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Use of Nano-Formulated Ayurvedic Medicines: A Bridge Between Tradition and Modern Science in South India

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ABSTRACT

The integration of nanotechnology with traditional Ayurvedic medicine represents an exciting and emerging area of healthcare innovation. By combining the age-old wisdom of Ayurveda with the precision and efficiency of modern nanotechnology, researchers are developing new ways to enhance the effectiveness of herbal treatments. Nanotechnology allows for the creation of tiny drug delivery systems that can improve how Ayurvedic medicines are absorbed and utilized in the body, potentially making them more effective and faster-acting.

This study focuses on understanding how people from various communities in South India perceive this modern twist on traditional medicine. It explores their level of awareness about nano-formulated Ayurvedic products, their attitudes towards using such medicines, and whether they are willing to accept and adopt these innovations in their daily lives. The goal is to gain insight into how well traditional beliefs and cutting-edge science can coexist and be embraced by different cultural groups.

A cross-sectional survey was conducted with 1,200 respondents from Tamil Nadu, Kerala, Karnataka, Telangana, Andhra Pradesh, and Puducherry. Findings indicate there is growing interest coupled with moderate knowledge about nano-Ayurvedic therapies, especially among the educated and health-conscious population. Although there is considerable trust in conventional formulations, more than 60% of respondents expressed willingness to try nano-enhanced products, which indicates great potential for this area of integrative medicine. The study advocates for the development of public education campaigns, clinical trials, and regulations to systematically support the integration of evidence-based nano-Ayurvedic strategies into India's healthcare system.

Keywords: Ayurvedic Medicine, Nanotechnology, Nano-formulations, South India, Traditional Medicine, Public Perception, Integrative Healthcare

1. Introduction

Ayurveda, or "Science of Life", is one of the oldest known holistic healing systems that originated over 3,000 years ago in the Indian subcontinent. Following the theories of balancing the body's energies (doshas), Ayurveda uses a variety of herbal mixtures, nutrition, and lifestyle modifications to manage and mitigate illness. Today, Ayurveda is regarded not only as a cultural heritage in India but as a formal system of medicine [1].

With its acceptance and historical significance, Ayurvedic medicine has faced scientific scrutiny in the past few decades. The main concerns are the lack of reproducibility in pharmacokinetics, inconsistent herbal mixtures, delayed therapeutic effects, and lack of evidence- based clinical trials that meet contemporary legal standards [2], [3]. However, due to these difficulties, it remains a complementary and alternative form of medicine in many regions of the world, hindering its adoption as a primary medical system. These issues can be solved like never before using nanotechnology.

Nanotechnology, which involves the design, development, and application of systems and materials at the nanoscale (1 to 100 nanometers), has improved the pharmaceutical sciences through enhanced drug solubility, bioavailability, delivery targeting, and controlled release [4], [5]. The integration of nanotechnology with Ayurveda increases the bioavailability of herbal formulations, allowing for precise cellular targeting for herbal extract release, further augmenting therapeutic outcomes [6].

Bhasma, the incinerated metal and mineral preparations in Ayurveda, practiced long before we had any knowledge of nanoscience, relied on barebone principles of what would today be called nanoscience. Recent scientific research has shown that many traditional bhasmas include nanoparticles [7]. So, rather than being a form of deviation from traditional practices, modern nano-formulations in Ayurveda serve to augment ancient wisdom using contemporary technologies.

This is just one such context, while South India – the region of India which includes Tamil Nadu, Kerala, Karnataka, Telangana, Andhra Pradesh, and Puducherry – occupies a unique place in the world map of traditional medicine. It has well established systems like Ayurveda and Siddha and is famous for the extensive use of medicinal herbs in both rural and urban healthcare settings.

The area has an established academic infrastructure for biomedical research and local pharmaceutical activities, as well as having the capability to develop and assess nano-structured drugs [8], [9].

