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A Review of the Antibacterial Properties of Selected Southern African Plant Species Used in Traditional Medicine

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ABSTRACT

Introduction: The rise in bacterial resistance has caused significant global health challenges and reduced the effectiveness of antibiotics. For thousands of years, plants have been used in traditional medicine to combat disease associated with infections, serving as natural remedies due to their antimicrobial properties. **Aim of the Study:** This study aimed to review and summarise the antibacterial properties of selected South African plant species and its ethnobotanical use, with the aim of promoting further studies in this area. **Materials and Methods:** Original scientific literature, reviews and online databases were searched to identify plant species traditionally used for treating bacterial infections in South Africa. A subsequent search was conducted to find studies that focuses on antibacterial activity of these plant species, summarising the existing knowledge and highlighting areas for further investigations. **Results:** 6 plant species traditionally used in South Africa to treat bacterial infections were investigated. Roots, barks, leaves, stems and fruits were the most utilized plant parts. These parts were often ground into a fine powder and extracted with water for consumption. Of these, only five plant species have been scientifically studied for antibacterial activities. Those studies screened against limited bacterial panels and generally did not focus on the mechanisms of action and safety for therapeutic applications. **Conclusion:** The selected plant species have significant antibacterial potential to, although the previous research has primarily focused on a narrow range of bacterial species. Further studies are required to investigate these plant-based medicines against a boarder spectrum of bacterial strains. Additionally, studies are required to isolate and identify the phytochemicals responsible for their activity and to elucidate their mechanisms. Comprehensive studies should be undertaken to evaluate the efficacy and safety of these plant-derived treatments for potential therapeutic applications.

Keywords: Antibacterial, Ethnobotany, Bacterial resistance, African plants, Traditional medicines.

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INTRODUCTION

For millennia, plants have played an important role in traditional medicine, serving as vital resources for the treatment of various health conditions such as infections, wounds, digestive issues and chronic ailments.[1,2] Many traditional remedies were derived from plant leaves, fruits, roots, bark, seeds and flowers, each offering unique bioactive compounds that combat disease and promote health.[1] Modern medicine continues to draw inspiration from these ancient practices, with numerous pharmaceuticals being synthesized or developed from plant-based compounds.[3] This enduring reliance on plants highlights their crucial role in both historical and contemporary approaches to healthcare. Our review focuses on 6 selected plant species that are traditionally used in South Africa for their antibacterial properties.

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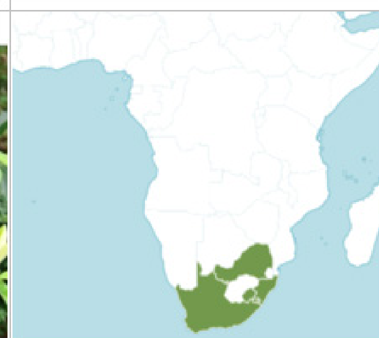
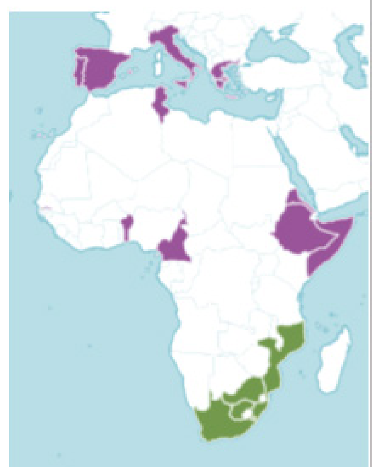
Antibiotic resistance

Antimicrobials have significantly reduced patient mortality while improving quality of life.[4] However, their effectiveness in treating microbial infections is steadily declining as antimicrobial resistance (AMR) continues to rise, threatening both public health and economic stability.[4,5] Among the various forms of AMR, antibacterial resistance is particularly alarming, as it accounts for the majority of resistant infections and death.[6] This issue is exacerbated by the rise of multidrug-resistant (MDR) bacteria, which renders many conventional antibiotics ineffective.[4-6] This highlights the importance of identifying new compounds that either function as a single compound to target different bacterial

Plant name	Images	Distribution	Referenc es
Harpagophytu m procumbens			12,13
Ocotea bullata			14,15
Plumbago auriculata			16,17

Ptaeroxylon obliquum			18,19
Pterocelastrus rostratus			20,21
Syzygium cordatum			22,23

Figure 1: The South African plants examined in this review, showing images of the plant species, as well as their geographical distribution. Images were sourced from the references indicated in the final column and are reproduced herein with all relevant permissions.

strains, or may be used as adjunctive to enhance the activity of existing antibiotics, potentially restoring their efficacy against resistant bacterial strains.

