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Development and evaluation of a red rice-vegetable soup premix as a functional food for tuberculosis recovery

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Abstract
Tuberculosis (TB) is a global health concern, often worsened by malnutrition, which weakens immunity and delays recovery. Functional foods, such as nutrient-rich soups, offer a promising dietary intervention for TB patients. This study developed and evaluated a red rice-vegetable soup premix formulated to support TB recovery. Red rice, rich in anthocyanins and antioxidants, was combined with vegetable powders (carrot, beans, onion, and garlic) to enhance immune function. Three formulations were tested for sensory appeal, nutritional composition, and microbiological safety. Sensory evaluation identified Variation C (50% vegetable powder, 40% red rice powder) as the most preferred due to its balanced taste, texture, and nutritional benefits. The soup provided 65.58 kcal per 100 ml, with significant polyphenol (17.6 mg) and anthocyanin (6.36 mg) content. While microbiologically safe, its short two-day shelf life requires further research on preservation methods. This study highlights red rice-vegetable soup as a potential functional food for TB recovery.

Keywords: Tuberculosis, functional food, red rice, nutritional recovery, antioxidants

1. Introduction
Tuberculosis (TB) remains a major global health concern, with high prevalence and mortality rates, particularly in developing countries like India (Sathiyamoorthy *et al*., 2020) [1]. Caused by *Mycobacterium tuberculosis*, TB primarily affects the lungs but can also impact other organs, spreading through airborne droplets (WHO, 2020) [2]. Malnutrition is a significant challenge faced by TB patients, exacerbating the disease's severity and complicating recovery (Wagnew *et al*., 2023) [3]. Nutritional interventions play a crucial role in improving immune function, enhancing treatment adherence, and supporting overall health during TB therapy (Prabhu and Jayadeep, 2017) [4].
Red rice, known for its rich nutritional profile, contains high levels of antioxidants, polyphenols, vitamins, and minerals that may aid in recovery by reducing oxidative stress and inflammation (Paiva *et al*., 2016) [5]. Additionally, vegetable soups offer an easily digestible and nutrient-dense dietary option, making them particularly beneficial for TB patients with reduced appetite or difficulty consuming solid foods (Van Buren *et al*., 2019) [6]. Integrating red rice into vegetable soups presents a promising approach to addressing nutritional deficiencies in TB patients (Kalona *et al*., 2020) [7].
This study aims to develop a red rice-incorporated vegetable soup premix tailored for TB patients. The research will focus on optimizing the formulation for sensory acceptability, conducting a comprehensive nutritional analysis, and evaluating the soup's potential benefits in enhancing immune function and supporting recovery (Rizk and Riyad, 2020) [8]. By providing a practical and evidence-based dietary intervention, this study seeks to contribute to improved health outcomes and quality of life for individuals affected by tuberculosis (Matorang *et al*., 2015) [9]. Additionally, the study aims to analyze the role of red rice in enhancing immune function and its effectiveness in promoting recovery, positioning the soup as a functional food for TB management.

2. Materials and Methods
This study focuses on developing a red rice-incorporated vegetable soup premix as a functional food aimed at TB recovery. The study was conducted in Coimbatore, Tamil Nadu, known for its accessibility to fresh agricultural produce and research facilities. Carrot (*Daucus carota*), beans (*Phaseolus vulgaris*), onion (*Allium cepa*), and garlic (*Allium sativum*) were sourced from local supermarkets. These were washed, sliced, dried, and

ground into powder. Red rice (*Oryza sativa*) was similarly procured, washed, soaked, dried, and ground into powder. The powders were used to formulate the soup premix.

2.1 Development of Red Rice-Incorporated Vegetable Soup

Three variations of the soup premix were formulated using red rice and selected vegetables. The mixtures were analyzed for their nutritional content, including polyphenols and anthocyanins. Based on the results, one optimized mixture was selected for further testing. The selected premix was prepared by adding 250-300 ml of boiling water to the powder and cooking for 2 minutes with continuous stirring. The prepared soup was then analyzed for nutritional and sensory properties.

Nutritional Analysis The final formulation was analyzed using standardized methods. Shelf-Life Estimation Shelf life was assessed based on nutrient stability, sensory properties, and microbial safety. The premix was stored in airtight containers in a controlled environment. Sensory Evaluation A panel of 25 semi-trained judges evaluated the soup using a nine-point hedonic scale. Sensory attributes assessed included appearance, color, taste, flavor, consistency, and overall acceptability. Data collected were analyzed to determine consumer preference and suitability for TB patients. This structured methodology ensures that the developed soup premix is nutritious, palatable, and suitable for TB recovery support.

3. Results and Discussion

3.1 Product Development

The red rice-vegetable soup premix was successfully developed using nutrient-dense ingredients, with red rice contributing anthocyanins and vegetables supplying essential vitamins and minerals. The inclusion of garlic, onion, and herbs enhanced both functional benefits and flavor. Three formulations were prepared, balancing macronutrients and bioactive compounds to optimize recovery support for tuberculosis patients.

