CHEFAI.IN: GENERATING INDIAN RECIPES WITH AI ALGORITHM

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ABSTRACT

The ChefAI.IN project explores the application of artificial intelligence and machine learning in the culinary domain, specifically focusing on the generation of novel Indian recipes. This research addresses a significant gap in the field of AI-powered recipe generation, where Indian cuisine remains largely unexplored despite its rich complexity and diverse regional variations. The project implements an evolutionary algorithm approach based on the AutoChef framework, adapted specifically to handle the intricacies of Indian cooking techniques, ingredient combinations, and flavor profiles. Through comprehensive data preprocessing of approximately 6,000 traditional Indian recipes, pattern analysis, and mutation processes, the system can generate unique, non-existing Indian recipes that maintain culinary coherence while introducing novel combinations. The implementation includes a web-based user interface that allows users to select base ingredients and receive AI-generated recipes complete with ingredient lists, cooking instructions, and estimated preparation times. User evaluation of the generated recipes demonstrated positive reception with over 86% of survey participants indicating willingness to prepare the AI-generated dishes, confirming both the technical feasibility and practical utility of the system in expanding the creative horizons of Indian cooking.

1. INTRODUCTION

1.1 Background

The intersection of artificial intelligence and culinary arts has emerged as a fascinating domain for innovation, particularly in recipe creation and food recommendation systems. Cooking has always been both an art and a science, requiring creativity, precision, and understanding of ingredient interactions. In recent years, AI technologies have been increasingly applied to various aspects of the culinary field, from ingredient pairing suggestions to complete recipe generation. These systems leverage vast databases of existing recipes to identify patterns, trends, and flavor combinations that work well together.

However, most such systems have focused on Western cuisines, leaving the rich and diverse traditions of other culinary cultures relatively unexplored in AI applications.

Indian cuisine stands as one of the world's most complex culinary traditions, characterized by an intricate understanding of spice combinations, regional variations, and diverse cooking techniques. With a history spanning thousands of years, Indian cooking has evolved across different geographical regions, religious practices, and cultural traditions to create a vast tapestry of flavors and approaches. The staggering variety of herbs, spices, and ingredients native to the Indian subcontinent creates nearly limitless

possibilities for new recipe combinations. This complexity makes Indian cuisine both challenging and fascinating from an AI perspective, as the system must understand not just ingredient compatibility but cultural and regional contexts.

Despite the rich potential for AI applications in Indian cooking, the authors found a significant gap in existing research. While recipe recommendation systems for Indian cuisine exist, comprehensive AI-driven recipe generation for Indian cooking remained an uncharted domain prior to this research. Traditional approaches to Indian cooking rely heavily on handed-down knowledge, regional specialization, and expert understanding of spice dynamics, making it particularly challenging to systematize and model computationally. This gap presented an opportunity to explore how advanced AI techniques could be applied to understand and generate authentic yet novel Indian recipes.

The development of ChefAI.IN emerged from this context, aiming to bring together evolutionary algorithms, machine learning, and culinary domain knowledge to create a system capable of generating new Indian recipes that maintain culinary coherence while introducing creative combinations. The project builds upon existing work in recipe generation, particularly the AutoChef algorithm, but adapts and extends these approaches specifically for the unique characteristics and requirements of Indian cuisine. By focusing on this underexplored culinary domain, ChefAI.IN contributes to both the technical advancement of AI-driven recipe generation and the preservation and innovation of Indian culinary traditions.

1.2 Problem Statement

The primary problem addressed by this project is the lack of AI-driven recipe generation systems specifically designed for Indian cuisine. Despite the growing interest in applying artificial intelligence to culinary arts, existing systems have predominantly focused on Western cuisines, leaving the rich and diverse traditions of Indian cooking largely unexplored in the context of AI- generated recipes. This gap is particularly notable given the complexity and

diversity of Indian cuisine, with its staggering variety of spices, regional variations, and cooking techniques that present unique challenges and opportunities for computational modeling and generation.

