ANTIOXIDANT ANALYSIS, PRODUCT DEVELOPMENT AND SENSORY EVALUATION OF RED AMARANTH LEAVES (*AMARANTHUS CRUENTUS L.)* INCORPORATED RECIPES

April, 2025

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CERTIFICATE

This is to certify the research work presented in this thesis has been carried out independently by Ms. Priyanka Kale under the guidance of Dr. Revati Shah in pursuit of a Master's degree in Foods and Nutrition (Dietetics) and this is her original work.

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AKNOWLEDGEMENT

With the divine blessings of Lord Ganesha, I would like to express my deepest gratitude to everyone who contributed to the successful completion of this research project, Antioxidant Analysis, Product Development and Sensory Evaluation of Red Amaranth Leaves (*Amaranthus Cruentus L.*) Incorporated Recipes

I am profoundly thankful to my guide, Dr. Revati Shah, Temporary Assistant Professor, Department of Foods and Nutrition, Faculty of Family and Community Science, The Maharaja Sayajirao University of Baroda, Vadodara, for her invaluable guidance, mentorship, and expertise throughout this endeavor.

I am also grateful to Prof. (Dr.) Anjali Pahad, Dean of Department of Foods and Nutrition, Faculty of Family and Community Science, The Maharaja Sayajirao University of Baroda, for her guidance and support. I am deeply appreciative of her insights and the opportunities she provided, which significantly contributed to the successful completion of this study.

I am immensely grateful to Prof. (Dr.) Mini Seth, Former Head of Department of Foods and Nutrition whose constant support to provide resources facilities and expertise has enriched my research endeavors and enhanced the quality of this work.

I am deeply grateful to Dr. V.H. Patel, Head of the P.G. Department, Sardar Patel University, Vallabh Vidyanagar, Anand, for granting me permission to conduct the standardization and antioxidant analysis and for providing the necessary facilities and support vital for this research.

I also extend heartfelt thanks to Dr. Neeta R. Dave, Professor of the P.G. Department, Sardar Patel University, Vallabh Vidyanagar, Anand, for her significant support in conducting the antioxidant analysis.

Additionally, I would like to thank Dr. Swati Dhruv, Dr. Shweta Patel, Dr. Shruti Kantawala and Riya Rammohan for their encouragement and support during this research project.

I am also grateful to Khushi Machhi for her kind assistance in practical work related to standardization and antioxidant analysis. Her help was instrumental in completing my research efficiently.

I would like to thanks my friends Tamanna Makwana, Anjali Solanki, and Abhishek Jain for their support during the sensory evaluation phase of my research.

Furthermore, I am deeply thankful to all the participants who dedicated their time and effort to this study. Their involvement was crucial in achieving meaningful results.

I am grateful to the researchers, authors and institutions whose work and publications have provided valuable insights and served as a foundation for this thesis

Lastly, I express my deepest gratitude to my family for their unconditional love, support, and encouragement throughout my research journey. Their motivation has been a constant source of strength.

Priyanka Kale

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ABBREVIATIONS

COPD- Coronary Obstructive Pulmonary Diseases

CVD- Cardio Vascular Disease

DALYs- Disability-adjusted life years

DHA- Docosahexaenoic Acid

DM- Diabetes Mellitus

DNA- deoxyribonucleic acid

DPPH-RSA - 2, 2-diphenyl-1-picrylhydrazyl radical scavenging activity assay

FOS- Fructose Oligosaccharide

FRAP- Ferric Reducing Antioxidant Power assay

GAE- Gallic acid Equivalents

GI- Glycemic Index

GPx- Glutathione Peroxidase

NADPH- Nicotinamide Adenine Dinucleotide Phosphate

NCD- Noncommunicable diseases

PUFAs- Polyunsaturated Fatty Acids

RAL- Red Amaranth Leaves

RE- Rutin Equivalents

RNS- Reactive nitrogen spices

ROS- Reactive oxygen spices

SODs- Superoxide Dismutase Enzymes

TAC- Total Antioxidant Capacity

TE- Trolox Equivalents

TPC- Total Phenolic Compound

WHO- World health organization

ABSTRACT

The fresh, tender leaves and stem of amaranthus are rich in nutrients and provide a delicious flavour. Varieties that are red or green can also be used in cooking. In every tropical and subtropical region, amaranthus is widely distributed. Because it is a warm-season crop, leaf amaranth grows best in hot, humid climates. It is also grown in the fall, spring, and summer in temperate climates, while it is grown year-round in tropical ones. Amaranth leaves are also great sources of protein, fiber, calcium, and iron. Eating such value-added products might assist improve the nutritional status of the population, especially for those who are most at risk.

The leafy vegetable known as red amaranth (*Amaranthus Cruentus L.*), which has a red velvet color, is high in nutrients, minerals, and antioxidants. Compared to green amaranth, red amaranth has more nutrients. Betalain pigments which are present in this leafy vegetable, have the potential to be utilized as natural coloring agents in a range of medicines and functional foods. A crop high in minerals, vitamins, crude protein, polyphenols, and flavonoids, amaranth is especially nutrient-dense in its leaves and seeds.

Red amaranth leaves (*Amaranthus cruentus L.*) covers a wide variety of potential health benefits and is most likely referring to a specific diet or supplement. It may aid in weight control and is believed to be good for keeping the digestive system healthy. Furthermore, RAL contains anti-diabetic properties that may aid in blood sugar regulation. It can provide essential nutrients throughout pregnancy, and preventing anemia is still another significant advantage. It has antioxidant and anticancer properties that increase its ability to stop cellular damage. Also essential for maintaining strong bones, RAL aids in blood coagulation. The fact that it is gluten-free makes it suitable for those who have celiac disease or gluten sensitivity.

The study aimed to analyze the antioxidant properties, standardize and develop recipes, and evaluate the sensorial attributes of the Red Amaranth Leaves (*Amaranthus cruentus L.*) incorporated recipes. It was conducted in three distinct phases. In phase 1, the antioxidant analysis of Red Amaranth Leaves, revealed significant antioxidant activity, including total phenolics (35.4 mg GAE/100g), flavonoids (50.3 mg RE/100g), FRAP (28.3 mg TE/100g), and DPPH-RSA (389.8 mg TE/100g). In phase 2, 10 recipes incorporating red amaranth leaves at 10%, 20% and 30% were developed and the sensory attributes of these recipes were assess for their acceptability using composite score card

and hedonic rating test. The findings emphasizes the nutritional and antioxidant potential of Red Amaranth Leaves, showcasing their versatility as an ingredient in enhancing both health benefits and culinary experiences. The nutrient analysis of recipes supplemented with Red Amaranth Leaves (RAL) at levels of 10%, 20%, and 30% revealed distinct variations, emphasizing the strengths of specific recipes. khakhra in experimental 3 showed consistent energy values of 284 kcal, the highest protein content at 7.1 g, improved iron levels peaking at 2.705 mg, and a significant calcium increase to 80 mg. However, handvo emerged as the most nutrient-dense recipe overall, boasting the highest energy content of 457 kcal, a remarkable protein increase to 22.8 g, and an exceptional vitamin A level of 900 mg. Thepla displayed moderate improvements in energy and protein while achieving a notable rise in vitamin C to 26 mg, highlighting its health benefits. Conversely, dosa had the lowest energy and protein levels but excelled in calcium content, reaching 121 mg. lastly, chilla maintained stable energy values while achieving significant boosts in protein (12.7 g), vitamin C (46 mg), and calcium (140 mg). While handvo proved to be the most nutrient-rich recipe overall, khakhra excelled in iron content, and chilla demonstrated substantial increases in vitamin C and calcium, showcasing the unique nutritional benefits of each recipe as valuable additions to a balanced diet. In phase 3, the sensory evaluation of Red Amaranth Leaves (RAL) incorporated recipes demonstrated a clear preference for certain formulations. The experimental 1 (10% RAL) dosa ranked highest with a hedonic score of 1.86, followed closely by experimental 2 (20% RAL) thalipeeth at 1.97. The experimental 1 (10% RAL) thalipeeth scored 2.06, while experimental 2 (20% RAL) dosa and experimental 3 (30% RAL) thalipeeth both achieved 2.14. The experimental 3 (30% RAL) dosa scored 2.17. Notably, air-fried namakpara recipes showed increasing appeal, with experimental 1 (10% RAL) handvo at 2.22, experimental 1 (10% RAL) air-fried namakpara at 2.25, experimental 2 (20% RAL) air-fried namakpara at 2.33, and experimental 3 (30% RAL) air-fried namakpara achieving the score of 2.42. In conclusion, the incorporation of RAL at varying levels enhances the sensory appeal and suggesting potential for innovative and nutritious food products.

INTRODUCTION

The largest cause of mortality globally, non-communicable diseases (NCDs) claim the lives of 38 million people annually, with low- and middle-income nations bearing the brunt of these deaths. Diseases or health issues that are not caused by infectious germs are known as non-communicable diseases (NCDs). These are slow-moving chronic illnesses brought on by a confluence of behavioral, physiological, environmental, and hereditary variables (WHO 2021). These conditions do not exhibit symptoms in their early stages and progress gradually. Chronic diseases are more likely to develop as a result of the fast changes in people's lifestyles and behavioral patterns. Adults in both industrialized and developing nations are increasingly suffering from chronic non-communicable diseases. While India had 204 deaths per 1000 males and 147 deaths per 1000 females in 2018, the global adult mortality rate from NCDs was 175.45 deaths per 1000 males and 121.19 deaths per 1000 females (Baitha U et al., 2020).

Nearly 5.8 million Indians lose their lives to NCDs (stroke and cancer diseases, heart, lung and diabetes) each year, meaning that one in four Indians could pass away before turning 70 (WHO report, 2015). In the WHO's South-East Asia Region, India is responsible for almost two-thirds of all NCD deaths. Chronic respiratory conditions, diabetes, cancer, and cardiovascular illnesses are the main causes of NCD morbidity and mortality. These diseases are caused by a combination of harmful alcohol use, poor food, tobacco use, and physical inactivity. Among the main metabolic risk factors are obesity, high blood pressure, high blood glucose, and high total cholesterol. Of all NCD, cardiovascular illnesses (heart disease, stroke, and hypertension) are responsible for 45% mortality. Chronic respiratory diseases come in second with 22%, followed by cancer with 13% and diabetes with 3% mortality (Prajapati et al., 2022).

These reactive free radicals build up excessively as a result of an imbalance between the production and elimination of Reactive oxygen spices (ROS) and Reactive nitrogen spices (RNS). Even though ROS and RNS function as signaling molecules in physiological concentrations, excessive levels of these molecules cause cellular damage through their harmful interactions with proteins, lipids, and DNA. This leads to the pathogenesis of a number of diseases related to oxidative stress, such as diabetes, obesity, and neurological conditions like Parkinson's disease and Alzheimer's disease (Reddy, 2023).

Although free radicals like ROS are byproducts of regular metabolic processes, their production can rise sharply in stressful situations, upsetting the delicate balance between free radicals and antioxidants and resulting in cellular damage and energy depletion. A vicious cycle of stress and energy loss results from this depletion of energy reserves, which impairs the health of individuals (Kalogerakou & Antoniadou, 2024).

Antioxidants are substances that reduce or stop oxidative damage to a target molecule. They are secondary metabolites found in fruits, vegetables, and the human body. Alkaloids, phenolic, and vitamins C and E are among the amazing array of antioxidants that plants produce to prevent oxidation of the susceptible substrate. Since the human body is unable to generate enough antioxidants to defend against the ongoing danger of ROS, plant-based dietary antioxidants are believed to be essential maintaining human health. The carbon-stealing reaction can be stopped when a single antioxidant molecule binds to one ROS at a time and neutralizes it by removing its electrons. By inhibiting damage to cells and tissues, antioxidants also function as scavengers. Physical and antioxidant defenses, healing mechanisms, and preventative procedures all aid cells in fending off an overabundance of free radicals (Ayoka et al., 2022)**.**

Scientists are working hard to find ways to prevent these non-communicable diseases by creating new food products with the assistance of food scientists and consumers. This will help reduce a number of diseases, including obesity, chronic illnesses, different types of diabetes, musculoskeletal disorders, gastrointestinal disorders, anxiety, depression, and stress brought on by aging, changes in lifestyle and some modifiable risk factors (Mattioli et al, 2016). Minerals and trace elements like copper, manganese, and selenium are responsible for functioning as a cofactor against antioxidant enzymes, which is how our body defends against oxidative stress (Gormley, 2013).

Chronic oxidative stress is linked to NCDs like obesity, cardiovascular disease, type-2 diabetes, certain cancers, and neurodegenerative diseases, and is frequently caused by lifestyle factors like poor diet, smoking, and inactivity. A plant-based diet, which includes tree nuts and peanuts, has been shown to reduce the risk of NCDs by counteracting oxidative stress and inflammation Oxidative stress involves an imbalance between pro-oxidants and antioxidants, which can result in potential cell, damage (Rajaram et al., 2023).

Natural or artificial compounds known as antioxidants have the ability to stop or postpone certain forms of cell damage. Fruits and vegetables are among the many foods that contain antioxidants. Oxidation reactions can be harmful even though they are essential for life; both plants and animals have intricate systems of different antioxidants, including glutathione, vitamin C, vitamin A, and vitamin E, as well as enzymes, including catalase, superoxide dismutase, and other peroxides. Ancient peoples mostly obtained their antioxidants from traditional herbal remedies and food, which protected them from the harm that free radicals may do (Yadav et al., 2016).

In the 1980, the idea of functional food was introduced by the Japan's Ministry of Health and Welfare, which later on spread to North America and other counties (Mellentin et al. 2014). Functional foods are crucial for preserving a healthy lifestyle and lowering the risk factors for a number of illnesses. The majority of foods contain a functional component that enhances health. Every food item, including cereals, meat, fish, fruit, vegetables, and dairy products, contains useful components. Plants and animals provide diverse natural substance containing bioactive compound that can influence bodily functions, highlighting the importance of studying their potential for health optimization. The prevention of chronic diseases, particularly cancer, heart disease, gastrointestinal problems, and neurological diseases, may be influenced by functional meals (Mohmed and Bishir et al. 2021).

The potential health benefits of functional foods, which are abundant in proteins, carbs, vitamins, and dietary fiber, have drawn attention beyond their fundamental nutritional value. Enriched with bioactive substances such alkaloids, flavonoids, polyphenols, and tannins, these foods have demonstrated potential in blocking cell signaling pathways linked to apoptosis, communication, and proliferation. Health advantages are provided by essential ingredients in functional foods. Omega-3 fatty acids lower the risk of chronic illnesses including cancer and heart disease by scavenging free radicals. Antioxidants included in foods like sesame seed oil provide anti-inflammatory and cardiovascular health benefits. Cancer is prevented by curcumin by inhibiting inflammatory cytokines (Vignesh et al., 2024)**.**

Important elements like vitamins, minerals, fiber, and healthy fats are often found in functional foods. Including a range of functional foods in the diet, such as both traditional and fortified meals can help avoid nutrient shortages. As a matter of fact, nutritional shortages are far less common worldwide now that fortified foods have been introduced (Dwyer JT et al. 2015).

Numerous diseases, including diabetes, atherosclerosis, coronary artery disease, cancer, inflammation, liver diseases, cardiovascular diseases, cataracts, nephrotoxicity, and neurodegenerative processes associated with aging, may be prevented or treated in large part by controlling oxidative stress processes (Flieger et al., 2021). Foods high in vitamins, phenolic compounds, carotenoids, and microelements, such as edible fruits, vegetables, spices, and herbs, are the primary source of natural antioxidants (Bansal S. et al., 2013).

Green leafy vegetables are rich in carotenoids, iron, calcium, ascorbic acid, riboflavin, folic acid, and other essential minerals. In India, 95% of β-carotene comes from fruits and vegetables, with green leafy vegetables contributing 52% and mangoes 38%. These vegetables, including spinach, amaranth, and coriander, are affordable, easy to prepare, and offer vital nutrients like iron and β-carotene. Carrots, also rich in β-carotene, can be as beneficial as a substitute to green leafy vegetables in the diet. The research by Singh et al. (2001), evaluates the nutritional value and phytochemicals in green leafy vegetables, focusing on both health-promoting and harmful substances. Additionally, Natesh et al. (2017) reports the identification of phytochemicals and their effects on human health. Green vegetables contain bioactive compounds like vitamins, minerals, antioxidants, and pigments, such as chlorophylls, which help in photosynthesis and indicate plant maturity and freshness (Limantara et al., 2015).

Amaranth is the most common and important short duration leafy vegetable crop grown throughout India. The genus Amaranths comprises about 70 species, 40 of which are native to the Americas. Among the 70 species, 17 are vegetable amaranths with edible leaves, and three are amaranths with edible seeds *A. caudatus*, *A. cruentus*, *A. hypochondriacus*.

The flowering plant *Amaranthus cruentus L*., also known as the "red amaranth" or the "Mexican grain amaranth," is a member of the Amaranthaceae family. It is an annual, pseudo-cereal, broad-leaved plant that is used as a forage crop, high-protein grain, or leafy vegetable. It produces edible seeds that can be eaten as cereal or cooked into a porridge, and its leaves can be cooked like spinach. It is drought tolerant and needs warm growth conditions (65° to 75°F) to germinate (Yaacob et al., 2012). Colored amaranth contains "amaranthine," a component of a larger group called betacyanins (Mabry and Dreiding, 1968).

A. cruentus L. is an annual, broad-leaf; drought-resistant plant that produces tiny, edible grains in the form of cereals and has vibrant inflorescences. Millions of seeds can be produced by each *A. cruentus* plant as a strategic adaptive germination pattern, enabling quick colonization of novel settings and widespread dissemination. Together with other species in the same family, *A. cruentus L.* was a staple food for pre-Columbian inhabitants (Gresta et al., 2020).

A.Cruentus L. consists of 10 g of carbohydrates, 1 g of dietary fiber, 4.9 g of protein, and 51 Kcal per 100g. It has 85.5 g of hydration and 0.5 g of fat. In addition to 80 mg of vitamin C, 5560 IU of vitamin A, B-complex vitamins viz 0.08 mg of vitamin B1, 0.3 mg of vitamin B2, and 1.2 mg of niacin (B3), minerals like 368 mg of calcium, 2 mg of iron, 111 mg of phosphorus, 42 mg of sodium, and 340 mg of potassium are among the other nutrients present (http:www.niftem.ac.in).

These nutrients provide diverse health benefits, including improved digestion, weight control, and blood sugar regulation. They are also crucial during pregnancy, help prevent anemia, and possess anticancer and antioxidant properties. Furthermore, they support blood clotting, maintain bone health, are naturally gluten-free, and contribute to cardiovascular well-being.

Although it’s functional relevance has long been up for debate, red pigmentation in leaves at specific developmental stages or in response to specific environmental stimuli is a physiological feature of plants. The main cause of leaf reddening in these leaves is a concentration of anthocyanin’s, or less frequently, betacyanins (Manetas 2006).

Commercial food coloring has made use of natural pigments such anthocyanins and betacyanins (Von Elbe et al., 1983). Some plant sources have been extensively studied as potential substitutes for beetroots and red amaranth leaves (Beta vulgaris), which have been a major source of betacyanins (Cai et al., 2001).

A variety of products like Noodles and cookies are developed by certain researcher incorporating or substituting Red Amaranth Leaves at varying level ((Hossain et al., 2022), (Johnst et al., 2022)).

RATIONALE

1) Red Amaranth Leaves (*Amaranthus Cruentus L.*) has been discovered as promising food crop mainly due to it's resistance to heat, drought, diseases and pests and the high nutritive value of both seeds and leaves.

2) It is rich in protein and micronutrients such as iron, calcium, zinc, vitamin C and vitamin A. It is also high in several antioxidants like Gallic acid, p-hydroxybenzoic acid, vanillin acid, as well as flavonoids such as Quercetin, catechin, myricetin, and apigenin.

3) Red Amaranth Leaves (*Amaranthus Cruentus L.*) offer a multitude of health benefits, making them an excellent addition to your diet. They improve heart health, support digestion, and help treat anemia. Additionally, they enhance the immune system, reduce cholesterol levels, and aid in weight loss. These leaves are particularly beneficial during pregnancy, contribute to improved eye health, and promote skin quality. They also assist in maintaining blood pressure, support hair thickness, and possess anti-cancer properties.

4) The Red Amaranth Leaves (*Amaranthus Cruentus L.*) are more popular and widely consumed in South India. However, it is underutilized in the other parts of the country. Keeping this in view, the present study is planned on Red Amaranth Leaves (*Amaranthus Cruentus L.*) to analyze its antioxidant content followed by product development and sensory evaluation of the recipes developed.

REVIEW OF LITERATURE

NON-COMMUNICABLE DISEASES

Long-lasting and slowly progressing medical disorders are referred to as non-communicable diseases (NCDs) or chronic illnesses. The term non-communicable diseases (NCDs) refer to illnesses that have a lengthy duration and a sluggish onset and development. NCDs are defined as conditions such as heart disease, stroke, diabetes, chronic respiratory diseases, and some types of cancer. Tobacco use, poor nutrition, excessive alcohol use, and physical inactivity are among the modifiable risk factors that have been demonstrated to contribute to a lower prevalence of NCDs. Additional NCD risk factors include age, high blood pressure, dyslipidemia, increased blood glucose and cholesterol levels, waist circumference, and a body mass index greater than 25 kg/m^2 (Alexander tl & EV, 2013).

Diabetes, cancer, chronic respiratory conditions, and cardiovascular illnesses were the main NCDs that caused these fatalities. NCDs are at danger due to the shifting patterns of unhealthy living. NCDs are caused by unhealthy food and lifestyle choices, and the death rate is negatively correlated with the gross national income of the nation, disproportionately affecting the poor (Dhimal et al., 2019).

Non-communicable diseases in low- and middle-income nations can no longer be disregarded or viewed as a diversion from the task of infectious disease prevention and control. At economically and socially active ages, people die from chronic conditions: 80% of fatalities from chronic diseases occur in low- and middle-income nations, which is indicative of both the size of these populations and the epidemiologic shift from infectious to chronic diseases (Miranda et al., 2008).

