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Development and evaluation of a black rice-tomato soup premix as a functional food for prostate cancer prevention

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Abstract
Prostate cancer is a significant global health concern, necessitating effective dietary interventions. This study aimed to develop a black rice-tomato soup premix rich in anthocyanins and lycopene, known for their antioxidant and anti-carcinogenic properties. Three formulations were prepared with varying proportions of black rice and tomato powder, evaluated for nutritional composition, sensory acceptability, and microbiological safety. The most preferred formulation (50% black rice, 30% tomato powder) exhibited high consumer acceptability, with superior sensory attributes (overall acceptability score: 8.2). Nutritional analysis confirmed high antioxidant content, with lycopene at 1163 mg/100 ml and anthocyanins at 3.64 mg/100 ml. Statistical analysis (ANOVA, $p< 0.001$) validated these results. However, the product's short shelf life (2 days) presents a challenge, requiring further research on preservation techniques. This study highlights the potential of functional foods in prostate cancer prevention and underscores the need for future optimization.

Keywords: Prostate cancer, functional food, black rice, lycopene, anthocyanins

1. Introduction
Prostate cancer is a major global health concern, ranking as the most frequently diagnosed cancer in men, particularly affecting older individuals (JNCCN, 2024) [1]. The prostate, a small gland responsible for seminal fluid production, can develop cancer that may initially remain asymptomatic but, in advanced stages, can cause severe complications such as urinary difficulties, bone pain, and metastasis (WHO, 2020) [2]. In 2020 alone, over 1.4 million new cases were reported worldwide, with India accounting for approximately 3% of all cancers, equating to 33,000-42,000 new diagnoses annually (Anuradha *et al*., 2024) [3]. This prevalence underscores the urgent need for preventive strategies, particularly dietary interventions, to mitigate prostate cancer risk.

Dietary factors play a crucial role in prostate cancer prevention, with bioactive compounds such as lycopene and anthocyanins showing significant promise. Lycopene, a carotenoid abundant in tomatoes, exhibits strong antioxidant properties and has been associated with a reduced risk of prostate cancer through mechanisms such as inhibition of cancer cell proliferation and induction of apoptosis (Ellinger *et al*., 2006; Giovannucci *et al*., 2002) [4, 5]. Similarly, anthocyanins, flavonoid compounds found in black rice, possess antioxidant and anti-inflammatory properties that inhibit oxidative stress, inflammation, and cancer cell invasion (Chen *et al*., 2006; Das *et al*., 2023) [6, 7].

The combination of black rice and tomatoes in a soup formulation presents a practical and effective dietary intervention. Research suggests that cooking methods impact the retention of beneficial compounds such as phenolics and lycopene, necessitating optimized processing techniques to maximize health benefits (Surh & Koh, 2014; Alda *et al*., 2009) [8, 9]. This study focuses on developing a black rice and tomato soup, ensuring optimal retention of key bioactive compounds while maintaining sensory acceptability and nutritional value.

By formulating a nutrient-rich soup premix, this research aims to provide an accessible, palatable dietary option that supports prostate health. The integration of functional foods like black rice and tomatoes into daily diets may contribute significantly to reducing prostate cancer incidence and improving overall well-being (USDA, 2020) [10].

This study aims to develop a black rice-incorporated tomato soup as a functional food for prostate cancer prevention. This project aims to create a nutritious and palatable soup premix

that combines the antioxidant-rich properties of lycopene from tomatoes and anthocyanins from black rice. The study will optimize the formulation to ensure nutrient retention, evaluate sensory characteristics such as taste, texture, aroma and analyze the nutritional composition, including key antioxidants and bioactive compounds. By providing a simple, accessible dietary intervention, this research seeks to promote prostate health and contribute to cancer prevention efforts.

2. Materials and Methods

This study was conducted during 2023–2024 to develop a black rice-incorporated tomato soup premix aimed at prostate cancer prevention. The methodology was divided into two main phases: product development and sensory evaluation.