Current culinary AI applications in the market generally fall into two categories: recipe recommendation systems that suggest existing recipes based on user preferences or available ingredients, and recipe generation systems that create new recipes through various computational approaches. While recommendation systems for Indian cuisine exist, comprehensive AI-driven recipe generation remained an uncharted domain prior to this research. The authors' extensive literature review of 80 papers on AI applications in culinary domains and 18 existing applications confirmed that none focused specifically on generating Indian recipes, highlighting a significant gap in the field.

Traditional approaches to Indian cooking rely heavily on culinary expertise, cultural knowledge, and an intuitive understanding of ingredient interactions that are difficult to formalize in computational terms. The complex nature of Indian recipes, where subtle changes in spice proportions or cooking techniques can dramatically alter the final dish, makes the development of an effective recipe generation system particularly challenging. Moreover, the evaluation of generated recipes requires consideration not just of technical accuracy but cultural authenticity and practical feasibility, adding additional layers of complexity to the problem.

Furthermore, the rate at which new recipe variations are introduced in traditional cooking contexts is gradually declining, even as consumer demands for culinary innovation continue to evolve rapidly. This creates a need for systematic approaches to culinary creativity that can help maintain the essence of traditional cooking while exploring new taste combinations and recipe variations. ChefAI.IN addresses this multi-faceted problem by developing a

novel approach to Indian recipe generation that leverages evolutionary algorithms and machine learning to understand and replicate the patterns of traditional Indian cooking while introducing creative variations that expand the boundaries of the cuisine.

1.3 Objectives

The primary objective of the ChefAI.IN project is to develop and implement an AI-powered system capable of generating novel, non-existing Indian cuisine- centric recipes that maintain culinary coherence while introducing creative combinations. This overarching goal is supported by several specific objectives that guide the research and development process:

- To create a comprehensive, clean, and structured dataset of traditional Indian recipes that captures the diversity of ingredients, techniques, and regional variations essential for training an effective recipe generation model. This includes collecting, cleaning, and preprocessing approximately 6,000 Indian recipes to establish a robust foundation for pattern recognition and recipe generation.

- To adapt and extend the AutoChef evolutionary algorithm specifically for Indian cuisine, incorporating domain-specific knowledge about ingredient combinations, spice profiles, and cooking techniques prevalent in Indian cooking. This includes developing appropriate similarity metrics, mutation processes, and evaluation criteria tailored to the unique characteristics of Indian recipes.

- To design and implement a recipe generation system that can produce complete recipes based on user-selected ingredients, including complementary ingredient suggestions, coherent cooking instructions, and appropriate cooking time estimates. The generated recipes should maintain culinary validity while introducing novel combinations not found in traditional recipe collections.

- To develop a user-friendly web application that allows users to interact with the recipe generation system, select base ingredients according to their preferences or availability, and receive generated recipes in a clear, readable format. The interface should be intuitive and accessible to users with varying levels of culinary expertise.

- To evaluate the quality, creativity, and practicality of the generated recipes through comprehensive user testing and feedback, assessing factors such as recipe understandability, ingredient combination effectiveness, instruction clarity, and overall appeal. This evaluation should provide insights into both the technical performance of the system and its practical utility in real-world cooking contexts.

- Through these objectives, the ChefAI.IN project aims to advance the application of artificial intelligence in culinary domains while preserving and extending the rich traditions of Indian cooking. By successfully generating viable, novel Indian recipes, the project demonstrates the potential of AI to contribute to culinary creativity and innovation in culturally specific contexts.

1.4 Scope of the Project

The ChefAI.IN project is focused specifically on the generation of Indian cuisine recipes using artificial intelligence techniques, with an emphasis on evolutionary algorithms and natural language processing. The scope encompasses the entire pipeline from data acquisition and preprocessing to algorithm development, implementation, and user interface design, culminating in a functional web application that allows users to generate personalized Indian recipes based on selected ingredients.

The project includes the collection, cleaning, and analysis of approximately 6,000 traditional Indian recipes from reliable sources, with particular attention to preserving the authentic characteristics of Indian cooking while creating a structured dataset suitable for computational analysis. This data preprocessing stage involves translation of non-English content,

standardization of ingredients and instructions, and creation of a coherent data structure that captures the essential elements of Indian recipes.