Table 2.1 Prevalence of NCDs

Global Prevalence of NCDs		
Author	**Location/Place**	**Result**
Balakumar et al., 2016	USA	A majority of people have diabetes mellitus, with 90% to 95% of cases being type 2. Type-2 diabetes, has previously been diagnosed primarily in adults aged 40 and older, although it is becoming more prevalent in children and young people. It has been demonstrated that from 2001 and 2009, its prevalence in children and youth increased by 30.5%, and it currently accounts for about 50% of all cases of pediatric diabetes mellitus. Men and women with diabetes mellitus typically live 7.5 and 8.2 years fewer, respectively, than those without the condition. Diabetes mellitus is typically associated with a reduced life expectancy.
Gowshall & Taylor-robinson, 2018	UK	With a population of about 17 million, Malawi is a tiny nation in South-Eastern Africa that is frequently ranked among the world's poorest countries. In Malawi, NCDs are thought to be responsible for 28% of fatalities, a percentage that is steadily increasing across Sub-Saharan Africa (SSA).
Cesare; Moro; Bert; Olivero; Rossello; Corradi, 2019	London, UK	Between 1980 and 2014, there were 422 million persons worldwide who had diabetes, up from a total of 108 million in 1980. Only a small number of nations (mainly in western Europe) have a fifty percent or better chance of stopping the growth in diabetes by 2025, according to estimates based on current trends. In 2015, over 20% of male and female men and women worldwide had high blood pressure. In 1975,

		there were 594 million adults worldwide with high blood pressure; by 2015, that figure had risen to 1.13 billion, mostly in low- and middle-income nations.
Gouda et al., 2019	Sub-Saharan Africa	The percentage of all DALYs attributed to NCDs grew from 18% to 28% of the total burden, as seen by the 67.0% increase in across-age overall DALYs due to NCDs between 1990 (90.6 million) and 2017 (151.3%). In 2017, the age-standardized DALY rate (per 100,000 population) from NCDs was 21757.7 DALYs, which was nearly equal to the rate from communicable, infant, maternal, and nutritional illnesses (26491.6 DALYs), even though the majority of this rise can be attributed to population growth and aging. With 22 million DALYs that (1% of the overall NCD burden), cardiovascular diseases were the second most common cause of NCD burden in 2017. This was followed by the category of disorders classified as other types of NCDs.
Wang & Wang, 2020	China	The global average mortality rate for NCDs would be 75.26% of all deaths by 2030, and the average worldwide age-standardized NCD mortality ratio should be 510.54 (according to per 100,000 people).

Biswas et al., 2022	Australia	The survey included about 487,565 teenagers between the ages of 11 and 17years. The incidence of at least four NCD risk factors grew steadily over time, per trend analysis. The prevalence of at least four NCD risk factors rose from 14.8% in 2003–2007 to 44% in 2013–2017, or over three times the previous rate (44.0%). Comparable patterns were also noted for risk factors two and three. In every area, there was significant heterogeneity in the prevalence of teenagers with at least four risk factors between nations. In comparison to the Western Pacific Region (minimum China = 3%, maximum Niue = 72%), the European Region (minimum Sweden = 13.9%, maximum Ireland = 66.0%), the African Region (minimum Senegal = 0.8%, maximum Uganda = 82.1%), and the Eastern Mediterranean Region (minimum Libya = 0.2%, maximum Lebanon = 80.2%), the South-East Asia Region had a greater country-level range (minimum Sri Lanka = 8%, maximum Myanmar = 84%). Three of the top four risk factors across all regions were inadequate eating of fruits and vegetables, as well as a lack of physical exercise.
Kangusamy et al., 2024	India	Alcohol and tobacco usage prevalence's were 15.9% and 32.8%, respectively. A majority of adults (98.4%) ate fewer than five servings of fruits and/or vegetables per day, the mean daily intake of salt was 8 g (95%), and over one-third (41.3%) were physically sedentary. 28.5 percent (95%) and 9.3% (95%) of the population had

		elevated blood pressure and blood glucose, respectively. 12.8% (95%) of persons aged 40–69 had pre-existing CVD or a 30% ten-year risk for CVD.
D. G. G. Id et al., 2024	US	9.1% of the population had no formal education, which was greater for people with hypertensive (17.5%) than among those without either prehypertension (7.8%) or hypertension (6.7%). The majority of respondents were either married (60.5%) or resided in a rural area (58.7%); the prevalence of hypertension similarly affected both factors.
National Prevalence of NCDs		
Nethan et al., 2017	Noida	In comparison with India (15%), the prevalence of using smoked tobacco products was somewhat lower in Sri Lanka (14.1%) but significantly greater in Thailand (24%), Bengal (24%), Myanmar (24%), Maldives (27%), Nepal (32%), and Indonesia (highest: 33%). The intake of smoke-free tobacco (SLT) products was more common in India (25.9%) than in Thailand (1.3%), Sri Lanka (15.8%), Nepal (18.6%), and Bhutan (19.4%); nevertheless.
Srivastav et al., 2017	Uttar Pradesh	The incidence of drinking alcohol4.6%,, sedentary habits 15.4%, cigarette smoking 0.0%, and nonsmoking tobacco usage was 19.0% for females and 26.0%, 35.1%, 16.9%, and 9.6% for males. Males were 15.6% and 13.0% more likely to have hypertension and diabetes, respectively, whereas females were 20.0% and 7.7% more likely to have these conditions. 5.2% of men and 13.8% of women had hypercholesterolemia, whereas 22.1% of men and 16.9% of women had a high level of

		hypercholesterolemia.
Sajeev & Soman, 2018	Kerela	In comparison with Kerala's overall population, the Kani tribal had a greater prevalence of hypotension (48.3%), using tobacco (81.5%), and drinking alcohol (36.2%). Kani tribes have a greater rate of abdominal obesity (22.1%) than other Indian tribal groupings. Compared to many other Indian tribes, their physical inactive rate (9.7%) was greater and comparable to urban Kerala.
Sudeepti et al., 2024	Jaipur	It was discovered that 21.51% of people had hypertension, while 12.15% had diabetes. Diabetes progression was substantially correlated with advancing age, overweight and a lack of activity, favorable heritage, and tobacco and alcohol use.
Patel et al., 2024	Jammu	According to Israel defense force projections, sixty-three million people will have diabetes by 2030, and 784 person by 2045.
S. B. Id & Saikia, 2024	Mumbai	According to the study, the overall incidence of NCDs is higher in urban areas (61.45%) than in rural areas (42.45%). The most common of the other non-communicable diseases is hypertensive (37.29%), which follows by diabetes (8.94%). After adjusting for socio demo graphic and physical activity factors, a person's risk of developing cancer is 19 times higher if they had smoked in the past.
Rajan et al., 2024	East India	The research population had a 46.4% overall incidence of common mental disorders, with an 11.7% prevalence when substance use was excluded. People with non-communicable illnesses, regardless of substance use, had treatment gaps for major mental illnesses of 98.3% and 93.3%, accordingly.

Kangusamy et al., 2024	Tamilnadu	Non-communicable diseases are a major health worry, as causing 74% of deaths worldwide, reported to the WHO. The 2019 worldwide burden of Disease Report states that over 65% of fatalities in India are attributable to NCDs. Even though the prevalence of NCDs started to increase in 2003, it hasn't been constant throughout all Indian states despite the change in epidemiology. India is a vast and diverse nation, and each state has distinct socioeconomic conditions, cultural standards, and developmental stages.
Nayak et al., 2024	Odisha	Approximately 26 percent were alcoholics and 57% chewed tobacco. Two percent of people had diabetes, while twenty percent had hypertensive. 28% are underweight, 9% are overweight, and over 80% were physically fit. Inappropriate eating selections could be caused by the extremely low level of knowledge that has been discovered. In the tribal group, more tobacco use has negative effects and increases the risk of developing NCDs.
P. S. Yadav et al., 2025	Hyderabad	According to research, hypertensive is among the most common NCD (~50%), closely followed by diabetes (<50%) but had a significant proportion of newly diagnosed cases. More over half of metropolitan ladies suffered from depression. Overweight and obesity were common, with men more likely to have a central obesity and women most like to be overweight. There were notable gender differences in diabetes, depression, hypertension, and visual impairments.

State prevalence of NCDs		
Bhagyalaxmi et al., 2013	Ahmedabad	In comparison with men in urban areas (who smoked 12.8% and smoked smokeless cigarettes 23.1%), men in rural areas were more likely to smoke (22.8%) and use smokeless tobacco (43.4%). The mean number of fruits and vegetables consumed in urban areas (2.18) and rural areas (1.78) differed significantly. Overweight and obesity, hypertension, and a lack of physical activity were far more common in urban areas for both men and women, whereas smoking, use of smokeless tobacco, and inadequate consumption of vegetables and fruits were more common in rural areas. The findings emphasize the necessity of strategies and initiatives to reduce the risk factors for non-communicable disease in both urban and rural regions.
Kumar et al., 2015	Anand	In the over-20 age group, the rate of smoking in any form was 34.5 percent for men and 52.7% for women. In the 20–69 age range, the average incidence of any NCD was 5.3%, with a slightly higher prevalence in females (5.4%) compared to males (5.2%). In the 20–69 age range, the prevalence of NCD multiple medical conditions (≥2 NCDs) was 0.7%. 94.9% of diabetics and 80.7% of hypertensive were receiving treatments. Anticoagulant medication was being taken by more women than men.
Chhaya et al., 2015	Ahmedabad	The average prevalence for risk variables, including drinking alcohol, smokeless use of tobacco, and cigarettes, was 5.90, 12.15, and 5.21, respectively. Males were more likely than females to have hypertension, diabetes, overweight, and obesity, with the relative specific to a disease incidences being 23.40 compared 26.38, 4.51 vs 3.10, 30.55 vs 22.91,

		& 10.41 vs 7.29. The following characteristics increased the chances ratio for NCDs: Smoking, stress at work, lack of exercise, being overweight, and being obese.
Arulmohi et al., 2017	Sabarkantha	Adolescents' lack of regular physical activity has been identified as a significant risk factor for NCDs; nevertheless, research have shown that the percentage of not physically active adolescents varies greatly, ranging from ten percent to ninety percent, with variations by gender.
Kshatri et al., 2022	Surendranagr	According to BMI, the rate of being obese in cities was forty percent, while in the country; it was 47.4% of the greater incidence in both urban (60%) & rural (70%) areas.
Kuruvilla et al., 2023	Vadodara	The institution's staff's NCD incidence was 10.15%. Diabetes (DM), cardiovascular diseases (CVDs), and hypertension were found to constitute 7.2 percent, 3.2 percent, and 17 percent of the population, respectively. People over 50 and those with a family record of ongoing illnesses are 2.17 per cent and 3.47 per cent times more likely to develop non-communicable diseases, respectively. Furthermore, the risk of these diseases is increased by overweight and obesity, an unfavorable waist-hip ratio, and hypertension. The result of the research suggests concentrating on workers with a history of chronic illnesses.

Types of NCDs

Cardiovascular diseases: The term cardiovascular disease (CVD) refers to a group of conditions affecting the heart and blood vessels, which include peripheral vascular disease, heart failure, rheumatic heart disease, congenital heart disease, coronary heart disease, heart attack, cerebrovascular disease, and cardiomyopathies (Boutayeb & Boutayeb, 2005).

It is anticipated that by 2015, it would rank as the leading cause of mortality in India. An estimated 17 million individuals died from cardiovascular diseases (CVDs), according to the WHO. 30% of all fatalities worldwide occurred in 2005, with low- and middle-income nations like India accounting for roughly 80% of these deaths (Upadhyay, 2012).

Diabetes mellitus: The main two types of diabetes are both lead to hyperglycemia. In type 1, the pancreatic b-cells cannot produce a sufficient amount of insulin, while in type 2, the body cells cannot respond properly to insulin. Other types of diabetes involve gestational diabetes mellitus, which occurs in pregnant women with glucose intolerance and type 3 diabetes, which is associated with Alzheimer's disease, where neurons in the brain cannot respond to insulin. While diabetes can be partially inherited, several lifestyle factors, such as obesity, high sugar consumption, and lack of physical activity can significantly contribute to the progress diabetes (Budreviciute et al., 2020).

Globally, the number of people with diabetes is predicted to rise from 194 million in 2003 to 330 million in 2030, with three out of four of them residing in developing nations (Boutayeb et al., 2005). With the highest number of diabetic patients, India is now undergoing an epidemic of type 2 diabetes mellitus. It's frequently called the world's diabetes capital. Diabetes prevalence in rural regions was 2.7% based on WHO standards and 1.9% based on American Diabetes Association criteria (Upadhyay, 2012).

Cancer: Cancer is a large group of diseases that can start in almost any organ or tissue of the body when abnormal cells grow uncontrollably, go beyond their usual boundaries to invade adjoining parts of the body and/or spread to other organs. The latter process is called metastasizing and is a major cause of death from cancer. A neoplasm and malignant tumour are other common names for cancer (WHO, 2018).

According to Boutayeb et al. (2005), the number of individuals with diabetes is expected to increase from 194 million in 2003 to 330 million in 2030, with three out of four of them living in developing countries. India is now experiencing the largest number of people with type 2 diabetes mellitus. Many refer to it as the diabetes capital of the globe. According to American Diabetes Association guidelines, the prevalence of diabetes in rural areas was 1.9%, but WHO standards put it at 2.7% (Upadhyay, 2012).

Chronic Obstructive pulmonary diseases: Chronic obstructive pulmonary disease, usually referred to as COPD (Chronic obstructive pulmonary disease), is a group of progressive lung diseases. The most common are emphysema and chronic bronchitis. Emphysema slowly destroys air sacs in the lungs, which interferes with outward air flow while, Bronchitis causes inflammation and narrowing of the bronchial tubes, which allows mucus to build up. Both the condition cause obstruction of air flow in the respiratory system and develops respiratory problems (Torpy et al., 2008).

Global health systems bear a heavy load from chronic respiratory conditions. For the assessment and treatment of chronic non-communicable respiratory conditions as asthma and chronic obstructive pulmonary disease (COPD), the majority of poor nations lack established guidelines (boutayeb et al., 2005). In 2005, chronic illnesses were responsible for 53% of all fatalities and 44% of DALYs lost, according to recent estimates from India. Chronic respiratory disorders were responsible for 7% of deaths and 3% of DALYs lost. Males are continuously more likely than females to have chronic obstructive lung illnesses, and the frequency of these conditions has stayed relatively constant in females throughout time (Upadhyay, 2012).

Causes of Non-communicable Diseases

Tobacco use: In India, tobacco smoking is a major risk factor for non-communicable diseases (NCDs), accounting for around 1.35 million deaths yearly. Both smoking (using bidis, cigarettes, and hookah) and smokeless tobacco (using khaini, gutkha, betel quid with tobacco) are the two main ways that tobacco is used in the nation. The most common kind of tobacco is smokeless tobacco, which is used by over 267 million individuals in India, or about 29% of all adults. Despite traditionally being greater than women, the gender gap in tobacco use is steadily closing. In India, a number of variables, including socioeconomic characteristics like caste, poverty, educational achievement, and geographic location, affect tobacco usage trends. Socially disadvantaged groups have higher rates of tobacco smoking, including those with poorer incomes, less education, and membership in scheduled castes and tribes (Sharma et al., 2024).

Physical inactivity: A substantial risk factor for non-communicable diseases (NCDs) in India is physical inactivity, with studies showing prevalence rates ranging from 20.3% to 66.8%. Interestingly, physical inactivity is more common among women, those who are literate, and those who currently use tobacco. Financial limitations, transportation problems, discomfort, lack of enjoyment, and a fear of falling are some of the obstacles to engaging in regular physical activity. To improve quality of life, social and professional participation, and physiological functioning, the who suggests a weekly total of at least 150 minutes of moderate physical exercise (sharma et al., 2024).

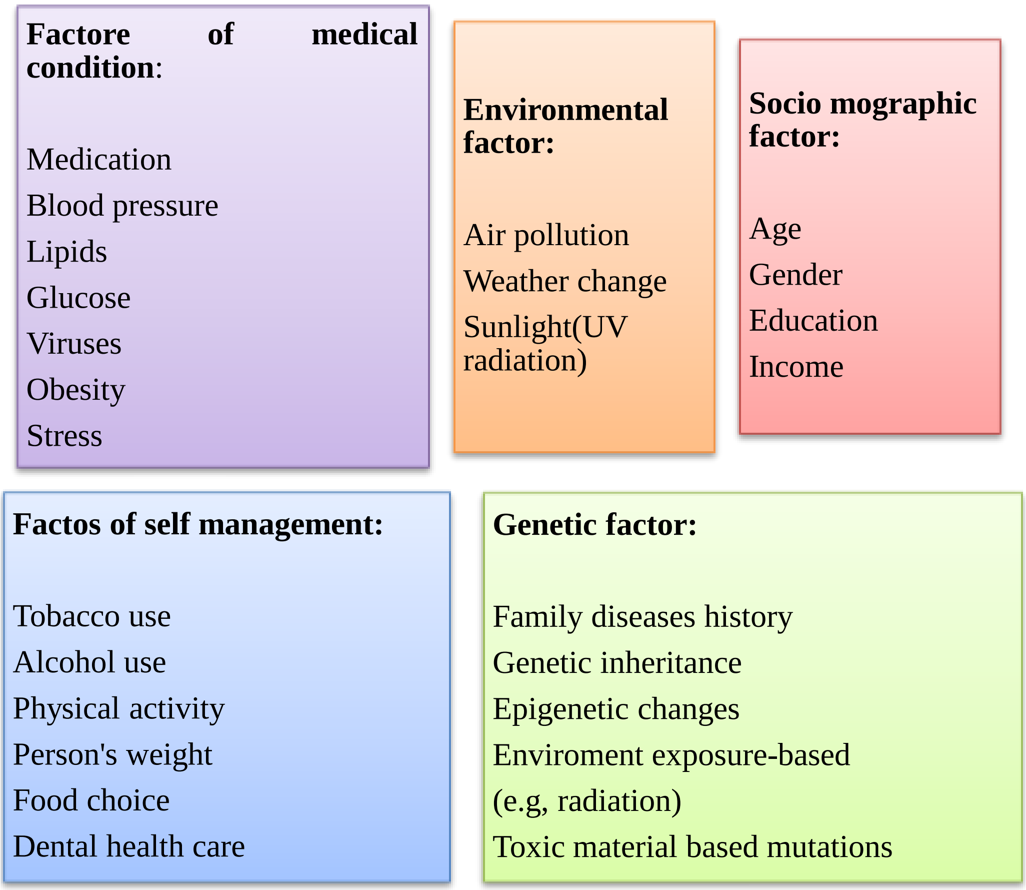
Harmful use of alcohol: "Harmful use of alcohol" refers to alcohol consumption that negatively affects a person's social, financial, or health circumstances. About 7.1% and 2.2% of the world's sickness burden, respectively, are caused by alcohol abuse. Alcohol usage is associated to a number of ailments, such as liver problems, cancer, cardiovascular diseases, and accidents. Alcohol usage poses a greater risk depending on factors such as lifetime alcohol use, frequency of drinking, and amount consumed on each occasion. Increasing prices on alcoholic drinks, restricting alcohol advertising, and limiting the physical availability of retail alcohol are three of the most cost-effective strategies to lower harmful alcohol use (sharma et al., 2024).

Air pollution: Elevated ambient PM 2.5 levels pose a serious danger to both the economy and human health, making air pollution a major environmental problem in India. Burning fossil fuels like coal or oil, biomass like wood and charcoal, crop leftovers, windblown dust, and industrial operations are the main causes of air pollution in the nation. Burning fossil fuels like coal or oil, biomass like wood and charcoal, crop leftovers, windblown dust, and industrial operations are the main causes of air pollution in the nation. A thorough "air shed" strategy is necessary since India's air pollution problem is essentially multi-sectorial and multi-jurisdictional (sharma et al., 2024).

Stress and mental health: The relationship between stress and mental health is a complex topic with wide-ranging effects. Anxiety, depression, substance misuse, sleep difficulties, and physical health problems including headaches, gastrointestinal problems, and high blood pressure are all made more likely by prolonged stress exposure. Stress may show itself in a number of different areas, such as cognitive (difficulty focusing, memory deficits), emotional (anxiety, anger, sadness), physical (headaches, tense muscles), and behavioral (differences in eating or sleeping habits). People who lack sufficient social support, are dealing with a lot of pressures, feel powerless or hopeless, or have experienced negative life events are high-risk groups that are susceptible to stress-induced mental health problems. Developing a strong support system, eating a balanced diet, exercising often, and using relaxation methods are all examples of self-care behaviors that are essential to effective stress management (Sharma et al., 2024).

Inadequate lifestyle choices and adverse social and physical surroundings are common causes of non-communicable diseases. Among NCDs, diabetes, cancer, heart disease, and chronic respiratory conditions are the most prevalent. Physical inactivity, poor diets (rich in fat and salt but low in fruits, vegetables, and whole grains), tobacco use (smoking, secondhand smoke, and smokeless tobacco), and hazardous alcohol use are the primary behavioral risk factors for NCDs (Prajapati et al., 2022).

Figure 2.1 Risk Factors of Non-communicable diseases



(Budreviciute et al., 2020)

With 38 million fatalities annually from non-communicable diseases (NCDs), over three-quarters of all deaths occur in low- and middle-income nations. NCDs are the main cause of death globally. Non-communicable diseases (NCDs) are diseases or health issues that are not caused by infectious germs. A mix of genetic, physiological, environmental, and behavioral variables contribute to the slow progression of certain chronic diseases. Early on, many diseases don't exhibit any signs and grow gradually. Rapid changes in people's habits and lives encourage the development of chronic illnesses. Both industrialized and developing nations are seeing an increase in the number of persons suffering from chronic non-communicable diseases. India had 204 fatalities per 1000 males and 147 deaths per 1000 females in 2018 due to NCDs, which is higher than the global average of 175.45 deaths per 1000 males and 121.19 deaths per 1000 females (Prajapati et al., 2022).

According to the World Health Organization (WHO), the number of deaths from NCDs would increase to 55 million annually by 2030 if prompt strategies for their prevention and control are not put in place. About 41 million people are killed by it annually, accounting for 71% of all fatalities worldwide, including 14 million individuals between the ages of 30 and 70. The great majority of deaths caused by NCDs can be prevented. According to reports from 2015, NCDs (cancer, diabetes, heart and lung illnesses, and stroke) claim the lives of around 5.8 million Indians annually, meaning that one in four Indians is at danger of passing away from an NCD before turning 70. Chronic respiratory conditions, diabetes, cancer, and cardiovascular illnesses are the main causes of morbidity and mortality from NCDs. Most of these diseases are caused by tobacco smoking, poor food, inactivity, and problematic alcohol consumption. Major metabolic risk factors include high blood pressure, high blood glucose, high total cholesterol, and obesity. The leading causes of death from NCDs are cardiovascular illnesses (heart disease, stroke, and hypertension), followed by chronic respiratory conditions (22%), malignancies (13%), and diabetes (3%). The likelihood of dying from four major non-communicable diseases (NCDs) between the ages of 30 and 70 is 26%, meaning that a person in their 30s has a one-fourth chance of dying from these conditions before turning 70 (Prajapati et al., 2022).

Given the diverse and overlapping relationships between individual (beliefs and attitudes), interpersonal (cultural and social norms), environmental (social, built, and natural environment), and policy (regional, national, and global) elements, comprehending and directing human behavior is extremely difficult. Different social cognitive paradigms that only emphasize stress. For example, self-regulation and self-control are crucial components of behavior. Theories of planned behavior and reasoned action are inadequate when considering the significance of habit formation and the contextual aspect of conduct. Even though many lifestyle choices are really illogical and rely on heuristics (habits) or irrational shortcuts, traditional therapies assume that people make logical decisions. Because the user is the expert of their own experience, most interventions that are created only from a content viewpoint are therefore more likely to fail. Interventions and solutions must "follow the natural flow of human behavior" (Matheson et al., 2013).