2.1 Product Development

The primary ingredients, black rice (*Oryza sativa var. Indica*) and tomatoes (*Solanum lycopersicum*) were selected for their high anthocyanin and lycopene content, respectively. Tomatoes were sourced fresh from a local supermarket, washed thoroughly, sliced, and dried at 50 °C for 12 hours in a tray dryer to retain maximum lycopene content. The dried tomatoes were then ground into a fine powder. Black rice was soaked for 4 hours, drained, dried at 55 °C for 8 hours, and milled into a powder. Additional ingredients included garlic powder (5%), onion powder (5%), mixed herbs (2.5%), salt (1.5%), and pepper (1%). Three formulations were prepared with varying black rice and tomato powder proportions: F1 (50% tomato, 30% black rice), F2 (55% tomato, 25% black rice), and F3 (60% tomato, 20% black rice). The formulations were evaluated based on nutritional composition, bioactive compound retention, and sensory characteristics.

2.2 Nutritional and Microbial Analysis

The proximate composition of the soup premix was determined using standardized AOAC (2005) and FSSAI methods. The moisture content was analyzed using the IS 3077:1992 method. Ash content, measured using the IS 3077:1992 method. The fat content was assessed using the AOAC 950.4 method. Protein content, determined using the IS 7219 method while carbohydrate content, estimated by the IS 1657 method. The total energy value was calculated using the EFLT/SOP/03/05 method.

For bioactive compounds, lycopene content was measured using spectrophotometry at 503 nm while anthocyanin content, determined using the pH differential method. Microbial analysis followed FSSAI guidelines, with total plate count confirming the microbiological safety of the product.

2.3 Sensory Evaluation

A semi-trained panel of 25 members evaluated the sensory characteristics of the soup prepared from each formulation. Each formulation was mixed with 600 ml of boiling water and cooked for 2 minutes before serving. The evaluation was conducted using a 9-point hedonic scale, rating attributes such as appearance, colour, taste, flavour, consistency, and overall acceptability.

2.4 Shelf-Life Study

The soup premix was stored in airtight containers at room temperature (25 °C ± 2 °C) and 45% RH to determine its shelf life.

3. Results and Discussions

3.1 Product Development and Nutritional Composition

The black rice-tomato soup premix was successfully developed, incorporating black rice (50%) and tomato powder (30%) as key ingredients, alongside garlic, onion, and herbs to enhance flavour and functional properties. The formulation aimed to maximize anthocyanin and lycopene content, which are known for their antioxidant and anti-carcinogenic effects.

Nutritional analysis of the selected formulation (Mixture C) revealed a moisture content of 81.3%, protein at 2.13%, carbohydrates at 13.27%, and an energy value of 72.31 kcal per 100 ml. The soup had an anthocyanin concentration of 3.64 mg/100 ml and lycopene content of 1163 mg/100 ml, supporting its potential role in prostate cancer prevention. Additionally, fiber content (1.16%) was lower than USDA recommendations, indicating a need for supplementary dietary fiber sources.

Table 1: List of three formulated mixture

S. No	Mixture	Combination	Ingredients
1	A	40% Tomato Powder + 40% Black Rice Powder	40% Tomato Powder + 40% Black Rice Powder + 5% onion powder + 5% Garlic powder + 5% Mixed herbs + 3% Pepper powder + 2% Salt
2	B	35% Tomato Powder + 45% Black Rice Powder	35% Tomato Powder + 45% Black Rice Powder + 5% onion powder + 5% Garlic powder + 5% Mixed herbs + 3% Pepper powder + 2% Salt
3	C	30% Tomato Powder + 50% Black Rice Powder	30% Tomato Powder + 50% Black Rice Powder + 5% onion powder + 5% Garlic powder + 5% Mixed herbs + 3% Pepper powder + 2% Salt

Table 2: Nutrient content and microbiological analysis of soup from selected formulated mixture C

S. No	Parameters	Values/100ml
1	Moisture	81.3%
2	Ash	2.11%
3	Fat	1.19%
4	Protein	2.13%
5	Carbohydrate	13.27%
6	Energy	72.31 Kcal
7	Fiber	1.16%
8	Lycopene	1163.0 mg
9	Anthocyanins	3.64 mg
10	Shelf life	2.0 days
11	TPC	2×10^3 CFU/ml
12	*E. coli*	Absent

3.2 Sensory Evaluation

Among the three formulations tested, Mixture C achieved the highest overall acceptability (8.2), with superior scores in appearance (8.4), colour (8.4), taste (8.2), flavour (8.2), and consistency (8.3). The soup's appealing sensory attributes, along with its nutritional benefits, indicate strong consumer potential.