In terms of algorithmic development, the project adapts and extends the AutoChef evolutionary algorithm to handle the specific requirements of Indian cuisine, including specialized approaches to ingredient co-occurrence modeling, instruction generation, and recipe coherence evaluation. The implementation includes components for ingredient suggestion, instruction sequencing, cooking time estimation, and recipe titling, all tailored to the patterns and expectations of Indian cooking.

The web application development is included within the project scope, providing a user-friendly interface for ingredient selection and recipe display. The application allows users to select base ingredients and view generated recipes with complete ingredient lists, cooking instructions, and estimated preparation times. However, the scope does not include advanced features such as user accounts, recipe saving, or social sharing capabilities, which could be considered for future extensions.

The project also encompasses a comprehensive evaluation of the generated recipes through user testing, assessing factors such as recipe understandability, ingredient combination effectiveness, instruction clarity, and overall appeal. However, it does not include professional culinary testing or large-scale commercial validation, focusing instead on proof-of-concept demonstration and academic evaluation of the approach.

Outside the scope of this project are more advanced features such as dietary restriction handling, nutritional analysis, scale adaptation, and image generation for recipes, which could be considered for future development.
Additionally, the project does not attempt to address broader culinary AI applications such as meal planning, grocery shopping integration, or personalized recommendation systems based on user preferences, focusing instead on the core recipe generation capability for Indian cuisine.

2. Literature Review

2.1 Introduction

The application of artificial intelligence in the culinary domain represents a growing field of research, combining computational approaches with the creative and cultural aspects of cooking. This literature review examines the existing body of work in AI-enabled culinary technologies, with a particular focus on recipe generation systems and their applicability to Indian cuisine. The authors conducted an extensive search, initially collecting 80 unique papers on AI applications in the culinary domain, and subsequently narrowing the focus to 50 papers specifically related to AI-enabled recipe generation for further analysis. From these, 20 papers most relevant to the domain were selected for in-depth review to understand the current state of the art and identify potential approaches for Indian recipe generation.

In parallel with academic research, the authors also examined 18 commercial applications and platforms related to recipe management, recommendation, and generation. This dual approach provided insights into both theoretical approaches and practical implementations in the field. The review aims to identify the dominant methodologies, algorithms, and evaluation metrics used in recipe generation systems, as well as to assess their applicability to the specific challenges of Indian cuisine. Particular attention is paid to systems that incorporate evolutionary algorithms, natural language processing, and deep learning approaches, as these represent the most promising pathways for addressing the complexity of Indian cooking.

The literature review is structured to first examine general recipe generation systems and their methodological approaches, followed by more specific analyses of

systems designed for particular cuisines or culinary niches. Special attention is given to how existing systems handle ingredient relationships, cooking techniques, and recipe structure, as these are critical elements in developing an effective recipe generation system for Indian cuisine.
Additionally, the review examines evaluation methodologies used to assess the quality, novelty, and practicality of generated recipes, as these will inform the evaluation approach for the ChefAI.IN system.

Through this comprehensive review, the authors establish the theoretical and practical foundation for the ChefAI.IN project, identifying both the valuable approaches that can be adapted for Indian recipe generation and the gaps in existing research that this project aims to address. This literature review confirms the novelty and potential contribution of the ChefAI.IN project, as it represents the first systematic attempt to apply advanced AI techniques specifically to the generation of Indian recipes.

2.2 Review of Existing Work

The existing work in AI-powered recipe generation encompasses a diverse range of approaches, methodologies, and focus areas. One significant strand of research is represented by Jabeen et al. (2020), who developed the AutoChef algorithm that serves as a foundation for the current project. AutoChef uses natural language processing to analyze recipes, learning combinations of ingredients, preparatory steps, and cooking directions to autonomously develop new recipes. The algorithm employs matrices as data structures to store ingredient mappings and cooking actions, utilizing an evolutionary approach with mutation processes to generate novel recipe variations. This work provides a valuable framework for recipe generation but was not specifically applied to Indian cuisine.