Table 2.2 Departmental studies on non-communicable diseases

Author	Study	Result
Sheth M. & Gandhi J. 2019	Impact evaluation of symbiotic supplementation to improve cognition and gut health in elderly with early signs and symptoms of Alzheimer's diseases	For mild to moderate AD patients, daily symbiotic buttermilk supplementation (200 ml probiotic buttermilk + 10 ml FOS) for 45 days is an alluring treatment for enhancing gut health and cognition.
Venugopal S. & Khanna S. 2021	Diabetes knowledge risk perception and diabetes risk assessment in teaching staff of The Maharaja Sayajirao University of Baroda	It is essential to understand diabetes and the risk factors for it. Educating people can help them perceive risks accurately. Diabetes can be avoided by promoting healthy lifestyle choices through awareness initiatives.
Kuruvilla A. & Kalasariya S. 2022	Risk factor profile and analysis for Non-Communicable diseases among university teaching empolyees	The study found that NCDs and modifiable risk factors are common in this demographic, hence workplace policies that promote healthy lifestyles are necessary..
Kuruvilla A. & Baladaniya S. 2022	Risk factor profile and analysis for Non-Communicable diseases among university Non-Teaching empolyees	University workers have a high prevalence of NCDs and modifiable risk factors, such as sedentary lifestyles, poor diets, and physical inactivity. To combat the rising trend of NCDs, aggressive behavior modification interventions are required.
Kuruvilla A. & Patel R. 2023	Intervention to control Non-Communicable disease and It's risk factors among university	Due to the study's brief length and small sample size, participants' risk of NCDs is probably the reason for the notable increases in knowledge, attitude, and

	employees	practice. To validate these improvements, a longer intervention time is required.

OXIDATIVE STRESS

It is suggested that oxidative damage is a significant contributing factor to the onset, progression, and development of a number of NCDs. Numerous neurological diseases, lipid oxidation, and inflammation have all been linked to the harm caused by ROS(reactive oxygen species)/ RNS(reactive nitrogen species) interactions It is suggested that the primary cause of this is the oxidative alteration of important cellular macromolecules, including proteins, lipids, carbohydrates (CHOs), and most especially, DNA. It has been suggested that a diet rich in fruits and vegetables can decrease the onset of oxidative damage by reducing oxidative stress and perhaps scavenging free radicals. ROS and RNS can be produced endogenously through the nicotinamide adenine dinucleotide phosphate (NADPH) route. When NADPH oxidase is active, a significant amount of oxygen (O2) and hydrogen peroxide (H2O2) are produced, which leads to widespread cellular growth. If left unchecked, this might cause more harmful cellular alterations and the onset of numerous inflammatory and age-related illnesses (Speer et al., 2020)

FUNCTIONAL FOODS

The health of people and the reduction of illness risk are greatly influenced by functional foods. In addition to the main nutritious components, all foods have a sufficient quantity of functional ingredients that either directly or indirectly enhance health. In our bodies, fresh, natural foods have a functional purpose. Fruits, vegetables, cereals, meat, fish, and dairy products are all examples of useful foods. These products are not costly or dangerous to use. When cereals and grains are supplemented, certain beneficial substances are found. Because of advancements in food for lowering the risk of chronic and cardiovascular disease and illness, all processed foods in supermarkets are not considered functional foods unless scientific evidence supports their use of the most important nutrients and their presence can reduce health deficiencies. This is because healthy eating and awareness of the relationship between foods and health have increased (Miano, 2016).

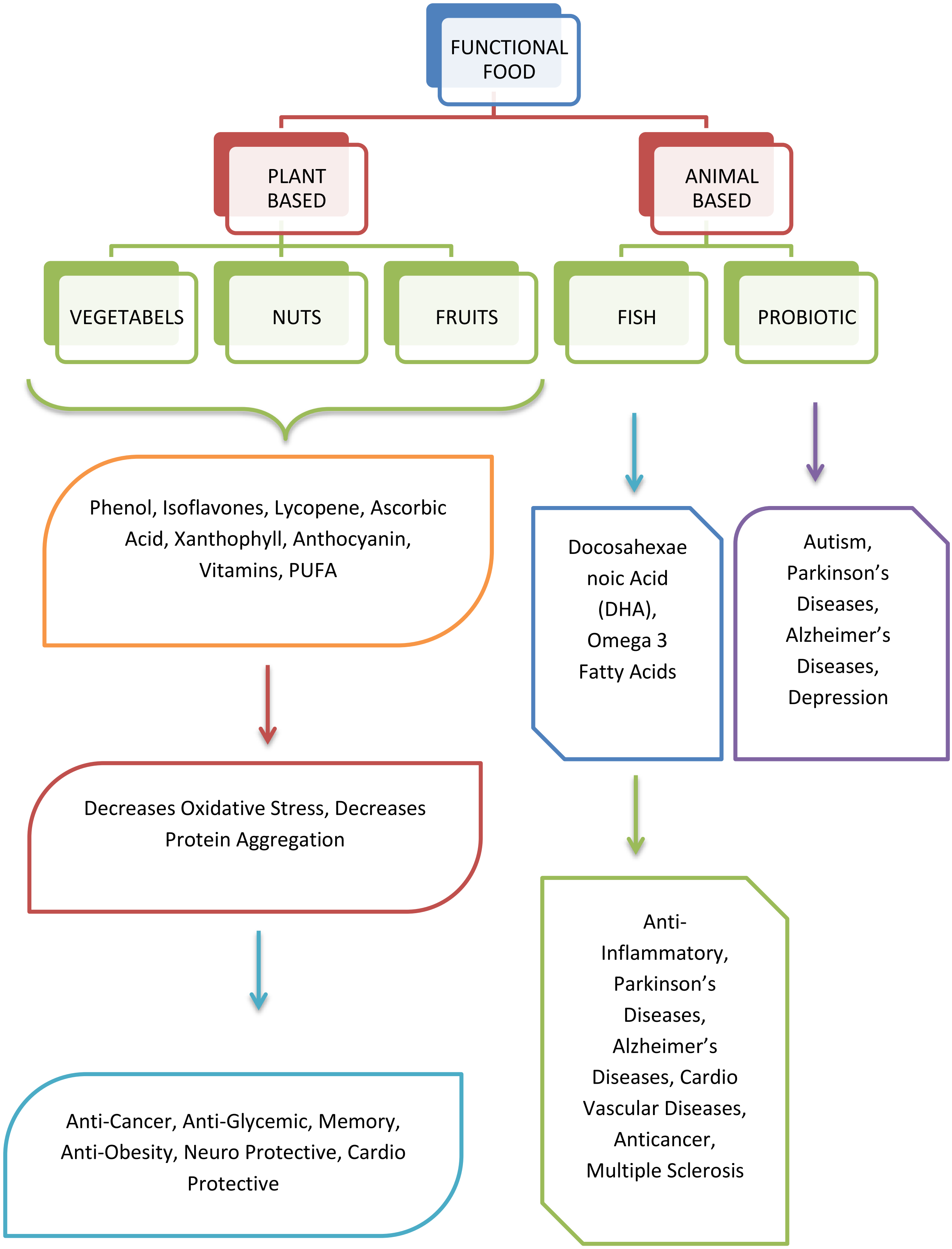
Foods enhanced with vitamins, minerals, probiotics, or fibers are a few examples. Foods high in nutrients, such as grains, nuts, seeds, fruits, and vegetables are also frequently regarded as functional foods. Important nutrients included in functional meals can aid in illness prevention. Antioxidants are particularly abundant in many. These molecules aid in the neutralization of dangerous substances called free radicals, preventing cell damage and a number of chronic illnesses, such as diabetes, cancer, and heart disease (Ajmera, 2020).

Vitamin C, vitamin E, folic acid, zinc, iron, and calcium were among the vitamins and/or minerals that were used to fortify the majority of the first functional food innovations. The emphasis then turned to meals supplemented with different micronutrients, such phytosterol, soluble fiber, and omega-3 fatty acid, to either prevent or promote illnesses like cancer. Functional food items are not evenly distributed throughout all food and drink industry groups, and customer tastes and health concerns may differ between markets (Istvan Siro et al., 2008).

Three categories can be used to classify functional foods: (1) normally used foods, (2) modified foods, and (3) food components. Traditional foods, such as fruits, vegetables, fish, grains, legumes, and dairy products, have not been altered and are consumed in their whole. Foods that have been fortified or enhanced with a particular nutrient to provide health benefits are known as modified foods. Common examples of modified functional foods include calcium, vitamin- and antioxidant-fortified drinks, bread that has been enhanced with calcium and folate, and goods that have been enhanced with plant fibers, sterols, and omega-3 fatty acids (Essa et al., 2023).

Figure 2.2 illustrates the categorization and health benefits of functional foods, which are broadly divided into plant-based and animal-based types. Plant-based functional foods include vegetables, nuts, and fruits, which are rich in bioactive compounds such as phenols, isoflavones, lycopene, ascorbic acid, xanthophyll, anthocyanin, vitamins, and polyunsaturated fatty acids (PUFAs). These components collectively contribute to reducing oxidative stress and protein aggregation in the body. As a result, they offer multiple health benefits, including anticancer properties, antidiabetic effects.

Figure: 2.2 Classifications of Functional Foods



(antiglycemic), neuroprotection, anti-obesity effects, memory enhancement, and cardiovascular protection.

Animal-based functional foods include fish and probiotics. Fish is a significant source of docosahexaenoic acid (DHA) and omega-3 fatty acids, which are known for their anti-inflammatory properties and their role in preventing or managing conditions such as Parkinson’s disease, Alzheimer’s disease, cardiovascular diseases, cancer, and multiple sclerosis. Probiotics contribute to mental health by potentially alleviating conditions like autism and depression while also supporting neurological health. Together, these functional foods play a critical role in improving overall health by addressing oxidative stress and inflammation while offering protection against chronic diseases.

ANTIOXIDANTS

Naturally occurring or artificially produced, antioxidants have the ability to stop or postpone some forms of cell harm. Vegetables and fruits are among the numerous foods that contain antioxidants. Even though oxidation processes are essential to life, they may also be harmful. Enzymes like catalase, superoxide dismutase, and different peroxides, as well as sophisticated systems of antioxidants like glutathione, vitamin C, vitamin A, and vitamin E, are maintained by plants and animals. The primary source of antioxidants that shielded ancient peoples from the harm caused by free radicals was found in traditional herbal treatments and dietary items. The protection of illnesses including cancer, coronary heart disease, and even altitude sickness has been studied for antioxidants, which are often included in dietary supplements (A. Yadav et al., 2016).

Another definition of an antioxidant is "any substance that significantly delays or inhibits oxidation of that substrate when present at low concentrations compared with that of an oxidizable substrate." As radical scavengers, antioxidants found in plant material aid in the transformation of radicals into less reactive species. Fruits, vegetables, tea, and other foods include a range of antioxidants that scavenge free radicals. Antioxidants are essential for preserving optimal health and wellbeing since they are our first line of defense against harm from free radicals. Chronic illness risk has been found to be decreased by regular eating of fruits and vegetables high in antioxidants (A. Yadav et al., 2016). Antioxidants include vitamins E and C, carotenoids, and selenium, which includes lutein, zeaxanthin, beta-carotene, and lycopene (Liu, 2022).

Antioxidants by their mechanism are divided into three types:

Primary antioxidants: Our bodies undoubtedly manufacture primary antioxidants, which are significant antioxidant enzymes. Our body's strongest protection against damaging inflammatory responses and free radicals is provided by these endogenous antioxidant enzymes. Catalase, glutathione peroxidase (GPx), and SOD are the only three main antioxidants (Liu, 2022).

Secondary antioxidants: Hydro peroxides are transformed into non-radical, non-reactive, and thermally stable compounds by secondary antioxidants, often referred to as hydro peroxide decomposers. They are frequently used with main antioxidants to provide synergistic stabilizing effects. Secondary antioxidants include glutathione reduction, a substance called glut-s-transferase, and glucose-6-phosphate dehydrogenase. Additionally, the activities of antioxidant enzymes are increased by iron, magnesium, zinc, copper, manganese, and selenium (Liu, 2022).

Tertiary oxidants: Through sources such as successive antioxidants or nutrition, tertiary oxidants (certain DNA enzymes, proteolytic enzymes, etc.) fix the oxidized molecules and carry out their activity (Liu, 2022).

Typically, antioxidants are divided into two categories: enzymatic and non-enzymatic. They include a variety of chemicals with distinct mechanisms, sites of action, and end results. Their individual roles inside the body are determined by their variety. The most efficient antioxidant defense is demonstrated by the network of interacting antioxidant enzymes, including glutathione peroxidase (GPx), glutathione reductase (GRd), superoxide dismutase enzymes (SODs), and catalase (Flieger et al., 2021).

Nowadays, a large number of naturally occurring antioxidants have been identified, thoroughly described, and made accessible for use in a variety of ways as preventative and therapeutic agents to lessen the negative effects that ROS produce. Microorganisms, such as cyanobacteria, fungus, lichens, actinomycetes, and bacteria, are also the source of bioactive chemicals and antioxidants. These organisms are a good source of naturally occurring bioactive compounds for industrial food, medicines, nutraceuticals, and agricultural uses since they can grow much faster than plants under extremely stringent circumstances (Flieger et al., 2021).

Antioxidants use several strategies to stop oxidation. Direct neutralization of reactive oxygen and nitrogen species (ROS/RNS) is accomplished by primary antioxidants. Conversely, secondary antioxidants work indirectly through chelating transition metals such as iron, regulating inflammation, promoting the synthesis of protective molecules, inhibiting the activity of xanthine oxidase and NADPH oxidase, and affecting redox-sensitive signaling pathways, such as polymerase inhibition and transcription factor regulation (Flieger et al., 2021).

Figure 2.3 provides a detailed classification of antioxidants, dividing them into natural and synthetic categories. Natural antioxidants are further subdivided into exogenous and endogenous types. Exogenous antioxidants are derived from external sources like vitamins, trace elements, carotenoids, and polyphenols, which help in neutralizing free radicals and reducing oxidative stress. Endogenous antioxidants, produced within the body, are categorized into enzymatic systems (primary defense systems) and non-enzymatic systems (secondary defense systems). Non-enzymatic systems include low molecular weight compounds and metal-binding proteins, both of which play critical roles in maintaining cellular health by mitigating oxidative damage.

Synthetic antioxidants, on the other hand, are artificially developed to mimic or enhance the effects of natural antioxidants. These include phenolic structures and nano-antioxidants, which are designed to provide targeted protection against oxidative stress. Synthetic antioxidants are particularly useful in industrial applications and as dietary supplements to compensate for deficiencies in natural antioxidant intake. Together, both natural and synthetic antioxidants are essential for combating oxidative stress, protecting cells from damage, and preventing chronic diseases such as cancer, cardiovascular disorders, and neurodegenerative conditions.

Figure: 2.3 Classifications of Antioxidants

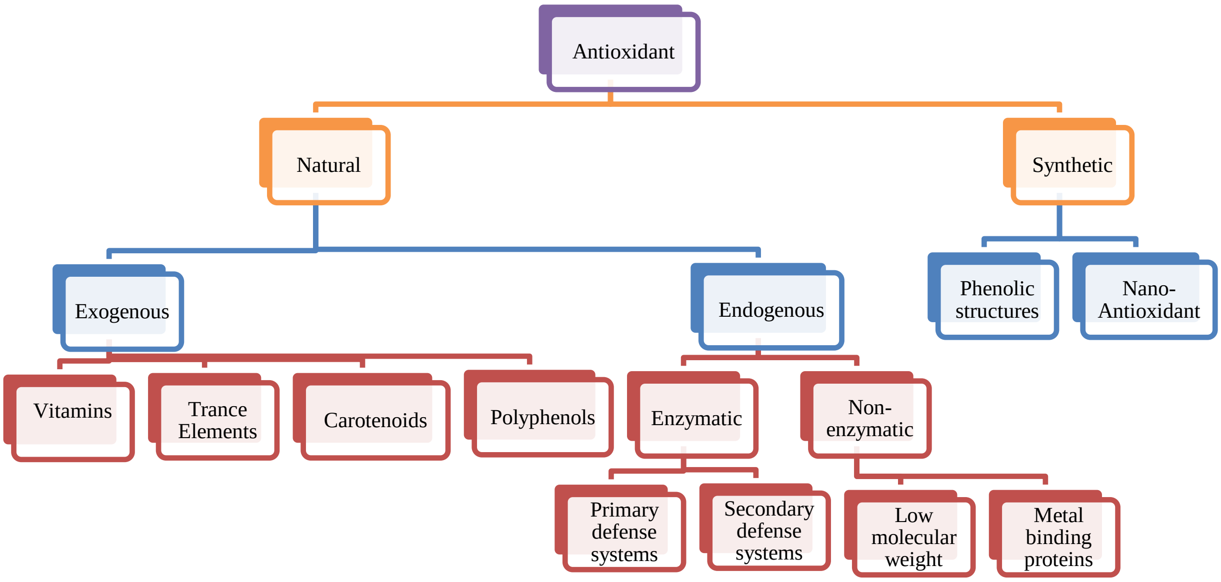


Table 2.3 Sources of Antioxidants

Fruits	Vegetables	Nuts and seeds	Herbs and spices	Other sources
Berries, Mangoes, Papaya, Pineapples etc.	Carrots, Tomatoes, Green leafy vegetables etc.	Almonds, Walnuts, Pumpkin seeds, Sunflower seeds etc.	Turmeric, Ginger, Basil, Cloves, Nutmeg etc.	Dark chocolate (70% cocoa), Fatty fish (salmon, sardines), Egg yolks, Avocados, (lentils, chickpeas), Whole grains (quinoa, brown rice), Fermented foods (kimchi, sauerkraut), Coconut oil etc.

GREEN LEAFY VEGETABELS

The phytonutrients and medicinal properties of various chemical components in leafy green vegetables are the primary causes of their significant health-promoting advantages. Malnutrition and famine are the results of the majority of foods being consumed that are poor primary source of micronutrient, Thus, a better way to attain a balanced diet is to include fruits and more green leafy vegetables are more source of vitamins and minerals are added in meal and consume frequently. Research has demonstrated that consistent intake of significant dietary phytochemicals reduces the incidence of a number of infectious diseases as well as chronic non-communicable diseases. Micro greens have become more popular in recent years due to their higher levels of bioactive components. According to Sarma and TR (2024), it is crucial for human health because it contains vitamins, minerals, and antioxidants.

Vegetable varieties have been categorized differently by large observational epidemiology investigations. This typically has to do with the fact that different vegetable varieties are not always easily accessible or available in different countries. While some extensive epidemiological studies have focused on individual vegetables, others have examined vegetable kinds that are grouped together according to plant parts, colors, or botanical groups. Plant parts, such as stems and stalks, leaves, legumes, bulbs, roots, and tubers, are categorized according to their edible parts. Because of their supportive structure, stem and stalk vegetables—like celery—are primarily abundant in nutritional fiber. Vegetable leaves, which are high in zinc, iron, folate, vitamin C, carotenoids, flavonoids, magnesium and calcium, are also often the most nutrient-dense and metabolically active portion of the vegetable. Dark green leafy vegetables, lettuces, allium bulbs, legumes, deep orange/yellow roots and tubers, tomatoes, and other red vegetables are frequently included in these groupings (Blekkenhorst et al., 2018).

The richest sources of carotene are green leafy vegetables, and the amount of β-carotene is correlated with the color green. Along with being good providers of vitamins and minerals, they are also fair suppliers of protein. Some food items contain ant nutrients that prevent certain nutrients from being absorbed. The nutrients' bioavailability is decreased by these anti-nutrients, which include dietary fibers, pro-anthrocyanidin, oxalates, tannin, and physic acid (Funke, 2011).

AMARANTH LEAVES

In underdeveloped countries, vegetable amaranth serves as a replacement for traditional meals due to its abundance and affordability in vitamins, minerals, amino acids, and fiber from food, flavonoids, which polyphenols, or antioxidant leaf pigments such as battalions, vitamin A, and chlorophyll. In recent years, food coloring has become more popular since it drastically changes food acceptability and is intrinsically linked to multisensory interactions, like taste perception and considerable meal satisfaction (Umakanta S. et all., 2018).

Three of the 70 species of amaranths in the Amaranthaceous family yield food grains, while 17 of them produce edible leaves. Amaranths varieties were plants which are C4 traits that develop decorative, grain, and vegetable plants quickly. It is grown and dispersed over Africa, Asia, North America, Australia, & Germany. With the necessary amino acids such as arginine and methionine, carotenoids and ascorbic acid, fiber from the diet, and vital minerals including potassium, calcium, magnesium, phosphorus, zinc, and iron copper, and manganese, amaranth leaves and succulent stems are a cheap and high-quality source of protein. In addition to being utilized as snake antidotes, some genera in this family are widely employed as traditional medicinal herbs to treat bacterial, helminthic, diabetic, malarial, and viral diseases. Aside from these, it is a great and rare source of antioxidant leaf pigments including β-cyanin, β-xanthin, and betalain. It also contains antioxidant phytochemicals like β-carotene, the antioxidant vitamin C, phenolics, and flavonoids, as well as other pigments like carotenoids, anthocyanin, and chlorophylls. Since the majority of these substances are organic antioxidants and help the body rid itself of numerous amaranths species have been shown to contain a variety of bioactive phytochemicals, including phenolic acids, flavonoids, carotenoids, and ascorbic acid. According to Al-mamun et al. (2016), amaranths possess a number of significant pharmacological qualities, such as antioxidant, anti-inflammatory, and anticancer effects, reactive oxygen species, they are crucial to the food business (Sarker & Oba, 2019).

Amaranth leaves whole plant

Amaranth seed

Green Amaranth leaves

Amaranths stem

Red Amaranth Leaves

RED AMARANTH LEAVES

Red Amaranth or *Amaranths Cruentus L.* It belongs to the Amaranthaceous family. It thrives in tropical climates worldwide and is highly well-liked in Bangladesh and India (Amin & Swaraz, 2015). The red velvet-colored leafy vegetable known as red amaranth (*Amaranthus Cruentus L.)* is rich in antioxidants, minerals, and nutrients. Red amaranth has a higher nutrient contains than green amaranth. For example, betalain pigments found in this leafy vegetable may be used as natural coloring agents in functional foods, the food industry, and a variety of pharmaceutical products (Putri et al., 2023).