Extensive studies have been conducted using traditional plant materials to identify compounds that potentiate the efficacy of conventional antibiotics against both antibiotic susceptible and resistant bacterial strains.[6] Numerous phytochemicals have been identified, including alkaloids, flavonoids, terpenoids, tannins, saponins, glycosides and polyphenols, which demonstrate antimicrobial properties either through direct inhibition, or by enhancing the effectiveness of existing antibiotics.[7,8] These compounds often act by disrupting bacterial cell walls, inhibiting protein synthesis, or targeting resistance mechanisms.[8] The integration of phytochemicals into antibiotic therapy holds significant potential for addressing the global challenge of antibiotic resistance.

South African ethnobotany

In South Africa, ethnobotanical traditions have been deeply embedded in the nation's health care system, reflecting a long-standing and continuous history of use.[9] Thus, a significant portion (12 to 15 million) of the population relies on medicinal plants as their primary source of healthcare to reduce the burden of high costs associated with modern healthcare services.[9] In South Africa, the practice of traditional healing is widespread, with over 200,000 traditional healers and around 3,000 plant species utilized for medicinal purposes.[10] A substantial informal commercial market thrives around these medicinal plants, which remain a primary source of healthcare for many individuals in the country.[10] Traditional healing remedies have predominantly been passed orally from one generation to the next, leading to limited evidence about these practices.[11] Therefore, the necessity for additional research and validation of these traditional medicinal plants is required.

Selected South African plant species

This review focuses on 6 selected endemic South African plants that have been used by indigenous South African populations. These plants include *Harpagophytum procumbens* (Burch.) DC. Ex Meisn, *Ocotea bullata* (Burch.) Baill, *Plumbago auriculata* Lam, *Ptaeroxylon obliquum* (Thunb.) Radlk, *Pterocelastrus rostratus* (Thunb.) Walp and *Syzygium cordatum* Hoschst. Ex Krauss (Figure 1).

MATERIALS AND METHODS

The review documents the current knowledge on selected South African traditional plants that are used in traditional medicine to treat various health conditions including bacterial infections. To identify relevant original scientific literature, several online databases were utilized including, PubMed, Elsevier and Google Scholar. Additionally, other articles were located via online sources or through references in previously identified publications. The following terms were used as keywords to filter the online databases: "South Africa", "traditional medicinal plant", "antibacterial properties", "bacterial infections", "infections", "herbal medicine", "ethnobotanical traditions", "ethnobotany", "antibiotics", "natural healing", "alternative medicine" and "natural remedies". All terms were searched individually and in combinations. The initial emphasis was on identifying and documenting the traditional uses of plant species to treat bacterial infections in South Africa. Subsequent searches were conducted on the selected traditional South African plant species in order to acquire any studies which focused their antibacterial properties.

Eligibility criteria

The abstracts of published articles were reviewed to ensure that the publication was relevant and was then further evaluated using the following inclusion and exclusion criteria.

Inclusion criteria

Studies that were included in the review were:

- English-language manuscripts published before December 2024.
- Studies that are unbiased.
- Studies involving plant species specifically documented for their use in treating bacterial infections; and,
- Ethnobotanical studies that focused solely on plants found in South Africa.

Exclusion criteria

Excluded from this review were studies that:

- Involved plant species where the treatments of bacterial infections were not clearly mentioned.
- Included taxonomically-related species for which there is no record of traditional use for this purpose.
- Focused on treatment of non-bacterial species; and,
- Comprised research that was funded by a relevant industry, to avoid conflict of interest issues.

Data collection

The different plant names and their global distribution were confirmed via the Plants of the World Online website (https://powo.science.kew.org). Additionally, plant species and the family names for each documented species were verified and updated using resources from The World Flora Online (http://www.worldfloraonline.org/) and the SANBI website (http://www.sanbi.org).