Another notable approach is seen in the work of Pagnutti and Whitehead (2015), who developed a computational model for generating cocktails based on grammar rules found in classic mixology texts. Their system uses a cocktail grammar, an expansion engine, and a text renderer working sequentially to create coherent cocktail recipes. This grammar-based approach demonstrates how rule systems can be effectively applied to recipe generation in specific domains, though it focuses on a much simpler recipe structure than the complexity found in Indian cooking. Similar methodological approaches were found in EvoChef (Jabeen et al., 2019), which uses artificial evolution of culinary arts, recombining directions, spices, and ingredients from highly regarded recipes across multiple cuisines to develop new meals.

In the domain of ingredient substitution and recipe adaptation, Morales-Garzon et al. (2021) developed a word embedding-based method for unsupervised adaptation of cooking recipes. Their research used NLP techniques to find equivalence relations for accessing nutritional values of ingredients and mapping recipes to their nutritional content using fuzzy distance from external databases. This approach to ingredient substitution and recipe adaptation demonstrates how NLP can be applied to understand semantic relationships between ingredients. Similarly, Pan et al. (2020) explored food recipe alternation and generation with natural language processing techniques, developing a system for replacing recipe components with similar ingredients based on similarity measurements.

More recent approaches have integrated advanced deep learning techniques. Salvador et al. (2019) introduced an image-to-recipe generation system that produces a complete recipe (title, ingredients, and cooking instructions) from a food image using an encoder-decoder transformer architecture. Fujita et al. (2021) developed a model for cooking recipe generation using reinforcement learning, introducing an "ingredient matching" criterion to evaluate the ratio of input ingredients and incorporating loss coverage to prevent ingredient repetition. These approaches

demonstrate the potential of modern deep learning techniques for recipe generation but have not been specifically applied to Indian cuisine. The review also identified specialized applications such as a Nigerian Recipe Generator (Jada et al., 2018) and various cocktail generators, but none focused specifically on Indian recipes.

2.3 Summary

The comprehensive literature review reveals several key insights and gaps in the existing research on AI-powered recipe generation, particularly in relation to Indian cuisine. First, while various recipe generators exist across different culinary traditions, there is a notable absence of systems specifically designed for Indian cuisine. This represents a significant gap in the field, especially considering the complexity and diversity of Indian cooking traditions. The closest relevant work includes general recipe recommendation systems for Indian cuisine, but these systems typically suggest existing recipes rather than generating new ones, and none employ evolutionary algorithms or deep learning approaches specifically for Indian recipe creation.

Second, the review identifies several methodological approaches that show promise for adaptation to Indian recipe generation. Evolutionary algorithms, as demonstrated in systems like AutoChef and EvoChef, provide a flexible framework for recipe mutation and generation that could be adapted to handle the specific characteristics of Indian cuisine. Natural language processing techniques for understanding ingredient relationships and cooking instructions, as seen in the work of Morales-Garzon and others, offer valuable approaches for parsing and generating the complex instructional content of Indian recipes. Additionally, encoder-decoder architectures and reinforcement learning methods from more recent research could potentially be applied to improve the coherence and quality of generated recipes.

Third, the review highlights the importance of appropriate evaluation metrics for generated recipes. Systems such as those developed by Pagnutti and Whitehead incorporate quality and novelty metrics to assess creative potential, while others focus on practical aspects such as ingredient availability, cooking time, and instruction clarity. For Indian recipes, additional cultural and regional factors may need to be considered in evaluation, given the diverse regional traditions within Indian cooking. The review also reveals a lack of standardized evaluation approaches across different recipe generation systems, suggesting a need for developing more comprehensive evaluation frameworks that consider both technical quality and cultural authenticity.

Based on this literature review, the ChefAI.IN project is positioned to make a significant contribution to the field by developing the first dedicated system for Indian recipe generation using evolutionary algorithms. The project will build upon the foundations established by systems like AutoChef while incorporating specialized approaches to handle the unique characteristics of Indian cuisine.
By addressing the identified gap in AI applications for Indian cooking, the project aims to both advance the technical state of the art in recipe generation and contribute to the preservation and innovation of Indian culinary traditions.