Despite these conditions being favorable, there is a lack of empirical data examining the public understanding, perception, and acceptability of nano-methods in Ayurvedic medicine. Public opinion does matter, particularly in the case of a health innovation that is a combination of traditional beliefs and modern science [10]. With growing appreciation of nanotechnology at the global level, it becomes important to evaluate the view of such care within culture bound systems like Ayurveda, especially in places where the two systems are present.

We trust this study will aid in bridging that gap exploring the residents of south India perceptions towards nano-formulated medicinal Ayurvedic medicines. This study goes beyond measuring the awareness and usage levels; it focuses on the willingness and the

socio-cultural, educational, and geographic factors that shape public perceptions about the integrative medical approach.

The findings will assist policy makers, pharmaceutical developers, and health care providers evaluate the public's level of trust and educational needs. It will also enable a more evidence-based approach to the incorporation of nano-Ayurveda into the healthcare systems.

2. Methods

2.1 Study Design and Population

A cross-sectional study was performed over six weeks starting from January to March 2025 in the South Indian states of Tamil Nadu, Kerala, Karnataka, Andhra, Telangana, and Puducherry. These regions are unique because of their differences in culture, socioeconomic status, and healthcare system which are helpful in enhancing the generalizability of the findings of the study. This study aimed to collect holistic data through the structured questionnaires incorporating demographic, lifestyle, health, and region-specific information relevant to the study objectives. Participants were identified from urban and suburban healthcare facilities, community centers, and academic institutions using purposive and convenience sampling techniques. All participants gave informed consent prior to participating in the study, and ethical approval was obtained from the relevant institutional review boards.

2.2 Sample Size and Sampling Method

At a 95 percent level of confidence and a 5 percent margin of error, the sample size was determined to be no less than 1,200 participants. To improve participation and minimize sampling bias, a stratified random sampling method was employed. The population was divided into strata based on key demographics such as geographic regions (rural and urban) and occupational groups like health care, industrial, office, and self-employment. Age categories from 18 to over 60 years were also included. Proportional allocation was implemented to ensure that the sample captured the demographic balance within each of the six regions. Such strategies help to ensure adequate representation for different subpopulations which enhances analyses conducted at the subgroup level and enables the overall findings of the study to attain greater validity.

2.3 Data Collection Tool

A validated comprehensive questionnaire was developed with recognition of understanding bias and content validity for different groups of respondents. This instrument had five main components:

(1) socio-demographics which aggregates: age, gender, education, occupation, income, and place of residence;

(2) Awareness, gauging the participant's knowledge of the subject;

(3) Perception, assessing beliefs and attitudes, and expected value or risks associated with the issue;

(4) Usage, measuring specific behaviors or practices regarding the subject under study and

(5) Feedback, gathering participant's suggestions about their general impressions concerning the topic and the subject as a whole. The questionnaire also had closed-ended questions that included multiple-choice and Likert scale items to facilitate quantitative analysis alongside open-ended questions aimed at providing rich qualitative insights.

In a bid to eliminate cultural and linguistic biases, the survey was translated and adapted into five regional languages: English, Tamil, Malayalam, Telugu, and Kannada. Each translation underwent independent verification and was tested with a group of bilinguals to ascertain clarity and consistency against the original text. This process ensured that the questionnaire was responsive to the multicultural and multilingual needs of the six South Indian regions.

2.4 Data Analysis

The data was analyzed systematically using IBM SPSS Statistics Version 26. The descriptive statistics were calculated for the study population's socio-demographic characteristics using basic frequencies, percentages, means, and standard deviations. For categorical variables such as demographic characteristics level (e.g., age, gender, education, occupation, and area of residence), the level of awareness was tested using Chi-square tests of independence. A p value of less than 0.05 was deemed statistically significant.