RESULTS AND DISCUSSION

General plant information and ethnobotanical uses

Information on the selected plant species, their common names and ethnobotanical uses is shown in Table 1. *Harpagophytum procumbens*, commonly known as Devil's Claw, is endemic to specific regions of Africa, including parts of South Africa, Namibia, Lesotho, Swaziland Zimbabwe and Botswana. Within South Africa, this plant is particularly found in KwaZulu-Natal, the Northern Provinces and the Cape Provinces.[13] These areas provide the dry, sandy soils and semi-arid climates that are ideal for its growth. Devil's Claw thrives in these regions due to their unique ecosystems, which support the plant's ability to develop its tuberous roots, which is the primary part used for its traditional South African medicine.[9] In South Africa, it has been traditionally used for its anti-inflammatory properties and as a remedy for ailments such as constipation, cough, diarrhoea and sexually transmitted infections.[9]

Ocotea bullata, commonly known as black stinkwood, is endemic to specific regions of Southern Africa, including parts of South Africa and Lesotho. Within South Africa, it is found in the Cape Provinces, KwaZulu-Natal and the Northern Provinces,[15] where it thrives in forested areas and along riverbanks, benefiting from the cool, moist conditions of these regions[24]. The bark of this tree species has been traditionally used to treat headaches, urinary disorders and stomach problems.[24,25]

Plumbago auriculata, commonly known as blue plumbago, is a blue-flowering shrub endemic to Southern Africa, particularly in the Cape Provinces, Free State, KwaZulu-Natal, Mozambique and the Northern Provinces of South Africa. Whilst *P. auriculata* is naturally endemic to Southern Africa, it has been widely introduced to various parts of the world.[17] Its global spread includes regions such as Ascension Island, Hawaii, Florida, Italy, Spain, Greece, Vietnam, Mexico, the Canary Islands, Madeira and the Windward Islands.[17] It has also been introduced to parts of Asia, including Assam, Bangladesh and Vietnam and regions of Central and South America, including Ecuador, Peru, Guatemala, Puerto Rico and Venezuela.[17] Despite its widespread introduction globally, its significance in its native regions of South Africa remains substantial. In traditional medicine, *P. auriculata* is valued for its leaves and roots, which are used to treat wounds, warts and black water fever.[26]

Ptaeroxylon obliquum, commonly known as sneezewood, is a tree primarily found in the subtropical biome and is endemic to Southern Africa and parts of East Africa.[27] Within South Africa, it grows in regions such as the Cape Provinces, KwaZulu-Natal and the Northern Provinces, where it thrives in warm, subtropical climates and well-drained soils.[19] The tree is also distributed across neighbouring countries, including Angola, Botswana, Mozambique, Namibia, Swaziland, Tanzania and Zimbabwe.[19] In traditional medicine, various parts of the tree, including the leaves, stems, bark, roots and twigs, are used to treat a range of ailments such as vaginal infections, liver disease, rheumatism, arthritis, diarrhoea, heart disease and malaria.[27]

Pterocelastrus rostratus, commonly known as cherrywood, is a tree species native to South Africa and grows primarily in the subtropical biome.[28] Within South Africa, its range includes the Cape Provinces, KwaZulu-Natal and the Northern Provinces,

Table 1: Selected Southern African plants, their common names and traditional uses.

Plant species	Family	Common name	Plant parts	Traditional uses	References
Harpagophytum procumbens	*Pedaliaceae*	Devil's Claw	Roots	Anti- inflammatory, constipation, cough, diarrhoea and venereal infections.	9
Ocotea bullata	*Lauraceae*	Black Stinkwood	Bark	Headaches, urinary disorders and stomach problems.	24,25
Plumbago auriculata	*Plumbaginaceae*	Blue Plumbago	Leaves and roots	Wounds, warts and black water fever.	26
Ptaeroxylon obliquum	*Rutaceae*	Sneezewood	Leaves, stems, bark, roots and twigs	Vaginal infections, liver disease, rheumatism, arthritis, diarrhoea, heart disease and malaria.	27
Pterocelastrus rostratus	*Celastraceae*	Cherrywood	Bark	Respiratory conditions.	28
Syzygium cordatum	*Myrtaceae*	Water berry	Leaves, roots, bark and fruits	Viral, bacterial and parasitic infections.	29

where it thrives in forested and subtropical areas with well-drained soils and moderate rainfall.[21] The species is also found in the neighbouring regions of Lesotho and Swaziland.[21] Traditionally, the bark of *P. rostratus* has been used in medicine, particularly for treating respiratory conditions, including respiratory infections.[28]