Although its functional relevance has long been up for discussion, red pigmentation of leaves at particular phases of development or in response to specific environmental stimuli is a physiological feature of plants. The main cause of leaf reddening in these leaves is a concentration of cyan pigments, or less frequently, betacyanins. Betacyanins are substitutes for the pigments in the nine categories of Caryophyllales. They are non-photosynthetic red pigments that belong to the betalain group. Since the Aztec era, red amaranth (*A. cruentus L*.), a C4 dicot that produces betacyanins, has been grown as a pseudo-cereal crop. Because of its high nutritional content, it has recently drawn a lot of interest as a food source for humans (Nakashima et al., 2011). Water-soluble substances called betalains are present in a small number of plant families. Amaranthus and other caryophyllales are a special source for betalains, which and have significant anti-free radical properties. In the flowers & fruits of the majority of plants in the Caryophyllales family, these hydrophilic nitrogenous metabolites that are secondary take the place of anthocyanins. Carotene, β-cyanins, and β-xanthins are antioxidants that scavenge free radicals and are crucial for human health. Their antibacterial, anticancer, and antilipidemic pharmacological properties suggest that betalains, which and carotenoids could be used as a source for functional foods (Umakanta S. et al., 2018).

Red amaranth (*Amaranthus Cruentus L*.), a kind of amaranth, has been shown to possess a high concentration of phytonutrients that may have a major impact on human health. Amaranth is a nutrient-dense crop that is rich in minerals, vitamins, crude protein, polyphenols, and flavonoids, particularly in the leaves and seeds. According to Ampapon et al. (2022), gallic acid, which vanillic acid and p-coumaric acid were the primary phenolic chemicals found in both leaves and seeds.

Figure 2.4 displays a map of India with consumption levels categorized as low (red), moderate (yellow), and high (green), alongside specific consumption percentages for several states. Gujarat and West Bengal show low consumption at 20% and 10%, respectively, while Maharashtra and Odisha also fall into the low consumption category with 30% and 15%. Karnataka, Kerala, and Tamil Nadu exhibit moderate consumption with percentages of 40%, 50%, and 60%. In contrast, Telangana and Andhra Pradesh demonstrate high consumption levels at 70% and 80%, respectively, as indicated by the green color-coding on the map.

Figure 2.4 Consumption patterns of Red Amaranth Leaves in India

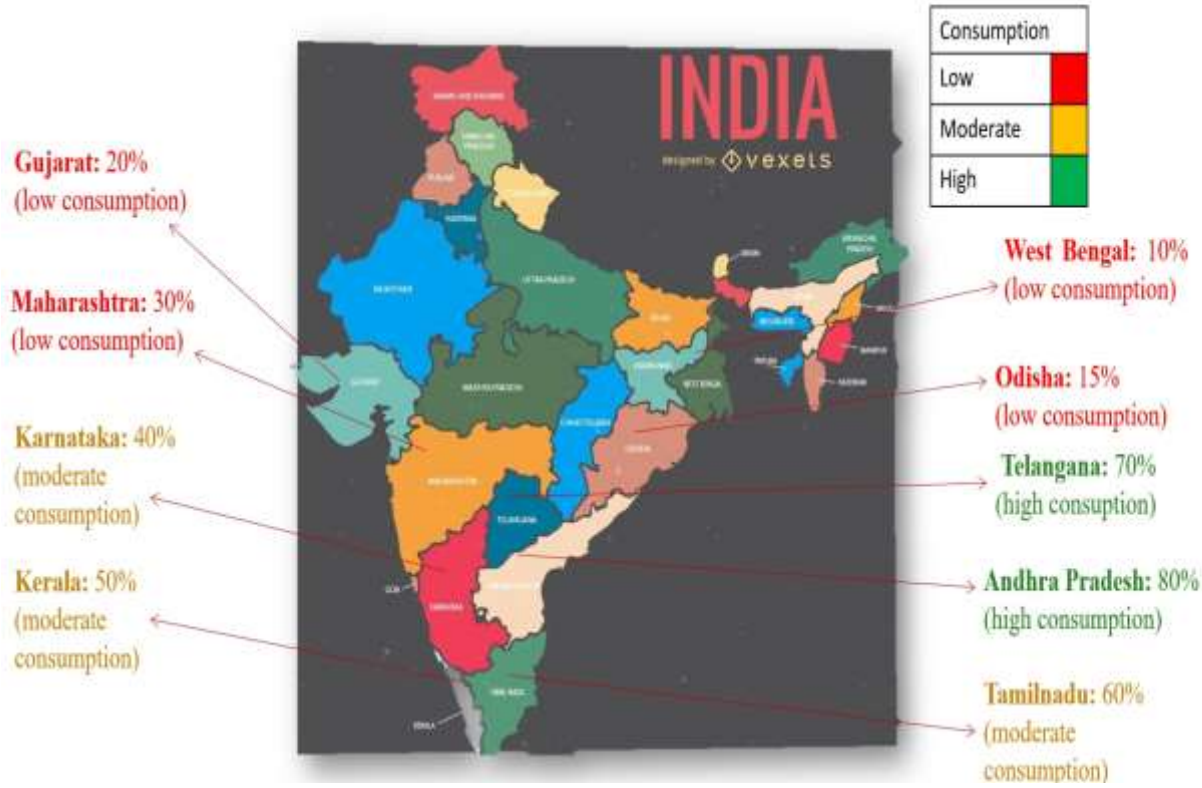


Table 2.4 Nutritional profile of Red Amaranth Leaves

Nutrients	Values reported by NIFTEM (100gm)	Values reported by IFCT, 2017 (100gm)
Calorie	51Kcal	33.6Kcal
Protein	4.9gm	3.93gm
Dietary fiber	1gm	4.91gm
Carbohydrate	10gm	2.37gm
Fat	0.5gm	0.63gm
Moisture	85.5gm	85.56gm
Vitamin B1	0.08mg	0.01mg
Vitamin B2	0.3mg	0.26mg
Niacin B3	1.2mg	0.62mg
Vitamin. C	80mg	86.20mg
Vitamin A	5560mg	8457mg
Calcium	368mg	245mg
Iron	2mg	7.25mg
Phosphorus	111mg	75.98mg
Sodium	42mg	14.58mg
Potassium	340mg	564mg

(http:www.niftem.ac.in and IFCT 2017)

Table 2.5 Antioxidant profile of Red Amaranth Leaves

Vitamin C	Red amaranth leaves are an excellent source of vitamin C, providing about 43.3 mg per 100g, which is approximately 70% of the daily recommended intake. Vitamin C acts as a powerful water-soluble antioxidant that helps protect cells from oxidative stress and supports immune function.
Phenolic Compounds	These include various flavonoids and phenolic acids, which exhibit strong antioxidant properties. Total phenolic content (TPC) in red amaranth leaves has been reported to be high, enhancing their ability to scavenge free radicals.

Carotenoids	The presence of carotenoids like β-carotene contributes to the antioxidant activity and overall nutritional value of the leaves.
Antioxidant Pigments	The leaves are rich in pigments like betalains (betacyanins and betaxanthins), carotenoids (including β-carotene), and chlorophylls. These pigments not only provide color but also have significant antioxidant activities that combat oxidative damage.
Total Antioxidant Capacity (TAC)	The total Antioxidant capacity of Red Amaranth Leaves has been measured using various assays (e.g., DPPH, ABTS), indicating their ability to neutralize free radicals effectively. This capacity varies among different genotypes of Red Amaranth.
Flavonoids	Red amaranth contains flavonoids such as quercetin, catechin, myricetin, and apigenin. These compounds contribute to the antioxidant capacity and may help reduce inflammation and lower the risk of chronic diseases.
Betalains	Red amaranth is rich in betalains, specifically betacyanins and betaxanthins, which not only provide the characteristic red color but also possess strong antioxidant properties

Health Benefits of red amaranth leaves offers a wide range of possible health advantages and is probably referring to a particular diet or supplement. It is thought to be beneficial for maintaining a healthy digestive tract and might help with weight control. Additionally, RAL has anti-diabetic qualities, which might help people control their blood sugar levels. It can offer important nutrients during pregnancy, and another important benefit is that it can help avoid anemia. Its capacity to prevent cellular damage is enhanced by the presence of antioxidant and anticancer capabilities. RAL is also necessary for keeping healthy bones and contributes to blood coagulation. It is noteworthy for being gluten-free, which makes it appropriate for people with celiac disease or gluten sensitivity. Lastly, RAL supports heart health, which enhances cardiovascular health in general.

Table 2.6 Product development using Green leafy vegetables

Author Name	Product Name	Result
Gupta & Prakash, 2011	Mathri And Thalipeeth	Drained greens have been added at the 4, 8, and 12% levels to "Thalipeeth," a shallow-fried food produced with a combination of cereals, and "Mathri," a deep-fried dish made with wheat flour. An untrained panel of 80 people evaluated the goods' olfactory perceptions against the control group, which did not include greens. A chemical composition examination revealed no significant change in the proximate, substance, and anti-nutrient content of dehydrated greens. The results of the sensory study indicated that the products with 4% dry greens were similar to the control in terms of texture, taste, and overall quality. However, acceptable scores dropped as the amount of greens grew. The addition of drying greens raised the nutritional densities of all products.
Prasoona Et Al., 2020	Instant Chutney Power/ Chutney Premix	Among a Typically Used Fruits and vegetables (Cuv), the best combo was Cvcp1 (Cabbage, The Basella, Greens (1:1:1) Incorporated Instant The Chutney's Powder). It was found that a mixture of vegetables and greens was more popular than just typical powder. The original flavor of the cabbage was retained by not blanching it. After the dried cabbage, spinach, and basella powder were added to regular chutney powder in different ratios, a sensory evaluation was carried out to determine what ten semi-trained panel members thought was sensory acceptable.
Mondal et al., 2020	Vegetable Soup	In order to turn neglected green leafy vegetables (Ipomoea aquatica, Lagenaria siceraria, and Basella alba) from the northeast of India into a wholesome vegetable soup, this study proposes a mathematical optimization technique. In

		order to obtain a low moisture level (3.21%), high levels of vitamin C (110.38 mg/100g), and strong antioxidant activity (80%), the research entailed improving drying techniques. With a solids-to-water ratio of 1:20 and a vegetable mix to corn flour ratio of 4:6, the ideal soup formulation was identified, yielding an extremely high sensory score of 8.4 out of 9. Desired shear-thinning qualities were demonstrated by the reconstituted soup. This approach provides a workable way to turn neglected vegetables into inexpensive, nutrient-dense soups that support agricultural sustainability and nutrition.
Okeyinka, 2024	Soups And Stews, Other Products Like Pastries, Drinks, Sauces And Salads	This study assessed the health advantages and customer acceptance of employing Native Green Leafy Vegetables (IGLVs) in chamber dish preparation. To find out how people felt about IGLVs in food preparation, a survey was given to 40 people. Only four of the 10 IGLVs that were found were often utilized, with amaranth being the least and maringa the most. According to sensory assessments of 10 meals made with these veggies, soups were the most popular, with pumpkins leaf soup receiving the best overall acceptability rating. According to the study's findings, IGLVs might improve chamber meals if new, enticing recipes are created, highlighting the significance of customer acceptability and hygiene in marketing these wholesome veggies.
Singh et al., 2025	Chocolate	The tricolor chocolate's composition enables us to enjoy the entire spectrum of its health advantages in addition to providing us with the benefit of having these necessary elements. As a consequence of the research, another variety of tricolor cocoa is being created to make it easier to consume and to offer further health benefits.

Table 2.7 Food Product Development using Amaranth grain and leaves

Author Name	Product Name	Result
Emire & Arega, 2012	Bread	By adding more protein, mineral substances, and other vital components, amaranth flour improves the nutritional value of wheat flour mixes. For bread manufacture, substituting 5–10% amaranth preserves suitable gluten levels and dough qualities. Blends with up to 10% amaranth replacement are appropriate for industrial baking, whereas bread with as much as 15% amaranth substitution is palatable to the senses. Food insecurity and malnutrition can be addressed using amaranth flour, particularly in regions with little rainfall.
Cárdenas-Hernández et Al., 2016	Pasta	With an emphasis on their nutritional advantages and antioxidant activity, this study examined the effects of employing dry amaranth leaves (DAL) and amaranth seed flour (AF) in the making of pasta. The findings demonstrated that, in comparison to semolina control pasta, pastas prepared with amaranth components had shorter cooking durations, more cooking loss, and decreased brightness. Higher levels of protein, dietary fiber, and minerals—especially iron, zinc, magnesium, calcium, and and potassium—were found in fortified pastas. Pastas containing DAL maintained increased antioxidant levels after cooking, despite cooking lowering total antioxidant capacity. Pasta's functional advantages were increased by the inclusion of DAL and AF, indicating their ability to raise the nutritional value of food items.

Nadu & Nadu, 2018	Dosa	In order to develop a wholesome and reasonably priced convenience meal that is appropriate for celiac patients in India, this study examined the use of free of gluten amaranth grains in dosa mixtures. After being dry-roasted and allowed to germinate, amaranth grains were mixed 1:1 with the Bengal gram dal flour. Significant variations in the functional characteristics and proximate composition between the experimental dosa mixtures and the control group (untreated amaranth flour) were found by nutrient and sensory studies. All samples were found to be equally acceptable by sensory examination. Amaranth grains' nutritional content increased as a result of germination, and they are now suggested as an element in classic dishes like dosa, increasing their accessibility and health advantages for people with gluten sensitivity.
Qumbisa et Al., 2020	Noodles	This study investigated how the nutritional makeup, physical characteristics, and consumer acceptance of instant noodles were affected by the addition of amaranthus leaf powder (ALP). ALP was added to noodle compositions at one percent, two percent, and three percent (w/w). The results demonstrated that while ALP addition had no discernible impact on dietary fiber, protein, or mineral content, it dramatically raised fat percentage (from 1.5 per cent to 4.57%), improving energy value. In terms of appearance, the ALP-fortified noodles were greener and had a softer texture than the control. According to 60 panelists' sensory evaluation, all fortification samples were just as palatable as the control, suggesting that ALP has the potential to raise the nutritious content of the instant noodles without sacrificing customer happiness.

Derkanosova et al., 2020	Bread	Amaranth is a very nutrient-dense pseudocereal that is great for enhancing cuisine because of its high protein, dietary fiber, vitamin, and mineral content. According to studies, amaranth leaves and seeds are very rich in antioxidants, phytochemicals, and vital amino acids, which can help with heart health and inflammation. Because of its adaptability, it may be successfully added to a variety of food products, such as bread and noodles, increasing their nutritious content while preserving their acceptance by consumers. All things considered, amaranth offers a viable way to increase food diversity and nutrition security.
Fish, 2020	Cookies, Laddo, Spicy Sevai, Amaranth Snack Bar,	Amaranth seeds were mixed with a variety of sweet treats. It could be combined with anything we wanted and was universally accepted. The taste of food remains unchanged when amaranth seeds are added. Every food product was developed in a clean setting with minimal to no waste of food ingredients. The food products were prepared without the use of preservatives. Amaranth snacks' high protein content aids in the battle against juvenile malnutrition. Additionally, amaranth seeds have been shown to be safe and beneficial for kids with celiac disease and lactose intolerance by eliminating allergens like dairy and wheat from goods.
Nganthoibi, 2021	Cake, Coconut Laddu, Burfi, Dosa	The primary components of the newly developed items were swapped out for amaranth grain flour, then biochemical analysis was used to compare the most popular products with the control. The biochemical analysis's findings indicated that the goods' nutritious value was increased by the addition of amaranth flour. When amaranth grain flour is added, the produced goods contain up to 50% higher levels of protein, fat, nutritional fiber, and ions including calcium, zinc,

		magnesium, iron, and phosphorus. Test findings for each product were significant ($P \leq 0.05$).
Chamidah & Amertaningtyas, 2023	Chicken Liver Nuggets	With an emphasis on yield quality, organoleptic characteristics, and color, this study examined the impact when adding green spinach flour (Amaranthus tricolor) to chicken liver nuggets. Tests were conducted on four treatments with different concentrations of spinach flour (0%, 5%, 10%, and 15%). Organoleptic characteristics (smell, taste, and color) were greatly affected, while yield and color did not alter considerably. Both yield (146.76%) & sensory evaluations were greatest in the untreated group (0% spinach flour). The results indicate that although spinach flour may change sensory qualities, more research into vegetable flours may improve product variety and formulations.
Gavhane & Kokani, 2023	Crakers	The creation of nutrient-dense crackers from amaranth leaves—which are high in protein, vitamins A, B1, B2, B3, C, and B9—and vital minerals (Ca, Fe, K, Zn, P, and Mg) is covered in the literature review. Refined flour from wheat, whole grain flour, and powdered amaranth leaves were used to make the crackers, which were then cooked for 15 to 20 minutes at 175°C. T2 was chosen for its higher sensory properties out of the three experiments that were carried out. The finished food had an energy equivalent to 350 kcal and a proximate composition that included 71% carbs, 7% fat, and 1.1% protein. At room temperature, the crackers showed a strong hold for as long as three months. All things considered, amaranth leaf crackers provide customers a wholesome and practical snack choice.

Pokhrel, 2024	Cake	The research conducted demonstrated that including Amaranthus viridis leaf into cakes is a useful method of enhancing their nutritious content. By providing thorough insights into the composition, nutritional impact, and sensory characteristics of the enhanced cakes, the study demonstrated the potential for creating healthier baked foods. This knowledge might be helpful to the food industry as well as consumers searching for healthy alternatives in baked products.
Abera Et Al., 2025	Flate bread	The review emphasizes how adding amaranth plant and grain powders to teff flour improves injera. In addition to greatly enhancing minerals like iron, magnesium, calcium, and zinc, this boosted the nutritious content and increased the injera's shelf life from the customary 3–4 days to up to nine to ten days. According to the study, teff-amaranth mixes offer an affordable method of making nutrient-dense, durable flatbread.

Table 2.8 Product Development using Red Amaranth Leaves

Author	**Product**	**Result**
Hossain et al., 2022	Noodles	When red amaranth leaf powder was used to make noodles at 5% and 10% substitutes for wheat flour, the sensory metrics were considerably different ($p<0.05$). The best overall acceptance of the created noodles was obtained when 5% wheat flour was substituted with powdered red amaranth leaves that had been sulphited and cabinet-dried.
Johnst et al., 2022	Cookie	According to the sensory investigation, the acceptance of the cookies is unaffected by the addition of chaya is and amaranth flour. Cookies have more nutritional value and contain more

		bioactive chemicals linked to health benefits when traditional foods like chaya and amaranth are included.
http://www.niftem.ac.in	Pakkavada	Amaranthus Pakkawada is made by combining boiled and crushed leaves with rice flour, basen, wheat flour, maida flour, chili powder, asafetida, and salt to form dough. The ribbon is then fried in high oil to resemble pakkawada.
http://www.niftem.ac.in	Squash	In order to make amaranthus squash, the leaves are extracted and then sweeten with sugar, citric acid, artificial taste, and class-II preservative.
http://www.niftem.ac.in	Cutlet	The stem of the amranthus plant, together with soy chunks, onion, potatoes, green ginger, garlic, and spices, are used to make this nutrient-dense snack.
http://www.niftem.ac.in	Pickle	A stem of the amaranthus is used to make amaranthus pickle, along with additional ingredients including, gingelly oil, garlic, chili powder, vinegar, asafetida, and. ginger

Table 2.9 Departmental Studies on Product Development:

Author	Study	Result
Iyer U. & Thakore, 2018	An intervention study on the supplementation of Guava leaves (*Psidium Guajava*) Powder incorporated crispy bites on the glycemic, lipidemic and inflammatory status of type-2 diabetes mellitus subject	Therapeutic impact, control blood sugar, cure gastrointestinal disorders including diarrhea, provide pain relief, and lessen period cramps,

Venugopal S. & Parikh, 2018	Study on product development, sensory evaluation Glycemic Index lipemic response of Pomegranate (*Punicagranatum*) seed powder incorporated recipe	It has been shown that pomegranate seed powder possesses hypoglycemic and hypolipidemic properties. While sindhi koki roti and upma were classified as medium GI, chilla and peas kabab was classified as low GI.
Venugopal S. & Arora, 2019	Study on product development, sensory evaluation, Glycemic Index & lipemic response of Chia Seed (*Salvia Hispanica*) incorporated recipe	Decrease in lipemic and postprandial glucose reactions. Chia seeds are a functional food that can help control diabetes and its related co-morbidities.
Sheth M. & Chheda, 2019	Impact evaluation of virgin coconut oil (VCO) supplementation by Type-2 diabetes subject with mild-moderate Alzheimer's diseases of urban, Vadodara on sage score lipid profile and FBS level.	Inadequate consumption of certain nutrients, such as potassium, magnesium, phosphorus, protein, carbohydrates, and fate. Weight and BMI decrease.
Venugopal S. & Gandhi, 2020	Impact of supplementation of a functional seed mix (Flaxseed, Chia Seed and Fennel Seed) on Cardio-metabolic profile and assessment of Knowledge, Attitude and Practices on healthy eating and food safety of overweight and obese north east Indian female student studying at The Maharaja Sayajirao University of Baroda, Vadodara	Beneficial function in lowering the risk the chronic illnesses in those who are overweight or obese by assisting in the reduction of risk factors related to the heart and metabolism.

Dhruv S. & Agnihotri,2020	Impact of supplementation of a functional seed mix (Flaxseed, Chia seed and Fennel seed) on Cardio-metabolic profile and assessment of Knowledge, Attitude and Practices on healthy eating and food safety of overweight and obese north east Indian male student studying at The Maharaja Sayajirao University of Baroda, Vadodara	Control of obesity and its associated conditions. Contribute to the long-term reduction of the obesity pandemic.
Dhruv S. & Thite, 2021	Product Development and Sensory evaluation of Foxtail Millet incorporated recipe	In addition to helping to manage celiac disease, foxtail millet's advantageous nutritional qualities would also help to prevent and control non-communicable illnesses. By raising the population's intake of foxtail millet, the booklet would assist to increase the nutritious value of their diet.
Gandhi H. & Negandhi, 2021	A study on time trends in production and consumption of millet in Gujarat consumption patterns of major and minor millets in selected house hold of urban Vadodara and development of millet based recipes for prevention of NCDs.	Intake of millets and the incidence of concurrent medical conditions in the families. Health promotion initiatives were required to encourage the people to regularly consume millet.