For the open-ended responses, thematic analysis was used to identify and interpret the most salient patterns and storylines. Responses were coded manually and grouped into themes inductively through several rounds of review. The coding was completed by two independent researchers to enhance the inter-rater reliability, and disagreements were addressed

through discussions until an agreement was reached. The strength of this mixed-methods design was that it provided a more holistic view of quantitative and qualitative aspects of the data.

3. Results

3.1 Socio-Demographic Profile

Table 1: Demographic Characteristics of Respondents (N=1,200)

Variable	Category	Frequency	Percentage (%)
Gender	Male	618	51.5
	Female	576	48.0
	Other	6	0.5
Age	18–30 years	420	35.0
	31–45 years	384	32.0
	46–60 years	276	23.0
	Above 60	120	10.0
Education	Below 12th Grade	198	16.5
	Graduate	540	45.0
	Postgraduate & Above	462	38.5
Region	Tamil Nadu	252	21.0
	Kerala	216	18.0
	Karnataka	216	18.0
	Telangana	192	16.0
	Andhra Pradesh	216	18.0
	Puducherry	108	9.0

The study sample was made up of 1,200 participants from six South Indian regions. In terms of the sample's gender distribution, males comprised a higher proportion of the sample (51.5%, n = 618) than females, who made up 48.0% (n = 576). A small minority (0.5%, n = 6) were classified as non-binary gender and so identified freely, which indicates some participation from diverse gender categories (table-1).

In relation to age, the sample was mostly young and middle-aged. Respondents aged 18 to 30 years represented a significant portion (35.0%, n = 420), followed by those aged 31 to 45 years (32.0%, n = 384). Participants in the 46 to 60 years age bracket made up 23.0% (n = 276), and those above 60 made up 10.0% (n = 120). The older and younger adults in the population are well represented and thus can be usefully studied in age based subgroups.

More than half of the participants reported completing education below the 12th grade (16.5%, n = 198) and thus had relatively low educational attainment. However, some of the respondents were graduates accounting for 45.0% (n = 540), suggesting a rounded level of education attainment was present in the sample. In addition, 38.5% (n = 462) of participants possessed postgraduate degrees or higher qualifications.

Such a distribution indicates that a majority of respondents who took part in the study probably hold some level of higher education, which likely affects their level of awareness and perception that was measured in the study.

The representation of these regions was reasonably equally divided among the six regions of South India that were part of the research. Respondents from Tamil Nadu formed the highest proportion of respondents at 21.0%, n = 252. This was followed by Kerala, Karnataka and Andhra Pradesh with each of them contributing 18.0% n = 216. Telangana had 16.0% n = 192, and Puducherry had the least proportion with 9.0% n = 108. This proportionate allocation makes certain that the outcomes are regionally representative in terms of socio-cultural and economic diversity.

In conclusion, the findings related to the socio-demographic characteristics of respondents with valid addresses are geographically and ethnically diverse, thus enhancing the credibility and applicability of the research results [11].

3.2 Awareness and Perception

Table 2: Awareness and Perception about Nano-Ayurvedic Medicines

Question	Yes (%)	No (%)	Not Sure (%)
Heard of Ayurvedic Medicine	98.5	1.5	-
Heard of Nanotechnology in Medicine	62.3	29.4	8.3

Heard of Nano-Formulated Ayurvedic Products	43.8	48.7	7.5
Believe Nano-Ayurveda is more effective	58.2	19.5	22.3
Willing to try nano-Ayurvedic medicine	63.4	12.5	24.1
Prefer nano-enhanced Ayurveda over allopathy	38.7	41.2	20.1

Traditional Ayurvedic medicine remains relatively known, and appropriately so, since 98.5% of survey respondents had heard of it. This strongly illustrates the widespread recognition of Ayurveda and highlights its rich cultural heritage throughout South India. Nevertheless, awareness of the term 'nanotechnology in medicine' plummeted to 62.3%, meaning that although a considerable portion of the population knows basic modern medical concepts, one-third (29.4%) had not heard of such a topic and 8.3% were unsure (table-2).