Table 3: Organoleptic evaluation of the soup

Attributes	Control	Variation A	Variation B	Variation C
Appearance	7.28±0.97	6.44±0.91	7.32±0.80	8.44±0.65
Colour	8.2±0.5	6±1.08	7.4±0.70	8.36±0.63
Consistency	8.04±0.67	5.68±0.85	7.04±0.73	8.32±0.69
Flavour	7.4±0.86	5.84±0.62	7.48±0.71	8.2±0.64
Taste	7.4±0.76	6.08±0.99	7.16±0.8	8.16±0.68
Overall Acceptability	7.64±0.75	5.92±0.70	7.32±0.85	8.24±0.59

3.3 Microbiological Safety and Shelf Life

Microbiological analysis confirmed the safety of the prepared soup, with a Total Plate Count of 2×10^3 CFU/ml and no detectable Escherichia coli. However, the shelf life was limited to 2 days under refrigeration due to high moisture content, highlighting the need for preservation strategies to improve stability.

3.4 Functional and Health Benefits

The developed soup is a rich source of bioactive compounds. Anthocyanins from black rice and lycopene from tomatoes contribute to antioxidant capacity, reducing oxidative stress associated with prostate cancer. Additionally, garlic, onion, and herbs enhance anti-inflammatory properties, further supporting prostate health. The formulation aligns with USDA nutrient guidelines, except for fiber content, which may require dietary supplementation. The black rice-tomato soup premix successfully combines nutritional density, sensory appeal, and functional health benefits. The high antioxidant content makes it a promising dietary intervention for prostate cancer prevention. Future studies should focus on improving fiber content and extending shelf life through optimized processing and packaging methods.

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

		Sum of Squares	df	Mean Square	F	Sig.
Appearance	Between Groups	50.510	3	16.837	23.493	<.001*
	Within Groups	68.800	96	.717		
	Total	119.310	99			
Colour	Between Groups	87.230	3	29.077	50.060	<.001*
	Within Groups	55.760	96	.581		
	Total	142.990	99			
Consistency	Between Groups	106.910	3	35.637	64.794	<.001*
	Within Groups	52.800	96	.550		
	Total	159.710	99			
Flavour	Between Groups	74.110	3	24.703	47.813	<.001*
	Within Groups	49.600	96	.517		
	Total	123.710	99			
Taste	Between Groups	55.440	3	18.480	27.480	<.001*
	Within Groups	64.560	96	.673		
	Total	120.000	99			
Overall acceptability	Between Groups	72.560	3	24.187	44.998	<.001*
	Within Groups	51.600	96	.538		
	Total	124.160	99			

*Significant at $p<0.001$

4. Conclusion

The black rice-tomato soup premix developed in this study demonstrates strong potential as a functional food for prostate cancer prevention. The formulation rich in anthocyanins and lycopene provides significant antioxidant benefits, which may contribute to reducing oxidative stress and inflammation-key factors in cancer development. The sensory evaluation confirmed high consumer acceptability, particularly for Variation C, which had the most balanced taste and nutritional profile. Statistical analysis (ANOVA, $p< 0.001$) validated these findings. However, the short shelf life presents a challenge for commercialization, necessitating further research on natural preservatives and packaging techniques. Future studies should focus on clinical trials to substantiate health benefits and explore strategies to enhance product stability. Overall, this research lays a foundation for the development of innovative functional foods aimed at disease prevention through dietary intervention.

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