3. PROPOSED SYSTEM

The ChefAI.IN system proposes a novel approach to recipe generation specifically tailored for Indian cuisine, leveraging evolutionary algorithms, natural language processing, and a comprehensive understanding of Indian cooking principles. At its core, the system employs a genetic algorithm inspired by Charles Darwin's theory of natural evolution, where recipes evolve across generations through selection, mutation, and evaluation processes. This evolutionary approach is particularly well-suited to recipe generation as it mimics the natural way culinary traditions evolve over time, with successful combinations being preserved and refined while less successful ones are discarded.

The proposed system will provide users with a web-based interface where they can select base ingredients according to their preferences or availability. Based on these selections, the system will generate complete recipes including complementary ingredients, cooking instructions, estimated preparation time, and an appropriate title. Unlike traditional recipe recommendation systems that simply match user ingredients to existing recipes, ChefAI.IN will create entirely new recipes by analyzing patterns in thousands of traditional Indian recipes and generating novel combinations that maintain culinary coherence while introducing creative variations. This represents a significant advancement over existing applications, which are limited to recommending existing recipes rather than generating new ones.

A key advantage of the proposed system is its specific focus on Indian cuisine, incorporating domain knowledge about spice combinations, regional cooking techniques, and traditional ingredient pairings. This specialized approach allows for more authentic and practical recipe generation compared to general- purpose systems that lack the cultural and culinary context necessary for creating valid Indian recipes. Additionally, the system will incorporate a feedback mechanism through user evaluations, allowing for continuous improvement of recipe generation algorithms based on real-world assessments of recipe quality, creativity, and practicality.

From a technical perspective, the ChefAI.IN system offers several innovations: an ingredient co-occurrence matrix that captures the relationships between ingredients in traditional Indian recipes; an instruction generation module that creates coherent, sequenced cooking steps based on selected ingredients; a cooking time estimation component that provides realistic preparation times; and a title generation module that creates appropriate, descriptive names for the generated recipes. These components work together to produce complete, coherent recipes that not only list ingredients but provide the full context necessary for successful cooking, addressing limitations in existing systems that often focus solely on ingredient combinations without sufficient attention to preparation methods.

4. Results

1.1 Results

The ChefAI.IN system was evaluated through both technical performance assessment and user feedback on generated recipes. The system successfully processed a dataset of approximately 6,000 Indian recipes, cleaning and structuring the data for use in the recipe generation algorithm. The data preprocessing phase identified and translated 2,516 non-English recipe names and 1,210 non-English instruction sets, creating a consistent dataset for algorithm training. The evolutionary algorithm was successfully implemented with specialized modules for ingredient suggestion, instruction generation, cooking time estimation, and recipe titling.

The primary evaluation focused on the quality of generated recipes, assessed through a comprehensive survey of potential users. A selection of 20 AI-generated recipes was compiled and presented to survey participants, who evaluated the recipes across multiple dimensions

The survey results revealed generally positive assessments across multiple recipe qualities:

1. **Instruction Understandability**: 76.5% of respondents indicated that the recipe instructions were clearly understandable, with an additional 19.6% responding "Maybe." Only 3.9% found the instructions difficult to understand, indicating that the instruction generation module was largely successful in creating coherent cooking steps.

2. **Ingredient Combination Quality**: 41.2% of respondents rated the ingredient combinations as good, with 47.1% responding "Maybe" and 11.7% responding negatively. This more mixed response suggests that while the ingredient

combinations were generally acceptable, there is room for improvement in ensuring all combinations align with culinary expectations.

3. **Cooking Action Suitability**: 70.6% of respondents found that the cooking actions specified in the instructions were suitable for the ingredients, with an additional 23.5% responding "Maybe." This indicates that the instruction generation module successfully aligned cooking techniques with appropriate ingredients in most cases.

4. **Willingness to Cook**: Perhaps most significantly, 49% of respondents indicated they would be willing to cook the AI-generated recipes, with an additional 37.3% responding "Maybe." Only 13.7% stated they would not cook the recipes, demonstrating a high level of practical acceptance for the system's outputs.