Familiarity waned even further when participants were asked about nano-formulated Ayurvedic products, where only 43.8% admitted to being familiar with such products. A Majority (48.7%) had not heard of such products at all, with 7.5% being unsure. This demonstrates the lack of knowledge concerning the application of nanotechnology in traditional medicine systems like Ayurveda.

Surveyed participants displayed the most optimistic perception regarding the efficacy of nano-Ayurvedic formulations, as 58.2% believed that nano-Ayurvedic preparations could be more effective than traditional ones. Still, 22.3% were undecided and 19.5% disagreed, suggesting a mixed view – and possible skepticism – among a portion of the population [12].

Fortunately, the vast majority of respondents were willing to try nano-Ayurvedic medicine, at 63.4%, indicating that there is still hope for innovation in traditional healthcare systems.

Regardless, 12.5% of respondents were unwilling, while 24.1% of respondents were indifferent, showing promise for acceptance with more public outreach and educational communications focused on evidence.

With regards to preference, only 38.7% preferred nano-enhanced Ayurveda, with a slightly higher proportion of 41.2% favoring allopathic treatments. 20.1% of respondents opted for

the ‘don’t know’ option. This illustrates the enduring reliance on allopathy as the unquestioned standard, despite the budding interest in sophisticated Ayurvedic remedies.

In summary, while the general awareness of Ayurveda might be still extremely high, there is a striking drop in acquaintance as well as confidence when it comes to the focus on its nano-formulated versions. The data emphasizes the need of educational campaigns aimed at dispelling myths alongside broader dissemination of research to counter the discrepancy between perception and reality in regard to nano-Ayurvedic medicine [13].

3.3 Use and Experience

Table 3: Usage and Feedback on Nano-Ayurvedic Products

Indicator	Frequency	Percentage (%)
Used Nano-Ayurvedic Medicine	324	27.0
Found it Effective	246	76.0
Experienced Side Effects	48	14.8
Would Recommend to Others	288	88.8

From the 1,200 respondents, only 27.0% (n = 324) reported exercising the option of using nano-Ayurvedic medicines, which indicates that actual usage remains relatively low (table-3). This suggests that there is growing awareness and interest, albeit limited due to product constraints, low promotional activity, or safety and efficacy concerns [14].

Among product users, a significant majority—76.0% (n = 246)—considered the medicines to be effective. This underlines the therapeutic value experienced alongside the benefits associated with incorporating nanotechnology into Ayurvedic medicine. Such an outcome could increase adoption and trust among potential users.

With regard to side effects, 14.8% (n = 48) of users reported negative effects, which is low but still emphasizes a lack of adequate standardization, quality control, and straightforward guidelines which could result in negative consequences. Knowing the nature and extent of side effects would be crucial for further clinical evaluation.

In terms of recommendation behavior, the majority—88.8% (n = 288)—would recommend nano-Ayurvedic products to others, showcasing robust endorsement and confidence that stems from actual users. In regions where recommendations from other patients have a considerable impact on healthcare decisions, such endorsements could serve as important stimuli for adoption.

Overall, while the level of usage is low, user feedback from the surveys is mainly positive.

The information indicates that there is a helpful possibility for wider acceptance as long as side effect concerns are mitigated and reliable information increases accessibility and is made public [15].

4. Discussion

This study is amongst the first, if not the first, attempts at comprehensively documenting the awareness, perception, and receptivity levels concerning nano-formulated Ayurvedic medicines in South India. The juxtaposition of different traditional knowledge systems along with modern day nanotechnology, which is still in its infancy, presents enormous potential for therapeutic development. It is worth noting that the study showed that more than 60% of respondents were willing to try formulations of Ayurveda enhanced with nanotechnology, which suggests that there is growing public acceptability towards the more modernized versions of alternative medicine. These findings highlight the growing acceptance of the infusion of technology into the culture bound systems of healthcare.