Syzygium cordatum, commonly known as water berry, is a shrub or tree with a native range extending from Uganda to Southern Africa. It primarily grows in the seasonally dry tropical biome, thriving in areas with a mix of dry and wet conditions. Within South Africa, it is found in the Cape Provinces, KwaZulu-Natal and the Northern Provinces, where it typically grows along riverbanks, wetlands and in moist, subtropical woodlands.[23] The tree is also widely distributed across neighbouring regions, including Angola, Botswana, Burundi, Caprivi Strip, Gabon, Kenya, Malawi, Mozambique, Rwanda, Swaziland, Tanzania, Uganda, Zambia, Zaïre and Zimbabwe.[23] Traditionally, different parts of the tree, including the leaves, roots, bark and fruits, are used in medicine to treat viral, bacterial and parasitic infections. Its edible berries further contribute to its importance, providing nutrition for both humans and wildlife.[29]

Antibacterial activity of selected South African plants

The antibacterial properties of Southern African plants extracted with various solvents and evaluated against various bacterial pathogens is shown in Table 2. This summary also reveals the differences in susceptibility that was found between numerous Gram-positive and Gram-negative bacteria, as determined by their Minimum Inhibitory Concentration (MIC) values.

Staphylococcus aureus is a gram-positive bacterium is known for causing many different types of infections and has become a serious health concern, especially due to the rise in the Methicillin-Resistant *S. aureus* (MRSA) resistant strain.[34] The sensitive *S. aureus* species has been found to be susceptible to a number of the different plant extracts including *Harpagophytum procumbens*, with low MIC values of 10 µg/mL.[25] Similarly, *Ptaeroxylon obliquum* fractions demonstrated potent antibacterial effects. The hexane-acetone extract inhibited *S. aureus* at an MIC of 40 µg/mL, while the chloroform-acetone extract showed a lower activity with an MIC value of 240 µg/mL.[32,33] Extracts from *P. rostratus* were less effective (although still noteworthy), with methanolic and dichloromethane extracts yielding MIC values of 500 µg/mL.[31] Additionally, *S. cordatum* methanolic extracts inhibited *S. aureus* at 166 µg/mL, while dichloromethane extracts showed moderate activity at 266 µg/mL.[31] These results demonstrate the strong susceptibility of *S. aureus* to several plant extracts, particularly from *H. procumbens* and *P. obliquum*. Surprisingly, the *H. procumbens* water extract has also shown to inhibit the growth of MRSA with an MIC value of 20 µg/mL.[30] The observed MIC of 20 µg/mL suggests that this extract contains

Table 2: Selected Southern African plants and evidence of antibacterial properties as MIC values against different bacterial species.

Plant species	Extraction(s)	Bacterial strain	Antibacterial MIC values	Reference(s)
Harpagophytum procumbens	Extracted with water and resuspended in PBS.	*Staphylococcus aureus,* Methicillin-Resistant *S. aureus* (MRSA), *Staphylococcus epidermidis, Streptococcus pyogenes, Streptococcus agalactia, Pseudomonas maltophilia* and *Bacillus subtilis.*	10 ug/mL	30
		Enterococcus faecalis and *Pseudomonas aeruginosa.*	20 ug/mL	
		Escherichia coli.	100 ug/mL	
		Klebsiella pneumoniae.	No Inhibition	
Ocotea bullata	Methanol	*Bacillus cereus.*	66 ug/mL	31
		Enterococcus faecalis.	133 ug/mL	
		Escherichia coli, Salmonella typhimurium.	166 ug/mL	
		Shigella sonnei.	266 ug/mL	
	Dichloromethane	*Bacillus cereus.*	66 ug/mL	31
		Enterococcus faecalis.	150 ug/mL	
		Escherichia coli.	266 ug/mL	
		Salmonella typhimurium.	800 ug/mL	
		Shigella sonnei.	400 ug/mL	
Plumbago auriculata	No data available			