Dhruv S. & Sharma, 2022	Nutrient Profiling product development & sensory evaluation of Brown Top millet incorporated recipe	Extremely acceptable and suitable for partial or complete replacement. Brown top millets, which have favorable nutritional qualities and can help manage celiac disease, might be used in place of wheat or rice. They would also help prevent NCDs and increase population consumption, improving the dietary value of people's diets.
Gandhi H & Arora, 2023	Impact of Moringa leaves tablets on prolactin leaves of lactating women and weight gain patterns of infants	Neonates in the experimental group showed a better weight increase pattern than those in the placebo group. Consuming moringa oleifera has been shown to affect the hemoglobin levels of enrolled moms and aid in increasing milk supply.
Sheth M. & Nikam S., 2023	Situational analysis of consumption of bakery foods among university residential students and study the trans-fat content and sensory properties of bakery products prepared with interesterified fat	Bakery goods have a high fat content but no trans fats.
Venugopal S. & Gandhi. 2020	Impact of supplementation of a functional seed mix (Flaxseed, Chia Seed and Fennel Seed) on Cardiometabolic profile and assessment of knowledge,	Beneficial function in lowering the risk the chronic illnesses in those who are overweight or obese by assisting in the reduction of

	Aattribude and Practuces on healthy eating and food safety of overweight and obese north east indian female student studying at The Maharaja Sayajirao University, Baroda, Vadodara	risk factors related to the heart and metabolism.
Dhruv S. & Gajjar, 2024	Nutrient profiling product development, and sensory evaluation of Banyard Millet incorporated recipe	The favorable nutritional qualities of barnyard millet can help prevent and treat non-communicable illnesses, as well as benefit the general public and those with celiac disease by replacing wheat or rice.

Hence the present study was planned to carry out the antioxidant analysis, product development and sensory evaluation of Red Amaranth Leaves (*Amaranthus Cruentus L.)* incorporated recipes.

METHODS AND MATERIALS

In India, the most popular leafy vegetable is cultivated in the throughout season. Amaranthus's soft, fresh leaves and stem are very nutrient-dense and taste great when cooked. Red and green variants are also appropriate for use in cooking. In all tropical and sub-tropical areas, amaranthus is abundantly found. As a warm-season crop, leaf amaranth thrives in hot, muggy weather. In temperate locations, it is cultivated in the fall, spring, and summer, but in tropical regions, it is grown all year round. In addition, goods made with amaranth leaf powder are excellent sources of calcium, iron, fiber, and protein. Such value-added product consumption may help improve the population's nutritional condition, particularly for the most vulnerable (Singh et al., 2013).

Broad Objective:

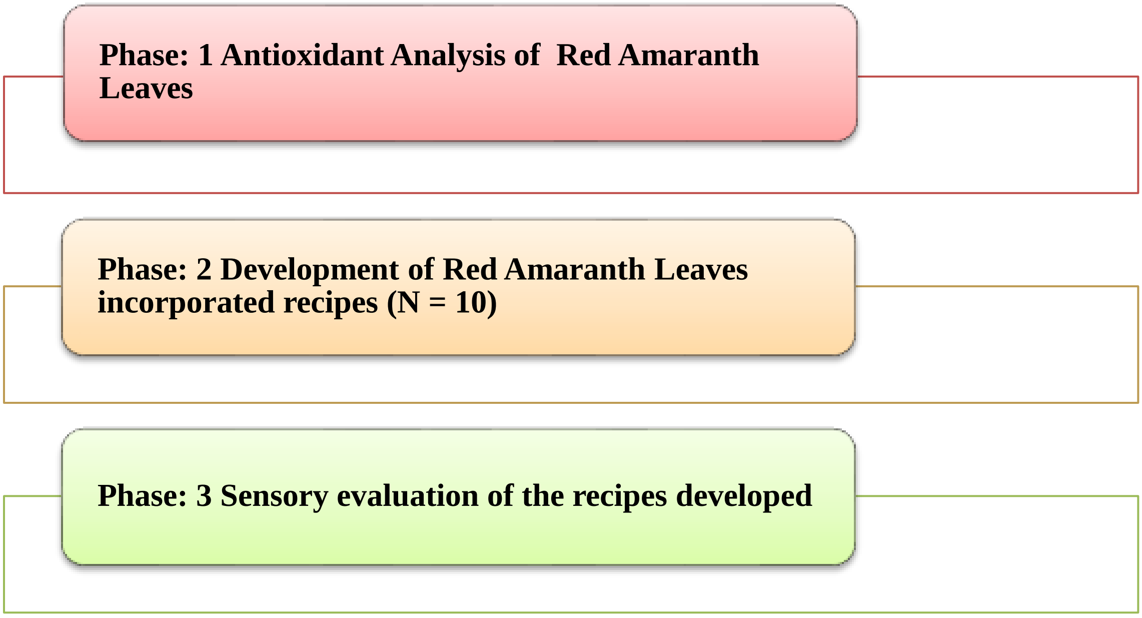
To carry out the antioxidant analysis, product development and sensory evaluation of Red Amaranth Leaves (*Amaranthus Cruentus L.)* incorporated recipes.

Specific Objectives:

1. Antioxidant analysis of Red Amaranth Leaves
2. Development of Red Amaranth Leaves incorporated recipes
3. Sensory evaluation of the recipes developed

The study was approved by the Institutional Ethics Committee for Human Research (IECHR), Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda. The study was allotted ethical approval number IECHR/FCSc/M.Sc./10/2024/43 (Appendix I).

Figure 3.1 Experimental plan of the study



Phase: 1. Antioxidant Analysis of Red Amaranth Leaves

1. **Procurement of Red Amaranth Leaves (*Amaranthus cruentus L.*):** The Red Amaranth Leaves were procured from the local market of Ahmedabad.
2. **Antioxidant analysis of the Red Amaranth Leaves using the following parameters:** Antioxidant parameters like Total Phenols, Flavonoids, FRAP and DPPH-RSA were analyzed at the laboratory of Foods and Nutrition, P.G. Department of Home Science, Sardar Patel University, Vallabh Vidyanagar, Anand, Gujarat (Figure 3.2)
   i. Total Phenols (Folin-Ciocalteu Method by Singleton and Rossi, 1965)
   ii. Flavonoids (Singleton et al., 1999)
   iii. FRAP (Ferric Reducing Antioxidant Power by Benzie et. al., 1996)
   iv. DPPH-RSA (2,2-diphenyl-1-picrylhydrazyl-radical scavenging activity assay by Brand Williams et al., 1995)

Figure 3.2: Phase 1- Antioxidant Analysis of Red Amaranth Leaves

Procurement of Red Amaranth Leaves (*Amaranthus Cruentus L.*) from the local market, Ahmedabad

↓

Antioxidant analysis of the Red Amaranth Leaves using the following parameters:

1. Total Phenols
2. Flavonoids
3. FRAP (Ferric Reducing Antioxidant Power assay)
4. DPPH-RSA (2,2-diphenyl-1-picrylhydrazyl radical scavenging activity assay)

Figure 3.3: Phase 2- Standardization and development of 10 recipes

Khakhra	**Muthiya**	**Thalipeeth**
Thepla	**Kothimbirwadi**	**Air-fried Namakpara**
Dosa	**Chilla**	
Kabab	**Handvo**	

Phase 2: Development of Red Amaranth Leaves incorporated recipes

The development of recipes incorporating red amaranth leaves involves a systematic approach to utilizing their nutritional and culinary potential. Red amaranth leaves, known for their vibrant color and robust flavour, are versatile and can be adapted into various dishes. Red amaranth leaves were procured from the local market of Vadodara and Ahmedabad. RAL was thoroughly cleaned to remove impurities. Depending on the recipe, the red amaranth leaves were chopped finely, used whole, or pureed. A red amaranth leaf was incorporated in different proportions (10%, 20% and 30%) to the control recipes and was processed in the same way as the control recipes. Preparation methods include steaming, roasting, air frying, and shallow frying. A total of 10 recipes were standardized and developed using red amaranth leaves like Khakhra, Thepla, Dosa, Chilla, Handvo, Muthiya, Kothimbirwadi, Kabab, Thalipeeth and air-fried Namakpara (Figure 3.3). Refer tables 3.1 to 3.10 for the composition of control and experimental recipes.

Phase 3: Sensory evaluation of the recipes developed

The sensory evaluation of the developed and standardized products, including Khakhra, Thepla, Dosa, Chilla, Handvo, Muthiya, Kothimbirwadi, Kabab, Thalipeeth and air-fried Namakpara, was conducted with a group of 36 semi-trained panel members from the faculty who willingly participated in the study for sensory evaluation (Appendix-II). The purpose of this evaluation was to determine the acceptability of the developed recipes when RAL was partially or fully substituted with other vegetables/green leafy vegetables in the traditional recipes, as well as to assess the various sensory attributes, if any. To select the panelists, based on inclusion and exculpation criteria baseline data on general information, medical history, and medication history were collected using a pre-tested questionnaire (Appendix-III). The 36 semi-trained panelists were then asked to score or rate each sensorial attribute of the developed recipes in the form of two sensory scoring cards: Composite Score Card and Hedonic Rating Test.

Composite Score Card: The composite rating scale involved a 100-point scoring test, which allowed for the separate rating of specific characteristics of the products. This helped identify any specific attributes that were not acceptable or had faults.

Hedonic Rating Test: This examination employs a 9-point rating system that spans from ‘like very much’ to ‘dislike very much’**,** with ‘neither like nor dislike’ as the neutral score.

This scale aids in determining the most and least favored recipes among the 10 developed recipes.

All the developed recipes were evaluated for the following sensorial attributes:

- Appearance
- Texture
- Flavour
- Taste
- After taste
- Overall acceptability

The flow chart for sensory evaluation can be found in Figure: 3.4. The distinct characteristics of each recipe are listed in Appendix IV (Composite Score Card) and Appendix V (Hedonic Rating Test).

Statistical analysis: The data obtained are expressed as mean ± SD (Student's t-test) using Jamovi (Version 2.6). One-way ANOVA (Analysis of Variance) and the significance of mean differences was determined by Duncan's post-hoc test considering $p \leq 0.05$ significant level of difference was carried out using SPSS 20.

Table 3.11 shows the summary of tools and techniques used throughout the study.

Figure 3.4: Phase 3- Sensory evaluation of the recipes developed

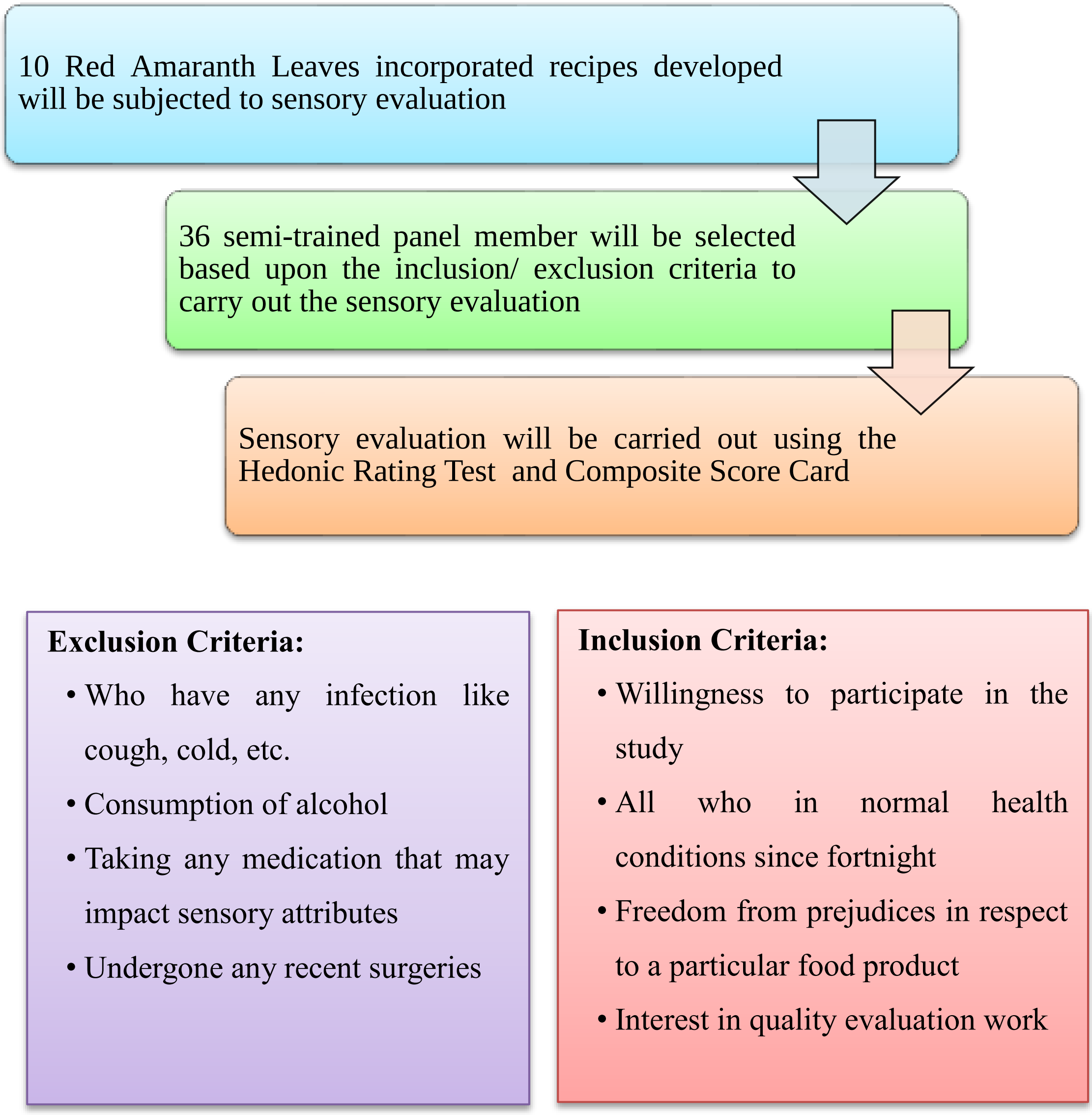


Table 3.1: Composition of Control and Experimental Khakhra

Ingredients	Control	Experimental 1	Experimental 2	Experimental 3
Wheat flour	50 g	50 g	50 g	50 g
Fenugreek L.	30 g	20 g	10 g	-
RAL	**-**	**10 g**	**20 g**	**30 g**
Oil	10 g	10 g	10 g	10 g
Sesame Seed	2 g	2 g	2 g	2 g
Turmeric	2 g	2 g	2 g	2 g
Red chilli powder	2 g	2 g	2 g	2 g
Coriander Powder	1 g	1 g	1 g	1 g
Salt	3 g	3 g	3 g	3 g
Total	**100g**	**100g**	**100g**	**100g**

Table 3.2: Composition of Control and Experimental Thepla

Ingredients	Control	Experimental 1	Experimental 2	Experimental 3
Wheat flour	30 g	30 g	30 g	30g
Bajar flour	24 g	24 g	24 g	24 g
Fenugreek Leaves	30 g	20 g	10 g	-
RAL	**-**	**10 g**	**20 g**	**30 g**
Ginger-garlic-chilli Paste	2 g	2 g	2 g	2 g
Cumin Powder	1 g	1 g	1 g	1 g
Turmeric Powder	1 g	1 g	1 g	1 g
Salt	3 g	3 g	3 g	3 g
Oil	7 g	7 g	7 g	7 g
Red Chilli Powder	1 g	1 g	1 g	1 g
Sesame Seed	1 g	1 g	1 g	1 g
Total	**100 g**	**100 g**	**100 g**	**100 g**

Table 3.3: Composition of Control and Experimental Dosa

Ingredients	Control	Experimental 1	Experimental 2	Experimental 3
Rice	67 g	60 g	58 g	50 g
Urad Dal	25 g	22 g	14 g	12 g
RAL	**-**	**10 g**	**20 g**	**30 g**
Oil	5 g	5 g	5 g	5 g
Salt	3 g	3 g	3 g	3 g
Total	**100g**	**100g**	**100g**	**100g**

Table 3.4: Composition of Control and Experimental Chilla

Ingredients	Control	Experimental 1	Experimental 2	Experimental 3
Besan	54 g	54 g	54 g	54 g
Ajwain	2 g	2 g	2 g	2 g
Salt	3 g	3 g	3 g	3 g
Turmeric	2 g	2 g	2 g	2 g
Onion	30 g	20 g	10 g	-
RAL	**-**	**10 g**	**20 g**	**30 g**
Red chilli powder	3 g	3 g	3 g	3 g
Ginger-garlic paste	2 g	2 g	2 g	2 g
Oil	4 g	4 g	4 g	4 g
Total	**100g**	**100g**	**100g**	**100g**

Table 3.5: Composition of Control and Experimental Handvo

Ingredients	Control	Experimental 1	Experimental 2	Experimental 3
Tur dal	10 g	10 g	10 g	10 g
Rice	10 g	10 g	10 g	10 g
Yellow moong dal	10 g	10 g	10 g	10 g
Chana dal	10 g	10 g	10 g	10 g
Urad dal	10 g	10 g	10 g	10 g
Curd	4 g	4 g	4 g	4 g
Bottle gourd	30 g	20 g	10 g	-
RAL	**-**	**10 g**	**20 g**	**30 g**
ginger-garlic-chilli Paste	1 g	1 g	1 g	1g
Oil	5 g	5 g	5 g	5 g
Salt	3 g	3 g	3 g	3 g
Coriander powder	1 g	1 g	1 g	1 g
Red chilli powder	1 g	1 g	1 g	1 g
Turmeric	1 g	1 g	1 g	1 g
Baking soda	2 g	2 g	2 g	2 g
Sesame seed	1 g	1 g	1 g	1 g
Mustard seed	1 g	1 g	1 g	1 g
Total	**100g**	**100g**	**100 g**	**100 g**

Table 3.6: Composition of Control and Experimental Muthiya

Ingredients	Control	Experimental 1	Experimental 2	Experimental 3
Kanki korma	30 g	30 g	30 g	30 g
Wheat flour	10 g	10 g	10 g	10g
Fenugreek L.	30 g	20 g	10 g	-
RAL	**-**	**10 g**	**20 g**	**30 g**
Ginger-Garlic-Chilli paste	6 g	6 g	6 g	6 g
Salt	2.5 g	2.5 g	2.5 g	2.5 g
Coriander Powder	1.5 g	1.5 g	1.5 g	1.5 g
Sugar	4 g	4 g	4 g	4 g
Curd	10 g	10 g	10 g	10 g
Turmeric	1 g	1 g	1 g	1 g
Oil	2 g	2 g	2 g	2 g
Mustard seed	1 g	1 g	1 g	1 g
Total	**100g**	**100g**	**100g**	**100g**

Table 3.7: Composition of Control and Experimental Kothimbirwadi

Ingredients	Control	Experimental 1	Experimental 2	Experimental 3
Besan	45 g	45 g	45 g	45 g
Rice Flour	5 g	5 g	5 g	5 g
Coriander L.	30 g	20 g	10 g	-
RAL	**-**	**10 g**	**20 g**	**30 g**
Ginger-garlic-chilli paste	2 g	2 g	2 g	2 g
Curd	6 g	6 g	6 g	6 g
Lemon juice	1 g	1 g	1 g	1 g
Baking soda	1 g	1 g	1 g	1 g
Oil	3 g	3 g	3 g	3 g
Cumin seed	1 g	1 g	1 g	1 g
Turmeric	1 g	1 g	1 g	1 g
Red chilli powder	1 g	1 g	1 g	1 g
Salt	3 g	3 g	3 g	3 g
Sesame seed	1 g	1 g	1 g	1 g
Total	**100g**	**100g**	**100g**	**100g**

Table 3.8: Composition of Control and Experimental Kabab

Ingredients	Control	Experimental 1	Experimental 2	Experimental 3
Potato	48 g	48 g	48 g	48 g
Spinach	30 g	20 g	10 g	-
RAL	-	**10 g**	**20 g**	**30 g**
Suji	13 g	13 g	13 g	13 g
Oil	5 g	5 g	5 g	5 g
Garam masala	1g	1 g	1 g	1 g
Coriander powder	1 g	1 g	1 g	1 g
Turmeric powder	1 g	1 g	1 g	1 g
ginger-garlic-chilli paste	1 g	1 g	1 g	1 g
Total	**100g**	**100g**	**100g**	**100g**

Table 3.9: Composition of Control and Experimental Thalipeeth

Ingredients	Control	Experimental 1	Experimental 2	Experimental 3
Besan	10 g	10 g	10 g	10 g
Wheat flour	10 g	10 g	10 g	10 g
Bajra flour	10 g	10 g	10 g	10 g
rice flour	10 g	10 g	10 g	10 g
Coriander leaves	30 g	20 g	10 g	**-**
RAL	**-**	**10 g**	**20 g**	**30 g**
Turmeric powder	2 g	2 g	2 g	2 g
Sesame seed	2 g	2 g	2 g	2 g
Ginger-garlic-chilli paste	2 g	2 g	2 g	2 g
Onion	8 g	8 g	8 g	8 g
Cumin seed	2 g	2 g	2 g	2 g
Salt	3 g	3 g	3 g	3 g
oil	6 g	6 g	6 g	6 g
red chilli powder	3 g	3 g	3 g	3 g
Total	**100g**	**100g**	**100g**	**100g**

Table 3.10: Composition of Control and Experimental Air-fried Namakpara

Ingredients	Control	Experimental 1	Experimental 2	Experimental 3
Wheat flour	47 g	47 g	47 g	47g
Bajra flour	30 g	20 g	10 g	-
RAL	**-**	**10 g**	**20 g**	**30 g**
Jeera	2 g	2 g	2 g	2 g
Ajwain	2 g	2 g	2 g	2 g
Til	2 g	2 g	2 g	2 g
Salt	3 g	3 g	3 g	3 g
Red chilli powder	4 g	4 g	4 g	4 g
Turmeric powder	2 g	2 g	2 g	2 g
Oil	8 g	8 g	8 g	8 g
Total	**100 g**	**100 g**	**100 g**	**100 g**

Table 3.11 Tools and Techniques

Parameters	Method/Tools
Total Phenols	Folin-Ciocalteu Method by Singleton and Rossi, 1965
Flavonoids	Singleton et al., 1999
FRAP (Ferric Reducing Antioxidant Power assay)	Ferric Reducing Antioxidant Power by Benzie et. al., 1996
DPPH-RSA (2,2-diphenyl-1-picrylhydrazyl radical scavenging activity assay)	2,2-diphenyl-1-picrylhydrazyl-radical scavenging activity assay by Brand Williams et. al. 1995
General information of semi-trained panel members	Pretested Questionnaire
Sensory Attributes	Hedonic Rating Test and Composite Score Card

RESULTS AND DISCUSSION

Red amaranth (*Amaranthus Cruentus L.*) is a leafy vegetable with red velvet color, rich in nutrients, and antioxidants. Nutrient content in red amaranth leaves are richer than those in other green leafy vegetables (Sarker & Oba, 2019). *Amaranthus cruentus l.*, family amaranthaceae, and solanum nigrum l., family solanaceae, are two important leafy vegetables that are available in the market and widely eaten in different parts of Asia. The nutritional and medicinal importance of these two key vegetables has been known to science for a long time. According to Amin et al. (2006), overwhelming scientific data from epidemiological studies indicate that diets rich in fruits, vegetables and grains are associated with a lower risk of several degenerative diseases, such as cancers (Adebooye et al., 2008) and cardiovascular diseases (Rimm et al., 1996). Amin et al. (2006) also stated that this association is often attributed to different antioxidant components, such as vitamin C, vitamin E, carotenoids, lycopene, polyphenols and other phytochemicals (Adebooye et al., 2008).

