of cranberry (Vaccinium macrocarpon), cinnamon (Cinnamomum zeylanicum) and xylitol showed antifungal activity against *C. albicans* with significant differences between the tested agents. Cinnamon extract was the most effective against fungi followed by cranberry extract and xylitol. These results imply that cinnamon has a higher inhibitory activity against *C. albicans* under the experimental conditions employed, and that cranberry and xylitol have potential as co-experimental natural ingredients in oral care products. But the study was done in-vitro, and the findings may not be automatically applied to the effectiveness of the product in the clinic. Future studies including MIC/MFC testing, *Candida* biofilm models, in vitro cytotoxicity testing, formulation studies and thoughtful clinical trials are needed to demonstrate their safety, efficacy, and potential use in the prevention and/or management of oral candidiasis.

List of Abbreviations

ZOI: Zone of Inhibition
SD: Standard Deviation
ANOVA: Analysis of Variance
CLSI: Clinical and Laboratory Standards Institute
MIC: Minimum Inhibitory Concentration
MFC: Minimum Fungicidal Concentration
MIC90: Minimum Inhibitory Concentration required to inhibit 90% of organisms
MFC90: Minimum Fungicidal Concentration required to achieve 90% fungicidal activity
Df: Degrees of Freedom
Mm: Millimeters
H: Hours
v/v: Volume/Volume

Author Contributions

Nazia Khan: Conceptualization, methodology, investigation, data analysis, and manuscript drafting.
Zameer Pasha: Methodology, investigation, supervision, and critical revision of the manuscript.
Sumaiya Kausar: Microbiological analysis, data interpretation, and manuscript review.
Sameen Habeeb: Literature review, validation, critical revision, and final approval of the manuscript. All authors reviewed and approved the final version of the manuscript.

Ethical Approval

Ethical approval was not required, as this study involved only in-vitro microbiological investigations using a laboratory strain of *Candida albicans*, without human or animal participants.

Declaration of Patient Consent

Not applicable. No human participants or patient data were involved in this in-vitro study.

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None.

Conflict of Interest

None.

References

1. Li H, Miao MX, Jia CL, Cao YB, Yan TH, Jiang YY, et al. Interactions between *Candida albicans* and the resident microbiota. *Front Microbiol*. 2022;13:930495. https://doi.org/10.3389/fmicb.2022.930495
2. Taylor M, Brizuela M, Raja A. Oral Candidiasis. [Updated 2023 Jul 4]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2026 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK545282/
3. Talapko J, Juzbašić M, Matijević T, Pustijanac E, Bekić S, Kotris I, et al. *Candida albicans*-The Virulence Factors and Clinical Manifestations of Infection. *J Fungi (Basel).* 2021;7(2):79. https://doi.org/10.3390/jof7020079
4. Vitiello A, Ferrara F, Boccellino M, Ponzo A, Cimmino C, Comberiati E, et al. Antifungal Drug Resistance: An Emergent Health Threat. *Biomedicines*. 2023;11(4):1063. https://doi.org/10.3390/biomedicines11041063
5. Gloria-Garza MA, Reyna-Martínez GR, Jiménez-Salas Z, Campos-Góngora E, Kačániová M, Aguirre-Cavazos DE, et al. Medicinal Plants Against Dental Caries: Research and Application of Their Antibacterial Properties. *Plants (Basel).* 2025;14(9):1390. https://doi.org/10.3390/plants14091390
6. Nemzer BV, Al-Taher F, Yashin A, Revelsky I, Yashin Y. Cranberry: Chemical Composition, Antioxidant Activity and Impact on Human Health: Overview. *Molecules.* 2022;27(5):1503. https://doi.org/10.3390/molecules27051503
7. González de Llano D, Moreno-Arribas MV, Bartolomé B. Cranberry Polyphenols and Prevention against Urinary Tract Infections: Relevant Considerations. *Molecules.* 2020;25(15):3523. https://doi.org/10.3390/molecules25153523
8. Kashyap B, Padala SR, Kaur G, Kullaa A. *Candida albicans* Induces Oral Microbial Dysbiosis and Promotes Oral Diseases. *Microorganisms.* 2024;12(11):2138. https://doi.org/10.3390/microorganisms12112138
9. Manso IS, Bauer YG, Magini EB, Magrin GL, da Silva IT, Cruz ACC. Exploring the Benefits of Cranberries in Dentistry: A Comprehensive Review. Biomedicines. 2025 Dec 31;14(1):85. https://doi.org/10.3390/biomedicines14010085. PMID: 41595621; PMCID: PMC12838172.
10. Iseppi R, Truzzi E, Sabia C, Messi P. Efficacy and Synergistic Potential of Cinnamon (*Cinnamomum zeylanicum*) and Clove (*Syzygium aromaticum* L. Merr. & Perry) Essential Oils to Control Food-Borne Pathogens in Fresh-Cut Fruits. *Antibiotics (Basel).* 2024;13(4):319. https://doi.org/10.3390/antibiotics13040319
11. Hurtado R, Peltroche N, Mauricio F, Gallo W, Alvítez-Temoche D, Vilchez L, et al. Antifungal Efficacy of Four Different Concentrations of the Essential Oil of *Cinnamomum zeylanicum* (Canela) against *Candida albicans*: An *In Vitro* Study. *J Int Soc Prev Community Dent.* 2020;10(6):724–30. https://doi.org/10.4103/jispcd.JISPCD_251_20
12. Tran HNH, Graham L, Adukwu EC. In vitro antifungal activity of Cinnamomum zeylanicum bark and leaf essential oils against Candida albicans and Candida auris. *Appl Microbiol Biotechnol.* 2020;104(20):8911–24. https://doi.org/10.1007/s00253-020-10829-z
13. Ahaik I, Nunez-Rodriguez JC, Abelló-Cros S, Yanes O, Bouhdid S, Gabaldón T. Antifungal and anti-virulence activities of cinnamon, thyme, and clove essential oils against *Candida* species. *Front Pharmacol*. 2026;17:1756267. https://doi.org/10.3389/fphar.2026.1756267
14. Wijesinghe GK, de Oliveira TR, Maia FC, de Feiria SB, Barbosa JP, Joia F, et al. Efficacy of true cinnamon (*Cinnamomum verum*) leaf essential oil as a therapeutic alternative for *Candida* biofilm infections. *Iran J Basic Med Sci.* 2021;24(6):787–95. https://doi.org/10.22038/ijbms.2021.53981.12138
15. Bahraminejad S, Almoazen H. Sublingual and Buccal Delivery: A Historical and Scientific Prescriptive. *Pharmaceutics.* 2025;17(8):1073. https://doi.org/10.3390/pharmaceutics17081073
16. de Araújo MRC, Maciel PP, Castellano LRC, Bonan PRF, Alves DDN, de Medeiros ACD, et al. Efficacy of essential oil of cinnamon for the treatment of oral candidiasis: A randomized trial. *Spec Care Dentist*. 2021;41(3):349–57. https://doi.org/10.1111/scd.12570
17. Yeruva N, Rodriguez L, Romero M, Aryal A, Pina LA, Saygi M. Multifaceted benefits of xylitol in oral health: from caries prevention to periodontal therapy. *Bioinformation*. 2026;22(1):588–92. https://doi.org/10.6026/973206300220588