Plant species	Extraction(s)	Bacterial strain	Antibacterial MIC values	Reference(s)
Ptaeroxylon obliquum	Acetone	*Mycobacterium tuberculosis.*	313 ug/mL	32,33
	Fractionated hexane-acetone	*Mycobacterium tuberculosis.* *Escherichia coli, Enterococcus faecalis.* *Pseudomonas aeruginosa.* *Staphylococcus aureus.* *Mycobacterium fortuitum, Mycobacterium smegmatis.*	620 ug/mL 80 ug/mL 160 ug/mL 40 ug/mL 20 ug/mL	32,33
	Fractionated chloroform-acetone	*Escherichia coli and Staphylococcus aureus.* *Enterococcus faecalis.* *Pseudomonas aeruginosa, Mycobacterium fortuitum.* *Mycobacterium smegmatis.*	240 ug/mL 320 ug/mL 80 ug/mL 630 ug/mL	32,33
	Fractionated 30% H_2O in MeOH -acetone	*Mycobacterium tuberculosis.* *Escherichia coli, Pseudomonas aeruginosa.* *Enterococcus faecalis, Staphylococcus aureus, Mycobacterium smegmatis.* *Mycobacterium fortuitum.*	625 ug/mL 630 ug/mL 320 ug/mL 40 ug/mL	32,33
	Fractionated butanol-acetone	*Escherichia. coli, Enterococcus faecalis, Pseudomonas aeruginosa, Mycobacterium smegmatis.* *Staphylococcus aureus.* *Mycobacterium fortuitum.*	1250 ug/mL 630 ug/mL 320 ug/mL	32,33
	Fractionated H_2O-acetone	*Escherichia. coli, Enterococcus faecalis, Mycobacterium smegmatis.* *Staphylococcus aureus, Pseudomonas aeruginosa, Mycobacterium fortuitum.*	2500 ug/mL 630 ug/mL	32,33
Pterocelastrus rostratu	Methanol	*Staphylococcus aureus.* *Pseudomonas aeruginosa.* *Klebsiella pneumoniae.*	500 ug/mL 250 ug/mL 66 ug/mL	32,33
	Dichloromethane	*Staphylococcus aureus.* *Pseudomonas aeruginosa.* *Klebsiella pneumoniae.*	500 ug/mL 200 ug/mL 83 ug/mL	32,33
Syzygium cordatum	Methanol	*Staphylococcus aureus.* *Pseudomonas aeruginosa.* *Klebsiella pneumoniae.*	166 ug/mL 200 ug/mL 100 ug/mL	31
	Dichloromethane	*Staphylococcus aureus.* *Pseudomonas aeruginosa.* *Klebsiella pneumoniae.*	266 ug/mL 333 ug/mL 66 ug/mL	31

compounds capable of inhibiting MRSA growth. Whilst this value is higher compared to vancomycin (0.5-2 μg/mL), which is one of the current conventional antibiotics used in treatment of MRSA infections, the reporting of similar inhibitory activity is promising given that the vancomycin control is a concentrated, pure compound.[35] Future research will be essential to isolate and identify the specific compound(s) responsible for this antimicrobial activity.

The gram-negative species *Escherichia coli* shows varying susceptibility among the plant extracts. *Ptaeroxylon obliquum* hexane-acetone fractions showed potent inhibition, with an MIC of 80 μg/mL, indicating high activity.[32,33] However, chloroform-acetone fractions displayed noteworthy activity, with an MIC value of 240 μg/mL.[32,33] Furthermore, methanolic extracts of *O. bullata* also demonstrated noteworthy activity against *E. coli*, with an MIC of 166 μg/mL, while butanol-acetone extracts from *P. obliquum* exhibited only moderate activity at 1250 μg/mL.[31-33]

Bacillus cereus, another Gram-positive bacterium, showed susceptibility against *O. bullata* methanolic extracts, which produced strong activity with an MIC value of 66 μg/mL.[31] Activity against *B. cereus* from other plant extracts was not explicitly reported, suggesting a need for further investigation of their antibacterial effects against this microorganism.