The figures come in relatively low for the proportion of respondents saying they are aware of nanotechnology in medicine (62.3%) and nano-Ayurveda (43.8%), but were relatively high amongst urban educated populations. This development mirrors findings from earlier regional studies conducted in Maharashtra and Gujarat. This suggests that there is a broader national trend where both urbanization and education serve as accelerators for acceptance of medical innovations. The much higher acceptability from individuals with graduate education further supports the argument that education influences progressive views on hybrid medical systems. This group does seem much more open to the application of evidence based developments in Ayurveda and consider nano-formulation a scientific improvement rather than a deviation from the roots of the practice [16].

Even though there is extreme familiarity with traditional Ayurveda (98.5%), the proportion of people actually using the nano-formulated products is much lower at only 27%. The barriers to adoption highlighted in the analysis of open-ended responses, including a "lack of access to authentic products," "limited promotional or public knowledge outreach," and "fear of side effects," most pointed to gaps in the public education and regulatory availability such as oversight, product availability, and education [17].

As the World Health Organization's recommendations regarding the regulation of herbal medicine mention [9], such obstacles could be lessened through formulating information dissemination strategies with the design of certified, clinically tested, and standardized nano-Ayurvedic products [18].

Most notably, this study revealed that among those who had tried nano-Ayurvedic formulations, an astounding 88.8% expressed their intention to recommend them to other people. The endorsement rate being this high is likely to indicate that experiences and effectiveness, as perceived by the participants, plays a significant role in the trust enabling them to recommend these formulations. Thus, user-driven advocacy offers powerful insights to complement formal campaigns aimed at increasing public awareness.

Furthermore, the regional patterns provided additional evidence regarding the role of cultural context on health-related choices. Both Kerala and Tamil Nadu, which are known to host deep-rooted Siddha and Ayurvedic Traditions, demonstrated significantly greater usage rates of nano-Ayurvedic products. This provides evidence in support of the assumption that there is a positive association between cultural exposure and historical dependence on traditional medicine and acceptance of its modern derivatives [19]. On the other hand, regions with less institutionalized support for traditional systems had, as expected, relatively lower uptake which highlights the need for targeted policy initiatives.

Taken together, these findings reveal that the adoption of nano-Ayurvedic medicine is promising, but still uneven across the regions.

The advancement for the integration of nanotechnology with Ayurveda for the various demographics in India will be highly facilitated through public involvement, valid research endorsement, equitable access, and through also policy barrier elimination [20].

5. Conclusion

This research highlights the enormous promise of nano-formulated Ayurvedic medicines as an Ayurvedic nanotechnology interface between traditional medicine and scientific innovation in the culturally rich and health-conscious South India. The results indicate that although the general awareness of nano-Ayurveda is modest, the receptiveness to using such formulations is particularly high among the educated population, indicating high acceptability of Ayurveda integrated with modern technology.

But there are large gaps concerning the responsible use and wider acceptance of nano-Ayurvedic products that pose challenges, such as lack of public availability of validated formulations, absence of defined safety regulations and standardization policies, and the absence of scientific communication directed to healthcare professionals and the public. Without guidelines regarding quality assurance, validation of efficacy, and controlled dissemination of information to the public, the potential of nano-Ayurveda will remain under-used.

The barriers are best dealt with using a combination of strategies. Public health campaigns with accurate and culturally relevant scientific information should be designed. They should aim to increase public awareness and tackle existing misconceptions. Controlled clinical studies and pharmacodynamic studies should be conducted to provide irrefutable evidence regarding safety, effectiveness, and appropriate dosage.

The incorporation of nano-Ayurveda into the formal educational frameworks of Ayurveda, pharmacy, and public health could cultivate practitioners and researchers capable of driving advancements in this discipline.

With evidence-based traditional medicine along with other forms of integrative healthcare, India is able to situate itself as a leader and in turn strengthen emerging gaps in-mid 21st century sustainable healthcare as globally innovated.

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