Presence of proteins that consist of albumin, globulin, glutelin, and prolamin fractions. Seeds do not contain gluten, so they can be introduced into the diet of patients suffering from celiac disease (Wolosik & Markowska, 2019). Red Amaranth leaves (*Amaranthus Cruentus, L.),* has been reported to contain high concentration of phytonutrients, in which they could exert a significant effect on human health (Ampapon et al., 2022, Pulipati et al., 2017).

Amaranth is a nutritious crop containing high levels of crude protein, minerals, vitamins, as well as polyphenols and flavonoids especially in the leaf and seeds (Ampapon et al., 2022).

Amaranthus.Cruentus l has high nutritional and functional values: it shows, among others, an interesting fatty acid profile and a valuable antioxidant potential and phenolic compounds, well-known as antioxidants (Gresta et al., 2020).

The leaves of the young *A. Cruentus* plants can be used in salads and soups, and the grains are utilized in the production of breads, cakes, and cookies and can be added to soups. In addition to the important nutritionally primary metabolites, amaranth plants also contain some specialized metabolite compounds that play an important role in the human diet. Because of the high nutritional value of A. *Cruentus*, the consumption of this plant has been recommended for its ability to contribute to different benefits, such as antioxidant activity, increased pro-vitamin a, and anticancer genic compounds, all of which can help in a healthy diet (Id et al., 2022)

Phase 1: Antioxidant analysis of Red Amaranth Leaves (RAL)

Phase 1 of the study comprised of the antioxidant analysis of the RAL. The antioxidant parameters were analyzed from 5 grams fresh RAL and extract using 50 ml 80:20 methanol water. Table 4.1 depicts the total phenol, flavonoid, FRAP, DPPH-RSA of RAL. The total phenol content was found to be 35.4 mgGAE/100gm. The flavonoids content was 50.3 mgRE/100gm. The FRAP assay revealed a reducing power of 28.3 mgTE/100gm. The DPPH-Radical Scavenging Activity was 59.72 % inhibition, corresponding to 389.8 mgTE/100gm. These results indicate that fresh red amaranth leaves (*Amaranthus Cruentus L.*) possess notable antioxidant activity.

Table 4.1: Antioxidant parameters of Red Amaranth Leaves

Antioxidant Parameters	Red Amaranth Leaves (per 100gm)
Total Phenol	35.4 ± 1.94 mgGAE
Flavonoids	50.3 ± 5.61 mgRE
FRAP	28.3 ± 3.93 mgTE
DPPH-RSA	389.8 ± 11.15 mgTE

Values are Mean±SD of 4 observations

The observed total phenolic content and total flavonoid content values in fresh red amaranth leaves suggests a significant presence of phenolic and flavonoid compounds, which are known to be potent antioxidants. The FRAP and DPPH radical scavenging assays further confirmed the antioxidant capacity of these leaves. The relatively low standard deviations indicate the reliability and consistency of the measurements. The use of fresh leaves, without drying, likely preserves the integrity of these compounds, contributing to the observed activity. The red coloration of amaranth leaves is often associated with betalains, in addition to other phenolics, which may contribute to the measured antioxidant activity.

Phase 2: Development of Red Amaranth Leaves (RAL) incorporated recipes

There is dearth of data concerning the food product development of red amaranth leaves especially concerning traditional Indian recipes that can be incorporated into daily diet. The development of ten traditional Indian recipes air-fried namakpara, khakhra, thepla, thalipeeth, chilla, muthiya, kothimbirwadi, dosa, handvo, and kabab was systematically standardized by incorporating red amaranth leaves at varying levels: 10%, 20%, and 30%, alongside a control group with no added amaranth. Each recipe was prepared according to its traditional method, as categorized by cooking style**:** roasted (khakhra, thepla, thalipeeth, chilla), fermented (dosa, handvo), steam-cooked (muthiya, kothimbirwadi), shallow-fried (kabab) and air-fried (namakpara). The incorporation of red amaranth leaves presented unique challenges and opportunities for each recipe, impacting texture, color, and flavour profiles. Throughout the development process, the varying levels of amaranth incorporation allowed for precise observation of its influence on each recipe's traditional characteristics, facilitating the identification of optimal percentages for maintaining culinary integrity while enhancing nutritional value.

Table 4.2 shows the nutrient composition of control and experimental khakhra, each receiving varying levels of RAL supplementation (10%, 20%, and 30%). Energy values remained consistent across all khakhras, ranging from 260 kcal in the control khakhra to 265 kcal in experimental 3 khakhra. The protein content exhibited a slight increase, commencing at 6.4 g in the control khakhra and rising to 6.8 g in experimental 3 khakhra. Fat content remained stable, demonstrating minimal variation between 11.0 g and 10.9 g across the control and experimental khakhra. Additionally, carbohydrate levels increased marginally, from 33 g in the control khakhra to 35 g in experimental khakhra 3. Vitamin A levels reached their peak at 462 mg in control khakhra but slightly a decrease to 450 mg in experimental 3 khakhra. Conversely, vitamin C levels improved from 17 mg in the control khakhra to 23 mg in both experimental 2 and 3 khakhras. Iron levels displayed a steady increase, starting at 3.8 mg in the control khakhra and attaining a maximum of 4.2 mg in experimental 3 khakhra. Fiber content consistently remained at 16 g in control and 17 g across all khakhras, whereas calcium levels significantly increased from 88 mg in the control khakhra to 107 mg in experimental 2 and 3 khakhra. Figure 4.1 shows the appearance of the control and experimental khakhra.

Table 4.2 Nutritive value of control and experimental Khakhra

Nutrients	Control	Experimental 1 (10% RAL)	Experimental 2 (20% RAL)	Experimental 3 (30% RAL)
Energy (kcal)	260	261.18	263	265
Protein (g)	6.4	6.5	6.6	6.8
Fat (g)	11.0	11.0	10.9	10.9
Carbohydrate (g)	33	33	34	35
Vitamin A (mg)	462	458	454	450
Vitamin C (mg)	17	20	23	26
Iron (mg)	3.8	3.9	4.1	4.2
Fiber (g)	16	17	17	17
Calcium (mg)	88	97	107	110

Table 4.3 Nutritive value of control and experimental Thepla

Nutrients	Control	Experimental 1 (10% RAL)	Experimental 2 (20% RAL)	Experimental 3 (30% RAL)
Energy (kcal)	253	254	259	258
Protein (g)	6.9	7.0	7.5	7.3
Fat (g)	8.9	8.9	9.0	8.9
Carbohydrate (g)	168	169	170	171
Vitamin A (mg)	462	458	454	450
Vitamin C (mg)	17	20	23	26
Iron (mg)	1.71	1.87	2.02	2.18
Fiber (g)	16	17	17	17
Calcium (mg)	88	98	135	117

Table 4.3 outlines the nutrient composition of control and experimental thepla supplemented with 10%, 20%, and 30% incorporation of RAL. Energy values slightly increase from 253 kcal in the control to 258 kcal in experimental 3 thepla. Protein content rises from 6.9 g in the control to a peak of 7.5 g in experimental 2 thepla, before decreasing slightly to 7.3 g in experimental 3 thepla. Fat remains stable across control and experimental thepla, ranging from 8.9 g to 9.0 g. Carbohydrate levels show a gradual increase from 168 g in the control to 171 g in experimental 3 thepla. Vitamin A steadily decreases from 462 mg in the control to 450 mg in experimental 3 thepla, while Vitamin C significantly increases, starting at 17 mg in the control and reaching 26 mg in experimental 3 thepla. Iron content rises progressively from 1.71 mg in the control to a maximum of 2.18 mg in experimental 3 thepla. Fiber remains constant at 16–17 g across all thepla, whereas calcium shows notable variation, increasing from 88 mg in the control to a peak of 135 mg in experimental 2 thepla, before slightly dropping to 117 mg in experimental 3 thepla. Figure 4.3 shows the appearance of the control and experimental thepla.

Table 4.4 represents the nutrient composition of control and experimental dosa. The findings reveal a significant decrease in energy content, which drops from 362 kcal in the control dosa to 284 kcal in experimental 3 dosa. Protein levels also decline, starting at 10.9 g in the control and falling to 8.1 g in experimental 3 dosa. The fat content remains fairly stable, ranging from 5.8 g to 5.6 g across all groups. Carbohydrates decrease from 64 g in the control to 48 g in experimental 3 dosa. While vitamin A is absent in the control, it increases to 450 mg in experimental 2 dosa. Vitamin C levels rise from 9 mg in experimental 1 dosa to 26 mg in experimental 3 dosa. Iron content shows a steady increase from 1.63 mg in the control dosa to 3.09 mg in experimental 3 dosa. Fiber remains constant at 5 g across all groups, and calcium shows a significant increase, rising from 19 mg in the control to 121 mg in experimental 3 dosa. Figure 4.3 shows the appearance of the control and experimental dosa.

Table 4.4 Nutritive value of control and experimental Dosa

Nutrients	Control	Experimental 1 (10% RAL)	Experimental 2 (20% RAL)	Experimental 3 (30% RAL)
Energy (kcal)	362	363	314	284
Protein (g)	10.9	9.7	8.7	8.1
Fat (g)	5.8	5.8	5.7	5.6
Carbohydrate (g)	64	59	54	48
Vitamin A (mg)	-	150	300	450
Vitamin C (mg)	-	9	17	26
Iron (mg)	1.63	2.16	2.50	3.09
Fiber (g)	5	5	5	5
Calcium (mg)	19	54	86	121

Table 4.5 Nutritive value of control and experimental Chilla

Nutrients	Control	Experimental 1 (10% RAL)	Experimental 2 (20% RAL)	Experimental 3 (30% RAL)
Energy (kcal)	243	243	243	244
Protein (g)	11.7	12.0	12.4	12.7
Fat (g)	6.7	6.7	6.8	6.8
Carbohydrate (g)	29	29	29	29
Vitamin A (mg)	-	150	300	450
Vitamin C (mg)	22	30	38	46
Iron (mg)	3.39	4.12	4.84	5.57
Fiber (g)	8	9	9	9
Calcium (mg)	36	70	105	140

Table 4.5 depicts the nutrient composition of a control chilla and three experimental chilla with varying levels of RAL supplementation (10%, 20%, and 30%). Energy content remains consistent across all groups, ranging from 243 kcal to 244 kcal. Protein levels increase gradually from 11.7 g in the control to 12.7 g in the experimental 3 chilla. Fat content is stable, varying minimally between 6.7 g and 6.8 g. Carbohydrate levels remain constant at 29 g across all groups. Vitamin A is absent in the control but increases to 450 mg in the experimental 3 chilla. Vitamin C also rises significantly, starting at 22 mg in the control and reaching 46 mg in the experimental 3 chilla. Iron content increases steadily from 3.39 mg in the control to 5.57 mg in the experimental 3 chilla. Fiber content increases from 8 g in the control to 9 g in the experimental groups. Calcium levels show a notable increase from 36 mg in the control to 140 mg in the experimental 3 chilla. . Figure 4.4 shows the appearance of the control and experimental chilla.

Table 4.6 describes the nutrient composition of control and experimental handvo with 10%, 20%, and 30% RAL supplementation Energy content increases from 264 kcal in the control to 275 kcal in experimental 3 handvo. Protein levels rise from 10.2 g in the control to 11.5 g in experimental 3 handvo. Fat content remains relatively stable, ranging from 11.4 g to 11.5 g across all groups. Carbohydrate levels increase gradually from 34 g in the control to 37 g in experimental 3 handvo. Vitamin A shows a dramatic increase, starting at 2 mg in the control and reaching 450 mg in experimental 3 handvo. Vitamin C also rises significantly, from 1 mg in the control to 26 mg in experimental 3 handvo. Iron content increases steadily from 2.00 mg in the control to 4.02 mg in experimental 3 handvo. Fiber content 6 mg is silimler to all the handvo. Calcium levels show a notable increase from 39 mg in the control to 145 mg in experimental 3 handvo. Figure 4.5 shows the appearance of the control and experimental handvo

Table 4.7 shows the nutrient composition of control group and experimental muthiya. Energy content increases slightly from 162 kcal in the control to 167 kcal in experimental 3 muthiya. Protein levels show a gradual rise, starting at 6.7 g in the control and reaching 7.0 g in experimental 3 muthiya. Fat content remains stable, varying minimally between 3.0 g and 2.9 g across all groups. Carbohydrates increase slightly from 27 g in the control to 29 g in Experimental groups 2 and 3. Vitamin A decreases steadily from 462 mg in the control to 450 mg in experimental 3 muthiya,

Table 4.6 Nutritive value of control and experimental Handvo

Nutrients	Control	Experimental 1 (10% RAL)	Experimental 2 (20% RAL)	Experimental 3 (30% RAL)
Energy (kcal)	264	268	272	275
Protein (g)	10.2	10.6	11.1	11.5
Fat (g)	11.4	11.4	11.5	11.5
Carbohydrate (g)	34	35	36	37
Vitamin A (mg)	2	151	301	450
Vitamin C (mg)	1	9	18	26
Iron (mg)	2.00	2.69	3.38	4.08
Fiber (g)	6	6	6	6
Calcium (mg)	39	75	110	145

Table 4.7 Nutritive value of control and experimental Muthiya

Nutrients	Control	Experimental 1 (10% RAL)	Experimental 2 (20% RAL)	Experimental 3 (30% RAL)
Energy (kcal)	162	164	166	167
Protein (g)	6.7	6.8	6.9	7.0
Fat (g)	3.0	3.0	2.9	2.9
Carbohydrate (g)	27	28	29	29
Vitamin A (mg)	462	458	454	450
Vitamin C (mg)	17	20	23	26
Iron (mg)	3.02	3.18	3.33	3.49
Fiber (g)	9	9	9	9
Calcium (mg)	90	99	109	118

while Vitamin C increases significantly, starting at 17 mg in the control and reaching 26 mg in experimental 3 muthiya. Iron content rises progressively from 3.02 mg in the control to 3.49 mg in the experimental 3 muthiya. Fiber remains constant at 9 g across all groups, and calcium shows a notable increase from 90 mg in the control to 118 mg in the experimental 3 muthiya. Figure 4.6 shows the appearance of the control and experimental chilla.

Table 4.8 outlines the nutrient composition of control and experimental kothimbirwadi supplemented with 10%, 20%, and 30% of RAL. Energy content increases slightly from 224 kcal in the control to 230 kcal in experimental 3 kothimbirwadi. Protein levels rise gradually, starting at 11.3 g in the control and reaching 11.8 g in experimental 3 kothimbirwadi. Fat content remains stable, varying minimally between 7.9 g and 7.8 g across all groups. Carbohydrates increase slightly from 26 g in the control to 28 g in experimental 3 kothimbirwadi. Vitamin A shows a significant increase, starting at 190 mg in the control and reaching 450 mg in experimental 3 kothimbirwadi. Vitamin C rises notably from 7 mg in the control to 26 mg in experimental 3 kothimbirwadi. Iron content increases steadily from 4.68 mg in the control to 5.27 mg in experimental 3 kothimbirwadi. Fiber remains constant at 8 g across all groups, while calcium shows a marked increase from 73 mg in the control to 141 mg in experimental 3 kothimbirwadi. Figure 4.7 shows the appearance of the control and experimental Kothimbirwadi.

Table 4.9 depicts the nutrient composition of control group and experimental kabab supplemented with RAL (10%, 20%, and 30%). Energy content increases slightly from 129 kcal in the control to 137 kcal in experimental 3 kabab. Protein levels rise progressively from 2.9 g in the control to 3.7 g in experimental 3 kabab. Fat content remains stable at 5.4 g across all groups. Carbohydrate levels increase gradually from 17 g in the control to 19 g in experimental 3 kabab. Vitamin A shows a significant increase, starting at 130 mg in the control and reaching 450 mg in experimental 3 kabab. Vitamin C also rises notably, from 9 mg in the control to 26 mg in experimental 3 kabab. Iron content increases steadily from 1.27 mg in the control to 2.26 mg in experimental 3 kabab. Fiber remains constant at 3 g across all groups, while calcium shows a marked increase from 33 mg in the control to 119 mg in experimental 3 kabab. Figure 4.8 shows the appearance of the control and experimental Kabab.

Table 4.8 Nutritive value of control and experimental Kothimbirwadi

Nutrients	Control	Experimental 1 (10% RAL)	Experimental 2 (20% RAL)	Experimental 3 (30% RAL)
Energy (kcal)	224	226	228	230
Protein (gm)	11.3	11.5	11.6	11.8
Fat (gm)	7.9	7.8	7.8	7.8
Carbohydrate (gm)	26	26	27	28
Vitamin A (mg)	190	277	363	450
Vitamin C (mg)	7	13	20	26
Iron (mg)	4.68	4.88	5.07	5.27
Fiber (gm)	8	8	8	8
Calcium (mg)	73	96	118	141

Table 4.9 Nutritive value of control and experimental Kabab

Nutrients	Control	Experimental 1 (10% RAL)	Experimental 2 (20% RAL)	Experimental 3 (30% RAL)
Energy (kcal)	129	131	134	137
Protein (gm)	2.9	3.1	3.4	3.7
Fat (gm)	5.4	5.4	5.4	5.4
Carbohydrate (gm)	17	17	18	19
Vitamin A (mg)	130	237	343	450
Vitamin C (mg)	9	15	20	26
Iron (mg)	1.27	1.70	2.13	2.56
Fiber (gm)	3	3	3	4
Calcium (mg)	33	62	90	119

Table 4.10 describes the nutrient composition of control group and experimental thalipeeth incorporating 10%, 20%, and 30% RAL. Energy content increases slightly from 203 kcal in the control to 209 kcal in experimental 3 thalipeeth. Protein levels rise gradually from 6.3 g in the control to 6.7 g in Experimental groups 3. Fat content remains stable at 7.5 g and 7.4 g across all groups. Carbohydrate levels increase slightly from 82 g in the control to 84 g in Experimental groups 3. Vitamin A shows a significant increase, starting at 190 mg in the control and reaching 450 mg in experimental 3 thalipeeth. Vitamin C rises notably, from 8 mg in the control to 27 mg in experimental 3 thalipeeth. Iron content increases steadily from 4.19 mg in the control to 4.78 mg in experimental 3 thalipeeth. Fiber remains constant at 9 g across all groups, while calcium shows a marked increase from 51 mg in the control to 118 mg in experimental 3 thalipeeth. Figure 4.9 shows the appearance of the control and experimental thalipeeth.

Table 4.11 represents the nutrient composition of control and experimental air-fried namakpara with increasing levels of RAL supplementation (10%, 20%, and 30%). Energy content decreases progressively from 326 kcal in the control to 237 kcal in experimental 3 air-fried namakpara. Protein levels decline from 8.2 g in the control to 6.4 g in experimental 3 air-fried namakpara, while fat content reduces slightly from 10.3 g to 8.9 g. Carbohydrate levels drop steadily from 49 g in the control to 33 g in experimental 3 air-fried namakpara. Vitamin A shows a dramatic increase, starting at 1 mg in the control and rising to 450 mg in experimental 3 air-fried namakpara. Vitamin C is absent in the control but increases significantly to 26 mg in experimental 3 air-fried namakpara. Iron remains relatively stable, ranging from 3.8 mg to 4.1 mg, while Fiber remains constant at 16 g across all groups. Calcium levels show a notable increase, starting at 8 mg in the control and reaching 116 mg in experimental 3 air-fried namakpara. Figure 4.10 shows the appearance of the control and experimental namakpara

This analysis indicates that RAL supplementation has a evident influence on specific nutrient levels, particularly vitamins and minerals, while maintaining stability in the macronutrient composition across the control and experimental recipes.