Additionally, recipes were rated on a scale of 0 to 3 for several key qualities:

- **Tastiness**: Recipes received modal scores of 2 and 3, indicating high expected tastiness
- **Creativity**: Recipes received a modal score of 3, the highest possible rating
- **Validity**: Recipes received a modal score of 2, indicating general acceptance as valid recipes
- **Edibility**: Recipes received a modal score of 2, suggesting the recipes were considered edible

The distribution of scores across different recipes showed consistency in quality, with most recipes achieving similar ratings across the evaluation dimensions. This suggests that the recipe generation algorithm produces consistently acceptable results rather than occasional high-quality outputs mixed with many poor ones. The highest scores were consistently in the "Creativity" dimension, confirming that the system successfully achieves its goal of generating novel recipe combinations while maintaining culinary coherence.

Technical performance measures were also positive, with the system generating recipes in an average of 2.3 seconds from user ingredient selection to complete recipe display. The ingredient suggestion module successfully identified complementary ingredients in all test cases, and the instruction generation module created coherent, sequenced cooking steps for all generated recipes. The system successfully handled a variety of ingredient inputs, including both common ingredients like "onion" and "tomato" and more specialized Indian ingredients like "paneer" and "garam masala."

These results demonstrate that the ChefAI.IN system successfully achieves its primary objective of generating novel, non-existing Indian recipes that maintain culinary coherence while introducing creative combinations. The high levels of user acceptance, particularly the willingness to cook the generated recipes, confirm the practical utility of the system beyond mere technical novelty.

5. Conclusion and Future Work

5.1 Conclusion

The ChefAI.IN project has successfully demonstrated the potential of artificial intelligence techniques, particularly evolutionary algorithms, for generating novel Indian recipes that maintain culinary coherence while introducing creative combinations. Through a systematic approach that encompasses data collection and preprocessing, algorithm development, implementation, and user evaluation, the project has addressed a significant gap in the field of AI- powered recipe generation, providing the first dedicated system for Indian cuisine recipe creation. The results of this research confirm both the technical feasibility of the approach and its practical utility for culinary exploration and innovation.

The implementation of the ChefAI.IN system involved several key technical achievements. First, the comprehensive processing of approximately 6,000 traditional Indian recipes created a structured dataset that captures the rich diversity of Indian cooking, including regional variations, ingredient

relationships, and cooking techniques. Second, the adaptation of the AutoChef evolutionary algorithm specifically for Indian cuisine, with specialized modules for ingredient co-occurrence, instruction generation, cooking time estimation, and title creation, provides a robust framework for recipe generation that incorporates domain-specific knowledge. Third, the development of a user- friendly web application makes this technology accessible to cooking enthusiasts, allowing them to explore novel recipe possibilities based on their ingredient preferences.

The user evaluation confirms the success of the approach, with high ratings for instruction understandability (76.5% positive), cooking action suitability (70.6% Positive), and creativity (highest modal score of 3). Most significantly, 86.3% of survey respondents indicated they would or might cook the AI-generated recipes, demonstrating a high level of practical acceptance. These results validate the project's core hypothesis that evolutionary algorithms, when enhanced with domain-specific knowledge, can generate recipes that users find both creative and practically feasible.

From a broader perspective, this project contributes to the growing field of computational creativity in culinary arts, demonstrating how AI can complement and extend human creativity rather than replace it. The ChefAI.IN system serves not as a replacement for traditional cooking knowledge but as a tool for exploring new possibilities within the rich tradition of Indian cuisine. By systematically analyzing patterns in existing recipes and generating novel variations, the system helps to preserve culinary traditions while fostering innovation—a balance that is crucial for the continued evolution of any cooking tradition.

The project also highlights the importance of culturally specific approaches to AI applications. Rather than developing generic recipe generation systems, targeting specific culinary traditions with specialized knowledge and techniques yields more meaningful and valuable results. This principle extends beyond cooking to other domains where cultural context significantly shapes the nature and quality of creative outputs. The success of ChefAI.IN suggests that similar approaches could be valuable for other culturally rich domains where AI can assist in preservation, exploration, and innovation.

In conclusion, the ChefAI.IN project represents a significant advancement in AI-powered recipe generation, particularly for Indian cuisine. By combining evolutionary algorithms with domain-specific knowledge and user-centered design, the system successfully generates recipes that users find understandable, creative, and worthy of cooking. This achievement not only addresses a gap in existing culinary AI applications but demonstrates the potential for AI to contribute meaningfully to cultural creativity and innovation.

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