Table 1: List of three Formulated mixtures

S.no	Mixture	Combination	Ingredients
1	A	30%Vegetable Powder + 60% Red Rice Powder	30% Vegetable Powder + 60% Red Rice Powder +5% Salt + 5%pepper
2	B	40%Vegetable Powder + 50%Red Rice Powder	40% Vegetable Powder +50% Red Rice Powder + 5% Salt +5% pepper
3	C	50%Vegetable Powder +40%Red Rice Powder	50% Vegetable Powder + 40% Red rice Powder + 5% Salt + 5% pepper

3.2 Sensory Evaluation

A sensory panel of 25 semi-trained individuals evaluated the soup using a 9-point hedonic scale. Among the three formulations, Mixture C (50% vegetable powder, 40% red rice powder) received the highest ratings across all attributes, including appearance (8.2), taste (8.2), flavor (8.4), texture (8.1), consistency (8.1), and overall acceptability (8.5). This indicates strong consumer preference, making Mixture C the most suitable for further development.

Table 2: Organoleptic evaluation of the judging panel

Attributes	Control	Variation A	Variation B	Variation C
Appearance	6.48 ± 0.69	6.2 ± 0.65	6.68 ± 0.69	8.48 ± 0.65
Colour	6.72 ± 0.67	6 ± 0.63	6.72 ± 0.67	8.36 ± 0.63
Consistency	6.64 ± 0.78	5.84 ± 0.7	6.96 ± 0.78	8.36 ± 0.7
Flavour	6.48 ± 0.81	5.96 ± 0.72	6.92 ± 0.81	8.24 ± 0.72
Taste	6.2 ± 0.78	5.96 ± 0.66	7.04 ± 0.78	8.24 ± 0.66
Overall acceptability	6.12 ± 0.88	6.32 ± 0.63	6.96 ± 0.88	8.36 ± 0.63

3.3 Nutritional and Functional Analysis

Mixture C exhibited a well-balanced nutritional profile. It provided 65.58 kcal per 100 ml, with macronutrient distribution as follows: protein (1.36%), carbohydrates (12.65%), fat (1.06%), and fiber (2.05%). The soup's anthocyanin content (6.36 mg/100 ml) and polyphenol concentration (17.6 mg/100 ml) highlight its antioxidant potential, crucial for reducing oxidative stress in tuberculosis patients. Despite its moderate fiber content, it remains a valuable dietary intervention when supplemented with fiber-rich foods.

Table 3: Macronutrient content of developed soup C

S.no	Nutrients	Values/100ml
1	Moisture	83.7
2	Ash	1.23
3	Fat	1.06
4	Protein	1.36
5	Carbohydrate	12.65
6	Energy	65.58
7	Fiber	2.03

3.4 Microbiological Safety and Shelf Life

Microbiological analysis confirmed the soup's safety, with a Total Plate Count of 4×10^4 CFU/ml and the absence of *Escherichia coli*. However, due to its high moisture content (83.7%), the soup exhibited a short shelf life of two days under refrigeration, necessitating potential improvements in preservation methods for extended storage stability.

3.5 Comparative Nutrient Analysis

The developed soup met most USDA (2010) nutritional guidelines, aligning with recommended energy, carbohydrate, protein, and fat content. However, its fiber content was slightly below the suggested levels, reinforcing the need for additional dietary fiber sources. The red rice-vegetable soup premix demonstrated a promising balance of sensory appeal, nutritional value, and functional benefits for tuberculosis recovery. The high acceptability of Mixture C, along with its rich antioxidant and nutrient profile, makes it a viable functional food for dietary interventions. Future research should focus on enhancing shelf life through optimized storage and preservation techniques to ensure wider applicability.

Table 4: One-way ANOVA for the sensory attributes of the developed soup

		Sum of Squares	df	Mean Square	F	Sig.
Appearance	Between Groups	79.920	3	26.640	47.430	<.001*
	Within Groups	53.920	96	.562		
	Total	133.840	99			
Colour	Between Groups	74.910	3	24.970	35.335	<.001*
	Within Groups	67.840	96	.707		
	Total	142.750	99			
Consistency	Between Groups	82.910	3	27.637	55.458	<.001*
	Within Groups	47.840	96	.498		
	Total	130.750	99			
Flavour	Between Groups	71.400	3	23.800	39.667	<.001*
	Within Groups	57.600	96	.600		
	Total	129.000	99			
Taste	Between Groups	79.560	3	26.520	45.076	<.001*
	Within Groups	56.480	96	.588		
	Total	136.040	99			
Overall Acceptability	Between Groups	76.840	3	25.613	43.290	<.001*
	Within Groups	56.800	96	.592		
	Total	133.640	99			

*Significant at $p<0.001$

4. Conclusion

The red rice-vegetable soup premix developed in this study presents a promising functional food designed to support the nutritional recovery of TB patients. The combination of red rice, rich in anthocyanins, and a blend of nutrient-dense vegetable powders provides essential micronutrients, antioxidants, and immune-boosting properties crucial for patients undergoing TB treatment. The sensory evaluation confirmed high consumer acceptability, with Variation C emerging as the most preferred formulation due to its balanced taste, texture, and nutritional composition. However, the short shelf life of the soup premix poses a challenge for long-term storage and distribution, particularly in resource-limited settings. Future research should explore natural preservatives, modified packaging, or alternative processing methods to enhance stability while maintaining nutritional integrity. Additionally, while the fiber content contributes to digestive health, it falls slightly below recommended levels, necessitating dietary supplementation with fiber-rich foods. Overall, this red rice-vegetable soup premix holds strong potential as a therapeutic dietary intervention for TB patients. With further optimization, it could serve as a commercially viable functional food, aiding in improved nutritional outcomes and recovery for individuals affected by TB.

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