Table 4.10 Nutritive value of control and experimental Thalipeeth

Nutrients	Control	Experimental 1 (10% RAL)	Experimental 2 (20% RAL)	Experimental 3 (30% RAL)
Energy (kcal)	203	205	207	209
Protein (g)	6.3	6.4	6.6	6.7
Fat (g)	7.5	7.5	7.4	7.4
Carbohydrate (g)	82	83	84	85
Vitamin A (mg)	190	277	363	450
Vitamin C (mg)	8	14	20	27
Iron (mg)	4.19	4.39	4.58	4.78
Fiber (g)	9	9	9	9
Calcium (mg)	51	73	96	118

Table 4.11 Nutritive value of control and experimental Air fried Namakpara

Nutrients	Control	Experimental 1 (10% RAL)	Experimental 2 (20% RAL)	Experimental 3 (30% RAL)
Energy (kcal)	326	297	267	237
Protein (g)	8.2	7.6	6.9	6.4
Fat (g)	10.3	9.8	9.3	8.9
Carbohydrate (g)	49	43	38	33
Vitamin A (mg)	1	151	300	450
Vitamin C (mg)	-	9	17	26
Iron (mg)	3.8	3.9	4.0	4.1
Fiber (g)	16	16	16	16
Calcium (mg)	8	44	80	116

Figure 4.1: Appearance of Control and Experimental Khakhra

Figure 4.2: Appearance of Control and Experimental Thepla

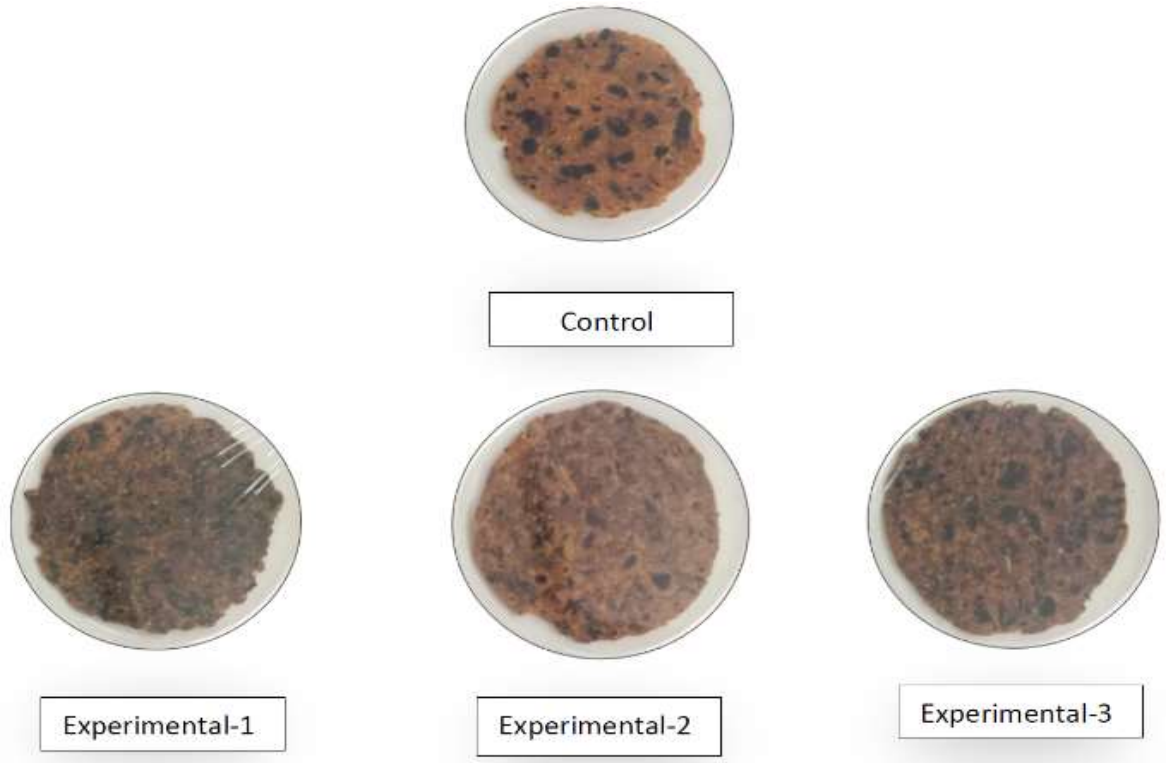


Figure 4.3: Appearance of Control and Experimental Dosa

Figure 4.4: Appearance of Control and Experimental Chilla

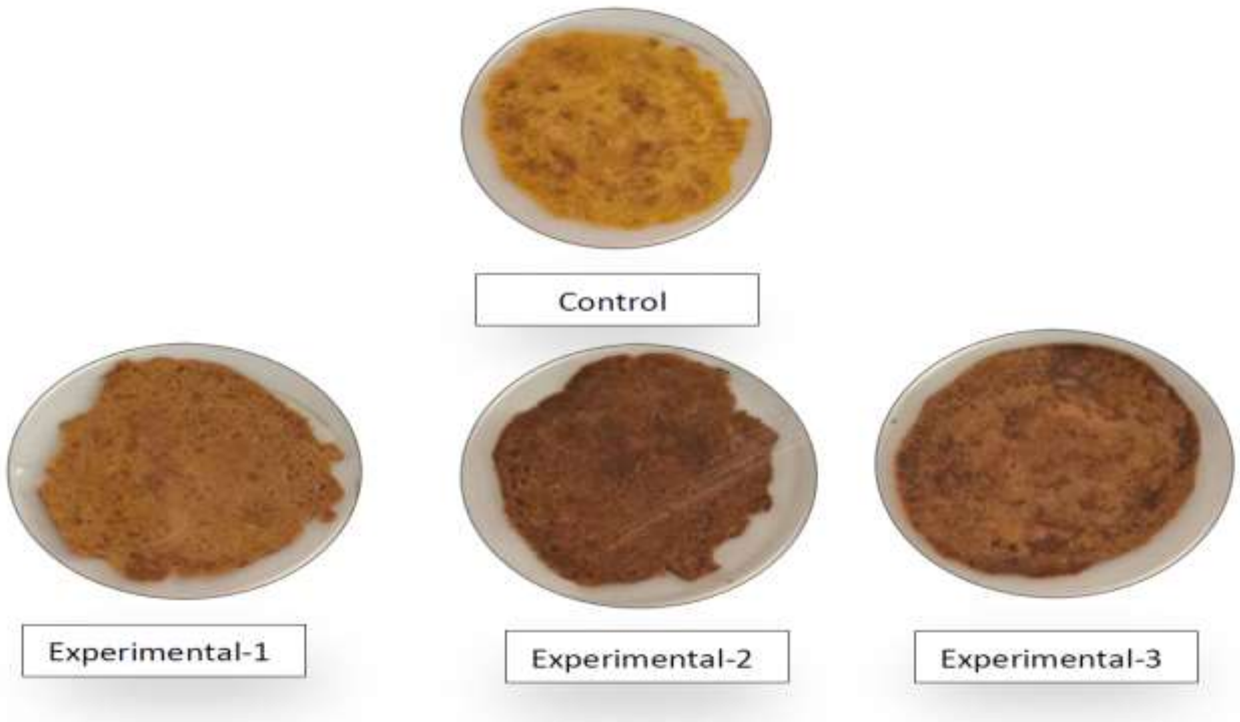


Figure 4.5: Appearance of Control and Experimental Handvo

Figure 4.6: Appearance of Control and Experimental Muthiya

Figure 4.7: Appearance of Control and Experimental Kothimbirwadi

Figure 4.8: Appearance of Control and Experimental Kabab

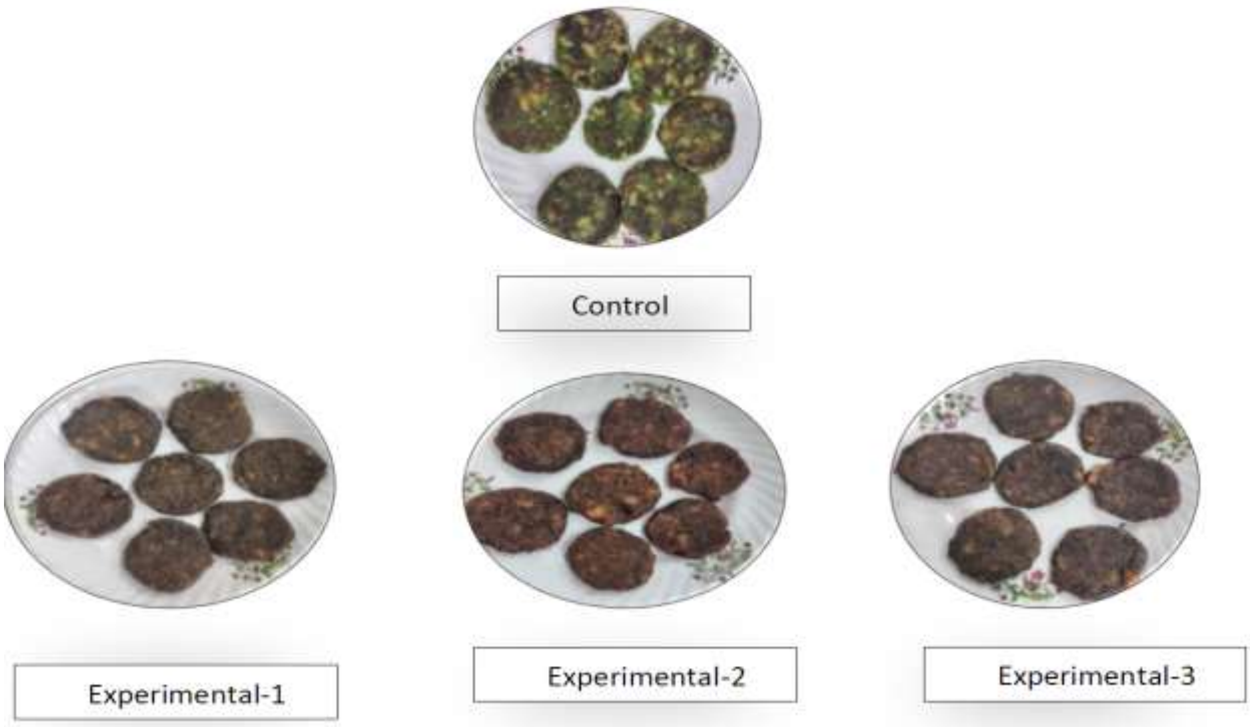
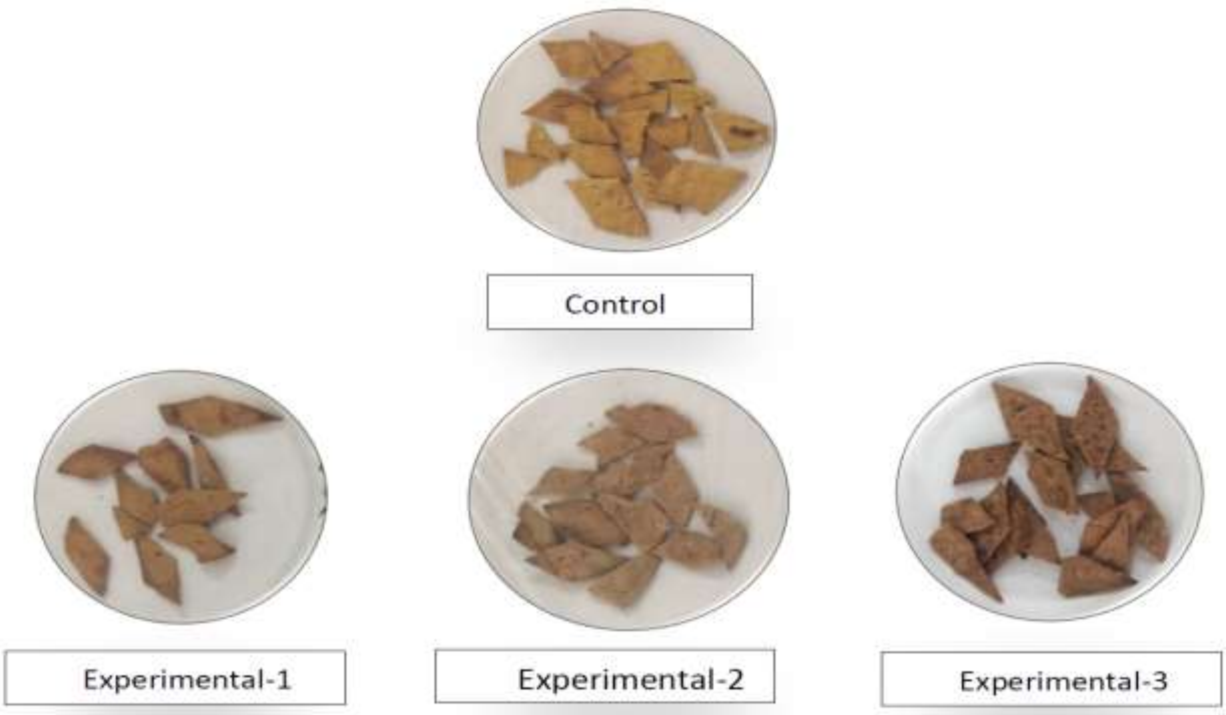


Figure 4.9: Appearance of Control and Experimental Thalipeeth

Figure 4.10: Appearance of Control and Experimental air fried Namakpara



Phase 3: Sensory evaluation of the recipes developed

The 10 recipes standardized and developed in phase 2 were subjected to sensory evaluation using composite score card and hedonic rating test. A semi-trained panel of 36 members was asked to evaluate several sensorial attributes of the recipes developed. The sensory evaluation was done in two parts: Composite score card and Hedonic rating test. The composite score card consisted of sensorial attributes like appearance (20), texture (20), flavor (15), taste (20), after taste (5) and overall acceptability (20) with a total score out of 100, where higher scores indicates better sensory activity. Whereas, the hedonic rating test focused on the overall liking of several attributes like appearance, texture, flavour, taste, after taste and overall acceptability of the developed recipes using a 9-point rating scale ranging from like extremely to dislike extremely with a middle score of neither like nor dislike.

Composite score of Red Amaranth Leaves incorporated recipes:

Table 4.12 describes the composite score of the control and experimental khakhra. The appearance score of the khakhra ranged from 16.75 to 17.44. Experimental 1 khakhra scores the highest (17.44) of all the samples. The texture score of the control and experimental khakhra ranged from 17.72 to 17.61. Experimental 3 khakhra obtained to highest texture score (17.61). The flavour score of khakhra ranged from 11.31 to 11.81, with control khakhra obtaining the highest score (11.81) and experimental 1 khakhra with the lowest score (11.31). The taste score of the khakhra incorporated with varying levels of red amaranth leaves ranged from 14.03 to 15.83. 30% red amaranth leaves incorporated khakhra sample scored the highest taste score (15.83) followed by 20% red amaranth leaves incorporated khakhra (15.17), 10% red amaranth leaves incorporated khakhra (14.17) and control (14.03) khakhra. The after taste score ranged from 3.17 to 3.75. The overall acceptability of the control and experimental khakhra ranged from 13.33 to 15.89. A higher overall acceptability was observed in 30% red amaranth leaves incorporated sample (15.89) followed by 20% (15.50), 10% (13.75) and control (13.33). The total score of the control and experimental khakhra ranged from 76.28 to 81.42 with experimental 3 khakhra having the highest score (81.42) followed by experimental 2 (80.42), experimental 1 (77.67) and control (76.28) khakhra.

Table: 4.12 Composite score of control and experimental Khakhra

Sample	Appearance (20)	Texture (20)	Flavour (15)	Taste (20)	After taste (5)	Overall acceptability (20)	Total (100)
Control	16.7 ± 2.96[a]	17.17± 3.04[a]	11.81 ± 2.53[a]	14.03± 3.86[a]	3.17 ± 1.52[a]	13.33 ± 4.00[a]	76.28± 13.32[a]
Exp 1 (10% RAL)	17.4 ± 2.27[a]	17.72 ± 2.83[a]	11.31 ± 3.40[a]	14.17± 4.60[a]	3.28± 1.37[a]	13.7 ± 4.12[ab]	77.67± 13.38[a]
Exp 2 (20% RAL)	17.0 ± 3.33[a]	17.44 ± 3.60[a]	11.53 ± 3.38[a]	15.17± 4.42[a]	3.72± 1.50[a]	15.50 ± 4.04[bc]	80.42± 16.61[a]
Exp 3 (30% RAL)	16.7 ± 3.33[a]	17.61 ± 2.57[a]	11.58 ± 3.02[a]	15.83± 3.55[a]	3.75± 1.32[a]	15.89 ± 3.13[c]	81.42± 12.18[a]
F-value	0.415	0.229	0.158	1.550	1.589	3.894	1.047
P-value	0.742[NS]	0.876 [NS]	0.925 [NS]	0.204 [NS]	0.195 [NS]	0.10 [NS]	0.374 [NS]

Values are Mean ± SD scores of a composite scoring test by a panel of 36 members
* indicates significant difference at $p \leq 0.05$
NS indicates no significant difference at $p > 0.05$
Same alphabetical superscript indicates no significant difference within row and column
Exp 1: Experimental 1, Exp 2: Experimental 2, Exp 3: Experimental 3

Table: 4.13 Composite score of control and experimental Thepla

Sample	Appearance (20)	Texture (20)	Flavour (15)	Taste (20)	After taste (5)	Overall acceptability (20)	Total (100)
Control	17.0 ± 3.18[a]	17.0±2.767[a]	11.69± 2.916 [a]	16.53± 3.605 [a]	4.17 ± 1.134 [b]	16.28 ± 3.518 [a]	82.72 ± 14.39[a]
Exp 1 (10% RAL)	16.6 ± 2.090[a]	16.2±3.104[a]	11.44± 2.501 [a]	15.53± 3.738 [a]	3.58 ± 1.273 [a]	15.03 ± 3.238 [a]	78.47 ± 12.907 [a]
Exp 2 (20% RAL)	16.2 ± 3.583 [a]	16.0±3.795[a]	13.02±0.503 [a]	16.00± 3.381 [a]	3.89±1.063 [ab]	15.39 ± 3.819 [a]	78.83 ± 15.504 [a]
Exp 3 (30% RAL)	16.1 ± 3.276 [a]	16.5± 3.046[a]	11.14± 2.727 [a]	14.75± 3.857 [a]	3.69±1.064 [ab]	15.56 ± 3.384 [a]	77.83 ± 13.03[a]
F-value	0.527	0.719	0.263	1.538	1.820	0.865	0.897
P-value	0.664 [NS]	0.543 [NS]	0.852 [NS]	0.207 [NS]	0.146 [NS]	0.461 [NS]	0.444 [NS]

Values are Mean ± SD scores of a composite scoring test by a panel of 36 members
* indicates significant difference at $p \leq 0.05$
NS indicates no significant difference at $p > 0.05$
Same alphabetical superscript indicates no significant difference within row and column
Exp 1: Experimental 1, Exp 2: Experimental 2, Exp 3: Experimental 3

Table 4.13 describes the composite score of the control and experimental thepla. The appearance scores of the thepla ranged from16.1 to17.0. Control thepla scores the highest (17.00) of the entire sample. The texture score of the control and experimental thepla ranged from 16.0 to 17.0. Control thepla obtained to highest texture score (17.00). The flavour score of thepla ranged from11.14 to 13.02, with experimental 2 thepla obtaining the highest score (13.03) and experimental 3 thepla with the lowest score (11.14). The taste score of the thepla incorporated with varying level of red amaranth leaves ranged from14.75 to 16.53. Control thepla ranged incorporated sample scored the highest taste score (16.53) followed by 20% red amaranth leaves thepla (16.00), 10 % red amaranth leaves thepla (15.53) and 30 % red amaranth leaves thepla (14.75). The after taste score ranged from 3.58 to 4.17. The overall acceptability of the control and experimental thepla ranged from15.03 to 16.28. A higher overall acceptability was observed in control incorporated sample (16.28) followed by 20% (15.39), 10% (15.03) and 30% (15.56). The total score of the control and experimental thepla ranged from 77.83 to 82.72 with control ranged the highest score (82.72) followed by experimental 2 thepla (78.83), experimental 1thepla (78.47) and experimental 3 thepla (77.83).

Table 4.14 describes the composite score of the control and experimental dosa. The appearance scores of the dosa ranged from 18.1 to 18.75. Control dosa score the highest (18.75) of the entire sample. The texture score of the control dosa and experimental dosa ranged from 17.94 to 18.81. Control dosa obtained to highest texture score (18.81). The Flavour score of dosa ranged from 12.92 to 13.67, with control and 10 % red amaranth leaves dosa obtaining the highest score (13.67) and 20 % red amaranth leaves dosa with the lowest score (12.92). The taste score of the dosa incorporated with varying level of red amaranth leaves ranged from 17.78 to 18.67. 10% RAL ranged incorporated sample scored the highest taste score (18.64) followed by 20% red amaranth leaves dosa score (17.78), 30% red amaranth leaves dosa score (17.92) and control dosa (18.36). The after taste score ranged from 3.85 to 4.19. The overall acceptability of the control and experimental dosa ranged from 17.94 to 18.56. A higher overall acceptability was observed in control dosa incorporated sample (18.56) followed by 20% (17.94), 10% (18.53) and experimental 3 (18.08). The total score of the control and experimental Dosa ranged from 88.6 to 92.3 with control

Table: 4.14 Composite score of control and experimental Dosa

Sample	Appearance (20)	Texture (20)	Flavour (15)	Taste (20)	After taste (5)	Overall acceptability (20)	Total (100)
Control	18.75 ± 1.481[a]	18.81± 1.411[a]	13.67± 11.80[a]	18.36± 1.624[a]	4.19± 1.037[a]	18.56± 1.731[a]	92.3± 6.87[a]
Exp 1 (10% RAL)	18.7± 1.296 [a]	18.64 ± 1.570[a]	13.67± 1.773[a]	18.64± 1.355[a]	4.00± 1.095[a]	18.53± 1.320[a]	92.2± 6.17[a]
Exp 2 (20% RAL)	18.1± 1.964[a]	17.94± 2.563[a]	12.92± 2.075[a]	17.78± 2.218[a]	3.85± 1.114[a]	17.94± 2.216[a]	88.6± 6.17[a]
Exp 3 (30% RAL)	18.1± 2.095[a]	18.19± 2.266[a]	13.36± 1.915[a]	17.92± 2.103[a]	4.06± 0.893[a]	18.08± 2.062[a]	89.8± 8.12[a]
F-value	1.286	1.400	1.260	1.648	0.689	0.997	1.832
P-value	0.282 [NS]	0.245 [NS]	0.291 [NS]	0.181 [NS]	0.560 [NS]	0.396 [NS]	0.144 [NS]

Values are Mean ± SD scores of a composite scoring test by a panel of 36 members
* indicates significant difference at $p \leq 0.05$
NS indicates no significant difference at $p > 0.05$
Same alphabetical superscript indicates no significant difference within row and column
Exp 1: Experimental 1, Exp 2: Experimental 2, Exp 3: Experimental 3

Table: 4.15 Composite score of control and experimental Chilla

Sample	Appearance(20)	Texture (20)	Flavour (15)	Taste (20)	After taste (5)	Overall acceptability (20)	Total (100)
Control	18.50 ± 1.404[b]	18.58± 1.317[b]	13.75± 1.180[b]	18.31 ± 1.451[b]	4.19 ± 0.856 [b]	18.56 ± 1.182 [b]	91.8± 5.87[b]
Exp 1 (10% RAL)	17.75 ± 2.062[ab]	17.94± 2.092[ab]	11.97 ± 2.104[a]	16.75 ± 2.359[a]	3.25± 1.273[a]	16.71 ± 2.620[a]	84.3± 9.823[a]
Exp 2 (20% RAL)	17.08 ± 2.750[a]	17.61± 2.544[ab]	11.89± 2.067[a]	16.11 ± 2.876[a]	3.50± 1.056[a]	16.11 ± 3.115[a]	83.3± 11.34[a]
Exp 3 (30% RAL)	16.86 ± 2.486[a]	17.56± 1.934[a]	11.11± 2.188[a]	15.53 ± 3.282 [a]	3.11± 1.090[a]	15.72 ± 2.845[a]	79.8± 10.72 [a]
F-value	3.930	1.964	12.049	7.724	7.168	8.703	10.329
P-value	0.010 [NS]	0.122 [NS]	<0.001[(*)]	<0.001[(*)]	<0.001[(*)]	<0.001[(*)]	<0.001[(*)]

Values are Mean ± SD scores of a composite scoring test by a panel of 36 members
* indicates significant difference at $p \leq 0.05$
NS indicates no significant difference at $p > 0.05$
Same alphabetical superscript indicates no significant difference within row and column
Exp 1: Experimental 1, Exp 2: Experimental 2, Exp 3: Experimental 3

obtained the highest score (92.3) followed by experimental 2 (88.6), experimental 1 (92.2) and experimental 3 (89.8) dosa.

Table 4.15 describes the composite score of the control and experimental chilla. The appearance scores of the chilla ranged from 16.86 to 18.50. Control chilla score the highest (18.50) of the entire sample. The texture score of the control and experimental chilla ranged from 17.56 to 18.56. Control chilla obtained to highest texture score (18.56). The flavour score of chilla ranged from 11.11 to 13.75, with control chilla obtaining the highest score (13.75) and experimental 3 chilla with the lowest score (11.11). The taste score of the chilla incorporated with varying level of red amaranth leaves ranged from 15.53 to 18.31. Control chilla ranged incorporated sample scored the highest taste score (18.31) followed by experimental 2 chilla (16.11), experimental 3 chilla (15.53) and experimental 1 chilla (16.75). The after taste score ranged from 3.85 to 4.19. The overall acceptability of the control and experimental chilla ranged from 15.72 to 18.56. A higher overall acceptability was observed in control incorporated sample (18.56) followed by 20% red amaranth leaves chilla (16.11), 10% red amaranth leaves chilla (16.71) and 30% red amaranth leaves chilla (15.72). The total score of the control and experimental chilla ranged from 79.8 to 91.8 with control obtained the highest score (91.8) followed by experimental 2 chilla (83.3), experimental 1 chilla (84.3) and experimental 3 chilla (79.8). Overall chilla samples, the highest acceptance was obtained by control incorporated chilla.