Pseudomonas aeruginosa was susceptible to a number of the plant extracts despite its intrinsic resistance to many antibacterial agents.[36] Water-based extracts of *H. procumbens* showed promising activity, with an MIC of 20 μg/mL, whilst hexane-acetone fractions from *P. obliquum* exhibited noteworthy activity at 160 μg/mL.[30,32,33] Chloroform-acetone fractions of the same plant were active, with an MIC of 80 μg/mL.[32,33] Extracts of *P. rostratus* also show good activity, with methanolic and dichloromethane extracts recording MIC values of 250 μg/mL and 200 μg/mL, respectively.[31] Similarly, methanolic extracts of *S. cordatum* inhibited *P. aeruginosa* at an MIC of 200 μg/mL, although the dichloromethane extract exhibited lower efficacy at 333 μg/mL.[31] These results highlight that whilst *P. aeruginosa* remains challenging due to its intrinsic resistance, water-based extracts of *H. procumbens* show promising inhibition and should be subjected to further investigation to isolate the compound(s) that may be responsible for the inhibition.[30,36] Furthermore, combination studies with the conventional antibiotics are required to examine whether the compound can potentiate the effect of those antibiotics.

The growth of *Enterococcus faecalis*, a Gram-positive bacterium, is inhibited by aqueous extracts of *H. procumbens* with a potent MIC value of 20 μg/mL.[30] Fractionated hexane-acetone extracts from *P. obliquum* also demonstrated high activity, with an MIC of 80 μg/mL, while the chloroform-acetone fractions exhibited good activity at 320 μg/mL.[32,33] These findings indicate that *E. faecalis* is susceptible to specific fractions of *P. obliquum* and *H. procumbens*.

Klebsiella pneumoniae, a Gram-negative pathogen, demonstrated selective susceptibility to the plant extracts. Dichloromethane extracts of *P. rostratus* showed high activity, with an MIC of 66 μg/mL, while methanolic extracts displayed reduced activity.[31] Notably, *H. procumbens* showed no inhibition against *K. pneumoniae*, reflecting its resistance to certain plant extracts.[30]

Mycobacterium fortuitum, a fast-growing mycobacterial species, exhibited notable susceptibility to fractionated extracts of *P. obliquum*.[32,33] The hexane-acetone fraction displayed high activity, with an MIC of 20 μg/mL, while the chloroform-acetone fraction demonstrated good activity at 80 μg/mL.[32,33] These results suggest that *M. fortuitum* is highly susceptible to the *P. obliquum* fractions.

Whilst these findings are promising, it is important to critically assess the extraction methods, particularly in the study where the authors have used acetone, DMSO or other organic solvents to resuspend the crude plant extracts and use them in the MIC assays. As an example, one study reconstituted the dried extracts in 100% acetone after the drying process,[33] while another used 50% DMSO as the resuspension solution.[32] This is likely to compromise the research findings, as acetone and DMSO are toxic to bacteria and would undoubtably contribute to the bacterial inhibition and produce erroneously low MIC values.[37] The authors also failed to conduct or report the control assays for the solvent controls, shedding further doubt on the validity of their experimental findings. Studies should be conducted, where relevant, using extracts prepared in aqueous resuspension solutions alongside appropriate controls in order to verify the antibacterial properties of the plants in question.

CONCLUSION

In this review, we focused on six South African species used in traditional antibacterial medicine. Of these, five species have been scientifically studied for their antibacterial properties. The findings for these five species are promising, demonstrating significant potential in inhibiting the growth of selected bacterial species. However, the existing studies have largely focused on limited bacterial strains, leaving gaps in understanding of broader antibacterial spectrum. Further research is needed to evaluate these plant medicines against a wider range of bacterial strains and to isolate and identify the specific phytochemicals responsible for their antibacterial activity, as well as their mechanism of action. Furthermore, comprehensive studies should be conducted to thoroughly assess the efficacy and safety of these plant-based medicines for potential therapeutic use.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

AMR: Antimicrobial Resistance; **MRSA:** Methicillin-resistant *Staphylococcus aureus*; **MDR:** Multidrug Resistant; **MIC:** Minimum Inhibitory Concentration.

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