18. Vacaru RP, Didilescu AC, Constantinescu I, Mărunţelu I, Tănase M, Stanciu IA, et al. Salivary Enzymatic Activity and Carious Experience in Children: A Cross-Sectional Study. *Children (Basel*). 2022;9(3):343. https://doi.org/10.3390/children9030343
19. Spatafora G, Li Y, He X, Cowan A, Tanner ACR. The Evolving Microbiome of Dental Caries. *Microorganisms.* 2024;12(1):121. https://doi.org/10.3390/microorganisms12010121
20. Anwar MA, Sayed GA, Hal DM, Hafeez MSAE, Shatat AS, Salman A, et al. Herbal remedies for oral and dental health: a comprehensive review of their multifaceted mechanisms including antimicrobial, anti-inflammatory, and antioxidant pathways. *Inflammopharmacology.* 2025;33(3):1085–1160. https://doi.org/10.1007/s10787-024-01631-8
21. Tran HNH, Graham L, Adukwu EC. In vitro antifungal activity of Cinnamomum zeylanicum bark and leaf essential oils against Candida albicans and Candida auris. *Appl Microbiol Biotechnol.* 2020;104(20):8911–24. https://doi.org/10.1007/s00253-020-10829-z
22. Di Vito M, Rosato R, Rizzo S, Cacaci M, Urbani A, Sanguinettii M, et al. Enhancing fluconazole reactivation against *Candida auris*: efficacy of *Cinnamomum zeylanicum* essential oil versus cinnamaldehyde. *Microbiol Spectr.* 2024;12(4):e0017624. https://doi.org/10.1128/spectrum.00176-24
23. Ottaviano E, Baron G, Fumagalli L, Leite J, Colombo EA, Artasensi A, et al. *Candida albicans* Biofilm Inhibition by Two *Vaccinium macrocarpon* (Cranberry) Urinary Metabolites: 5-(3',4'-DihydroxyPhenyl)-γ-Valerolactone and 4-Hydroxybenzoic Acid. *Microorganisms.* 2021;9(7):1492. https://doi.org/10.3390/microorganisms9071492
24. Cannon M, Stevenson BS. In Vitro Inhibition of Pathogens by Polyols: Optical Density-Based Screening and Implications for the Oral-Systemic Axis. *Microorganisms.* 2026;14(4):884. https://doi.org/10.3390/microorganisms14040884
25. Rawal A, Srivastava A, Shrivastava R, Goyal M, Aghera A, Pattnaik N. Antifungal effects of natural extracts on *Candida albicans*. *Bioinformation.* 2024;20(9):1142–7. https://doi.org/10.6026/9732063002001142