Table 4.16 describes the composite score of the control and experimental handvo. The appearance scores of the handvo ranged from 16.61 to 17.64. Experimental 1 handvo score the highest (17.64) of the entire sample. The texture score of the control and experimental handvo ranged from 16.11 to 16.72. Control obtained to highest texture score (16.72). The flavor score of handvo ranged from 11.97 to 12.69, with control handvo obtaining the highest score (12.69) and experimental 2 hanvo with the lowest score (11.97). The taste score of the handvo incorporated with varying level of red amaranth leaves ranged from 11.97 to 16.42. Control handvo ranged incorporated sample scored the highest taste score (16.42) followed by experimental 2 handvo (11.97), experimental 3 handvo (12.17) and experimental 1 handvo (16.08). The after taste score ranged from 3.25 to 3.69. The overall acceptability of the control and experimental handvo ranged from 16.31 to 16.64. A higher overall acceptability was

Table: 4.16 Composite score of control and experimental Handvo

Sample	Appearance (20)	Texture (20)	Flavour (15)	Taste (20)	After taste (5)	Overall acceptability (20)	Total (100)
Control	17.39 ± 2.686[a]	16.72± 2.525[a]	12.69± 2.638[a]	16.42± 3.307[a]	3.69 ± 0.980[a]	16.64 ± 3.092[a]	83.53 ± 13.568[a]
Exp 1 **(10% RAL)**	17.64 ± 0.606[a]	16.67± 1.897[a]	12.64± 2.332[a]	16.08± 3.046[a]	3.33 ± 1.069[a]	16.49 ± 3.106[a]	82.85 ± 10.281[a]
Exp 2 **(20% RAL)**	16.61 ± 2.791[a]	16.11± 2.984[a]	11.97± 2.558[a]	11.97± 2.558[a]	3.50 ± 1.115[a]	16.31 ± 3.206[a]	80.50 ± 14.608[a]
Exp 3 **(30% RAL)**	16.67 ± 2.908[a]	16.14± 3.118[a]	12.17± 2.752[a]	12.17± 2.752[a]	3.25 ± 1.344[a]	16.47 ± 3.247[a]	79.67 ± 14.626[a]
F-value	1.472	0.547	0.683	0.563	1.078	0.057	0.684
P-value	0.225 NS	0.651 NS	0.564 NS	0.641 NS	0.361 NS	0.982 NS	0.563NS

Values are Mean ± SD scores of a composite scoring test by a panel of 36 members
* indicates significant difference at $p \leq 0.05$
NS indicates no significant difference at $p > 0.05$
Same alphabetical superscript indicates no significant difference within row and column
Exp 1: Experimental 1, Exp 2: Experimental 2, Exp 3: Experimental 3

Table: 4.17 Composite score of control and experimental Muthiya

Sample	Appearance (20)	Texture (20)	Flavour (15)	Taste (20)	After taste (5)	Overall acceptability (20)	Total (100)
Control	17.53 ± 2.348[a]	17.25± 2.761[a]	12.9± 1.68[a]	17.22± 2.474[a]	3.58± 1.105[a]	17.69 ± 2.340[a]	86.26± 11.039[a]
Exp 1 **(10% RAL)**	17.53 ± 2.145[a]	16.89± 3.087[a]	12.5± 2.23[a]	16.61± 3.064[a]	3.65± 1.230[a]	16.97± 2.873[a]	84.24± 11.91[a]
Exp 2 **(20% RAL)**	17.53 ± 1.828[a]	17.47± 1.812[a]	13.0± 1.85[a]	16.81± 2.315[a]	3.75± 0.960[a]	17.39 ± 1.695[a]	86.00± 11.912[a]
Exp 3 **(30% RAL)**	17.06 ± 2.672[a]	17.25± 2.347[a]	12.4± 0.00[a]	16.53± 2.720[a]	3.90± 1.999[a]	16.92 ± 2.430[a]	84.13± 12.035[a]
F-value	0.390	0.324	0.791	0.489	0.361	0.863	0.390
P-value	0.761 NS	0.808 NS	0.501 NS	0.691 NS	0.782 NS	0.462 NS	0.761 NS

Values are Mean ± SD scores of a composite scoring test by a panel of 36 members
* indicates significant difference at $p \leq 0.05$
NS indicates no significant difference at $p > 0.05$
Same alphabetical superscript indicates no significant difference within row and column
Exp 1: Experimental 1, Exp 2: Experimental 2, Exp 3: Experimental 3

observed in control incorporated sample (16.64) followed by 20% red amaranth leaves handvo (16.31), 10% red amaranth leaves handvo (16.49) and experimental 3 red amaranth leaves handvo (16.47). The total score of the control and experimental handvo ranged from 79.67 to 83.53 with control obtained the highest score (83.53) followed by experimental 2 (80.50), experimental 1 (82.85) and experimental 3 (79.67) handvo.

Table 4.17 describes the composite score of the control and experimental muthiya. The appearance scores of the muthiya ranged from 17.06 to 17.53. Similar score of control, experimental 1 muthiya, and experimental 2 muthiya (17.53) and experimental 3 muthiya score (17.06). The texture score of the control and experimental muthiya ranged from 16.89 to 17.47, Experimental 2 muthiya obtained to highest texture score (17.47). The flavour score of muthiya ranged from 12.4 to 13.0, with experimental 2 muthiya obtaining the highest score (13.0) and experimental 3 muthiya with the lowest score (12.4). The taste score of the muthiya Incorporated with varying level of red amaranth leaves ranged from 16.53 to 17.22. Control ranged incorporated sample scored the highest taste score (17.22) followed by experimental 2 red amaranth leaves muthiya (16.81), experimental 3 red amaranth leaves muthiya (16.53) and experimental 1 red amaranth leaves muthiya (16.61). The after taste score ranged from 3.58 to 3.90. The overall acceptability of the control and experimental muthiya ranged from 16.31 to 16.64. A higher overall acceptability was observed in control incorporated sample (17.69) followed by 20% red amaranth leaves muthiya (17.39), 10% red amaranth leaves muthiya (16.97) and 30% red amaranth leaves muthiya (16.92). The total score of the control and experimental muthiya ranged from 84.13 to 86.26 with control obtained the highest score (86.26) followed by experimental 2 (86.00), experimental 1 (84.24) and experimental 3 (84.13) muthiya.

Table 4.18 describes the composite score of the control and experimental kothimbirwadi. The appearance scores of the kothimbirwadi ranged from 16.01 to 17.03. Control kothimbirwadi scores the highest (17.03) of the entire sample. The texture score of the control and experimental kothimbirwadi ranged from 16.11 to 16.61. Control obtained to highest texture score (16.61). The flavour score of kothimbirwadi ranged from 11.9 to 12.31, with control kothimbirwadi obtaining the

Table: 4.18 Composite score of control and experimental Kothimbirwadi

Sample	Appearance (20)	Texture (20)	Flavour (15)	Taste (20)	After taste (5)	Overall acceptability (20)	Total (100)
Control	17.03 ± 2.624[a]	16.61± 2.600[a]	12.31± 2.35[a]	16.2± 3.067[a]	3.46± 1.111[a]	16.2 ± 3.136[a]	81.90± 13.550[a]
Exp 1 (10% RAL)	16.85 ± 2.411[a]	16.56± 2.323[a]	11.9± 1.65[a]	15.9± 2.888[a]	2.97± 0.933[a]	16.0 ± 3.037[a]	80.35± 11.534[a]
Exp 2 (20% RAL)	16.47 ± 3.158[a]	16.31± 3.097[a]	12.4± 2.10[a]	15.6± 3.286[a]	3.25± 0.989[a]	16.3 ± 3.053[a]	80.47± 14.233[a]
Exp 3 (30% RAL)	16.01 ± 3.177[a]	16.11± 2.755[a]	12.2± 2.13[a]	15.08± 2.989[a]	3.28± 0.974[a]	16.36 ± 3.052[a]	78.46± 13.117[a]
F-value	0.884	0.264	0.341	0.983	1.439	0.287	0.416
P-value	0.451 NS	0.852 NS	0.796 NS	0.403 NS	0.234 NS	0.835 NS	0.742 NS

Values are Mean ± SD scores of a composite scoring test by a panel of 36 members
* indicates significant difference at $p \leq 0.05$
NS indicates no significant difference at $p > 0.05$
Same alphabetical superscript indicates no significant difference within row and column
Exp 1: Experimental 1, Exp 2: Experimental 2, Exp 3: Experimental 3

Table: 4.19 Composite score of control and experimental Kabab

Sample	Appearance (20)	Texture (20)	Flavour (15)	Taste (20)	After taste (5)	Overall acceptability (20)	Total (100)
Control	17.31 ± 1.754[a]	17.22± 1.929[a]	12.64± 1.710[a]	16.39± 2.476[a]	3.39± 1.103[a]	17.22 ± 2.030[a]	84.17 ± 8.351[a]
Exp 1 (10% RAL)	16.94 ± 2.097[a]	17.19± 2.202[a]	11.89± 1.55[bc]	15.58± 4.325[a]	3.14± 0.990[a]	16.67 ± 2.651[a]	81.42 ± 10.060[a]
Exp 2 (20% RAL)	16.58 ± 2.687[a]	17.31± 2.837[a]	12.89± 2.081[a]	16.72± 3.029[a]	3.28± 1.137[a]	16.94 ± 2.868[a]	83.72 ± 12.605[a]
Exp 3 (30% RAL)	16.33 ± 2.608[a]	16.61± 2.441[a]	11.58± 1.962[a]	15.94± 2.838[a]	3.14± 1.193[a]	15.97 ± 2.813[a]	79.58 ± 11.559[a]
F-value	1.208	0.646	4.023	0.853	0.430	1.518	1.413
P-value	0.309 NS	0.586 NS	0.009 NS	0.467 NS	0.732 NS	0.212 NS	0.242 NS

Values are Mean ± SD scores of a composite scoring test by a panel of 36 members
* indicates significant difference at $p \leq 0.05$
NS indicates no significant difference at $p > 0.05$
Same alphabetical superscript indicates no significant difference within row and column
Exp 1: Experimental 1, Exp 2: Experimental 2, Exp 3: Experimental 3

highest score (12.31) and experimental 1 kothimbirwadi with the lowest score (11.9). The taste score of the kothimbirwadi incorporated with varying level of red amaranth leaves ranged from 15.9 to 16.2. Control ranged incorporated sample scored the highest taste score (16.2) followed by experimental 2 red amaranth leaves kothimbirwadi (15.6), experimental 3 red amaranth leaves kothimbirwadi (15.08) and experimental 1 red amaranth leaves kothimbirwadi (15.9). The after taste score ranged from 2.97 to 3.46. The overall acceptability of the control and experimental kothimbirwadi ranged from 16.0 to 16.36. A higher overall acceptability was observed in 30% red amaranth leaves kothimbirwadi sample (16.36) followed by 20% red amaranth leaves kothimbirwadi (16.3), 10% red amaranth leaves kothimbirwadi (16.0) and control (16.2). The total score of the control and experimental kothimbirwadi ranged from 78.46 to 81.90 with control obtained the highest score (81.90) followed by experimental 2 (80.47), experimental 1 (80.35) and experimental 3 (78.46) kothimbirwadi.

Table 4.19 describes the composite score of the control and experimental kabab. The appearance scores of the kabab ranged from 16.33 to 17.31. Control scores the highest (17.31) of the entire sample. The texture score of the control and experimental kabab ranged from 16.61 to 17.31. Experimental 2 kabab obtained to highest texture score (17.31). The flavour score of kabab ranged from 11.58 to 12.89, with experimental 2 kabab obtaining the highest score (12.89) and experimental 3 kabab with the lowest score (11.58). The taste score of the kabab incorporated with varying level of red amaranth leaves ranged from 15.58 to 16.72. Experimental 2 kabab ranged incorporated sample scored the highest taste score (16.72) followed by control kabab (16.39), experimental 3 kabab (15.94) and experimental 1 kabab (15.58). The after taste score ranged from 3.14 to 3.39. The overall acceptability of the control and experimental kabab ranged from 15.97 to 17.22. A higher overall acceptability was observed in control incorporated sample (17.22) followed by 20% red amaranth leaves kabab (16.94), 10% red amaranth leaves kabab (16.67) and 30% red amaranth leaves kabab (15.97). The total score of the control and experimental kabab ranged from 79.58 to 84.17 with control obtained the highest score (84.17) followed by experimental 2 (83.72), experimental 1 (81.42) and experimental 3 (79.58) kabab.

Table 4.20 describes the composite score of the control and experimental thalipeeth. The appearance scores of the thalipeeth ranged from 17.42 to 18.01. Control thalipeeth scores the highest (18.01) of the entire sample. The texture score of the control and experimental thalipeeth ranged from 17.47 to 17.97. Experimental 1 thalipeeth obtained to highest texture score (17.97). The flavour score of thalipeeth ranged from 13.36 to 13.83, with experimental 1 thalipeeth and control thalipeeth obtaining the highest score (13.83) and experimental 3 thalipeeth with the lowest score (13.36). The taste score of the thalipeeth incorporated with varying level of red amaranth leaves ranged from 17.03 to 17.92. Control thalipeeth ranged incorporated sample scored the highest taste score (17.92) followed by experimental 2 red amaranth leaves thalipeeth (17.39), experimental 3 red amaranth leaves thalipeeth (17.17) and experimental 1 red amaranth leaves thalipeeth (17.03). The after taste score ranged from 3.79 to 4.24. The overall acceptability of the control and experimental thalipeeth ranged from 17.21 to 18.03. A higher overall acceptability was observed in control thalipeeth incorporated sample (18.03) followed by 20% red amaranth leaves thalipeeth (17.28), 10% red amaranth leaves thalipeeth (17.90) and 30% red amaranth leaves thalipeeth (17.21). The total score of the control and experimental thalipeeth ranged from 86.81 to 89.60 with control obtained the highest score (89.60) followed by experimental 2 red amaranth leaves thalipeeth (87.82), experimental 1 red amaranth leaves thalipeeth (88.32) and experimental 3 red amaranth leaves thalipeeth (86.81).

Table 4.21 describes the composite score of the control and experimental air fried namakpara. The appearance scores of the air fried namakpara ranged from 17.42 to 18.01. Control air fried namakpara scores the highest (18.01) of the entire sample. The texture score of the control and experimental air fried namakpara ranged from 17.47 to 17.97. Experimental 1 air fried namakpara obtained to highest texture score. (17.97). The flavour score of air fried namakpara ranged from 13.36 to 13.83, with experimental 1 and control air fried namakpara obtaining the highest score (13.83) and experimental 3 air fried namakpara with the lowest score (13.36). The taste score of the air fried namakpara incorporated with varying level of red amaranth leaves ranged from 17.03 to 17.92. Control air fried namakpara ranged incorporated sample scored the highest taste score (17.92) followed by experimental 2 air fried namakpara (17.39), experimental 3 air fried namakpara (17.17) and experimental 1 air fried namakpara (17.03). The after taste score ranged from 3.79 to 4.24. The overall acceptability of the control and experimental air fried namakpara ranged from 17.21 to 18.03. A higher overall acceptability was observed in control air fried namakpara incorporated sample (18.03) followed by 20% red amaranth leaves air fried namakpara (17.28), 10% red amaranth leaves air fried namakpara (17.90) and 30% red amaranth leaves air fried namakpara (17.21). The total score of the control and experimental air fried namakpara ranged from 86.81 to 89.60 with control obtained the highest score (89.60) followed by experimental 2 red amaranth leaves air fried namakpara (87.82), experimental 1 red amaranth leaves air fried namakpara (88.32) and experimental 3 red amaranth leaves air fried namakpara (86.81).

Table: 4.20 Composite score of control and experimental Thalipeeth

Sample	Appearance (20)	Texture (20)	Flavour (15)	Taste (20)	After taste (5)	Overall acceptability (20)	Total (100)
Control	18.01 ± 1.396[a]	17.86± 1.570[a]	13.83± 1.342[a]	17.92± 1.645[a]	3.94± 0.939[a]	18.03 ± 1.341[a]	89.60± 5.635[a]
Exp 1 (10% RAL)	17.97 ± 1.594[a]	17.97± 1.765[a]	13.83± 1.234[a]	17.03± 1.949[a]	4.24± 3.539	17.28 ± 1.632[a]	88.32± 7.024[a]
Exp 2 (20% RAL)	17.67 ± 1.927[a]	17.47± 1.732[a]	13.47± 1.320[a]	17.39± 1.856[a]	3.92± 0.967[a]	17.90 ± 1.443[a]	87.82± 7.399[a]
Exp 3 (30% RAL)	17.42 ± 2.089[a]	17.86± 1.743[a]	13.36± 1.570[a]	17.17± 2.467[a]	3.79± 1.104[a]	17.21 ± 2.340[a]	86.81± 9.511[a]
F-value	0.901	0.596	1.147	1.370	0.327	2.123	0.857
P-value	0.443 NS	0.618 NS	0.332 NS	0.255 NS	0.806 NS	0.100 NS	0.465 NS

Values are Mean ± SD scores of a composite scoring test by a panel of 36 members
* indicates significant difference at $p \leq 0.05$
NS indicates no significant difference at $p > 0.05$
Same alphabetical superscript indicates no significant difference within row and column
Exp 1: Experimental 1, Exp 2: Experimental 2, Exp 3: Experimental 3

Table: 4.21 Composite score of control and experimental air fried Namakpara

Sample	Appearance (20)	Texture (20)	Flavour (15)	Taste (20)	After taste (5)	Overall acceptability (20)	Total (100)
Control	18.01 ± 1.396[a]	17.8± 1.570[a]	13.83± 1.342[a]	17.92± 1.645[a]	3.94 ± 0.939[a]	18.03± 1.341[a]	89.60± 5.635[a]
Exp 1 (10% RAL)	17.97 ± 1.594[a]	17.9± 1.76[a]	13.83± 1.231[a]	17.03± 1.949[a]	4.24 ± 3.539[a]	17.28± 1.632[a]	88.32± 7.024[a]
Exp 2 (20% RAL)	17.67 ± 1.927[a]	17.4± 1.73[a]	13.47± 1.320[a]	17.39± 1.856[a]	3.92 ± 0.967[a]	17.90± 1.443[a]	87.82± 7.399[a]
Exp 3 (30% RAL)	17.42 ± 2.089[a]	17.8± 1.74[a]	13.36± 1.570[a]	17.17± 2.467[a]	3.79 ± 1.104[a]	17.21± 2.340[a]	86.81± 9.511[a]
F-value	0.901	0.596	1.147	1.370	0.327	2.123	0.857
P-value	0.443 NS	0.618 NS	0.332 NS	0.255 NS	0.806 NS	0.100 NS	0.465 NS

Values are Mean ± SD scores of a composite scoring test by a panel of 36 members
* indicates significant difference at $p \leq 0.05$
NS indicates no significant difference at $p > 0.05$
Same alphabetical superscript indicates no significant difference within row and column
Exp 1: Experimental 1, Exp 2: Experimental 2, Exp 3: Experimental 3

Hedonic score of Red Amaranth Leaves (RAL) incorporated recipes:

Table 4.22 depicts the hedonic sensory score of control and experimental khakhra. The appearance score of control and experimental khakhra ranged from 2.14 to 2.28. The experimental 3 khakhra score the highest texture score (2.06), followed by control khakhra (2.14), experimental 1 khakhra (2.14) and experimental 2 khakhra (2.22). The flavour score of control and experimental khakhra range from 2.50 to 3.42. The highest score was obtained by experimental 3 khakhra (2.50) which was liked very much whereas the other samples were liked moderately. 30% red amaranth leaves incorporated khakhra obtained the highest taste score (2.47) followed by 20% red amaranth leaves incorporated khakhra (3.19), control khakhra (3.50) and 10% red amaranth leaves incorporated khakhra (3.69). The after taste of the khakhra ranged from 2.83 to 4.00. The highest overall acceptability was obtained by experimental 3 khakhra (2.58) and the lowest overall acceptability was observed between the control and experimental khakhra.

Table 4.23 represents the hedonic sensory score of control and experimental Thepla. The appearance score of control and experimental Thepla ranged from 1.83 to 2.61. The control Thepla score the highest texture score (2.00), followed by experimental 3 thepla (2.36), experimental 1 thepla (2.58) and experimental 2 thepla (2.56). The Flavour score of control and experimental thepla range from 2.28 to 2.94. The highest score was obtained by control thepla (2.28) which was liked very much whereas the other samples were liked moderately. Control thepla obtained the highest taste score (2.06) followed by 20% red amaranth leaves incorporated thepla (2.78), 30% red amaranth leaves incorporated thepla (2.86) and 10% red amaranth leaves incorporated thepla (3.00). The after taste of the thepla ranged from 2.00 to 3.06. The highest overall acceptability was obtained by control thepla (2.11) and the lowest overall acceptability was observed between the experimental 1 and experimental 3 thepla.

Table 4.24 shows the hedonic sensory of control and experimental score of chilla. The appearance score of control and experimental chilla ranged from 2.47 to 2.86. The experimental 1 chilla score the highest texture score (2.36), followed by control chilla (2.72), experimental 2 chilla (2.72) and experimental 3 chilla (2.50). The Flavour score of control and experimental chilla range from 3.06 to 3.31. The highest score

Table: 4.22 Hedonic score of control and experimental khakhra

Sample	Appearance	Texture	Flavour	Taste	After taste	Overall acceptability
Control	2.28 ±1.63^{a}	2.14±1.50^{a}	3.36±2.06^{a}	3.50±2.09^{b}	4.00±2.22^{b}	3.53 ± 2.04^{a}
Exp 1 **(10% RAL)**	2.25 ± 1.13^{a}	2.14±1.38^{a}	3.42±1.84^{a}	3.69±2.11^{b}	3.97±2.26^{b}	3.36 ± 1.79^{a}
Exp 2 **(20% RAL)**	2.36 ± 1.62^{a}	2.22±1.73^{a}	3.17±2.12^{a}	3.19±2.15^{ab}	3.19±2.20^{ab}	3.28 ± 2.24^{a}
Exp 3 **(30% RAL)**	2.14 ± 1.15^{a}	2.06±1.12^{a}	2.50±1.46^{a}	2.47±1.38^{a}	2.83 ± 196^{a}	2.58 ± 1.42^{a}
F-value	0.153	0.080	1.792	2.699	2.590	1.733
P-value	0.927 ^{NS}	0.971 ^{NS}	0.151 ^{NS}	0.048^{NS}	0.055 ^{NS}	0.163^{NS}

Values are Mean ± SD scores of a hedonic scoring test by a panel of 36 members
* indicates significant difference at $p \leq 0.05$
NS indicates no significant difference at $p > 0.05$
Same alphabetical superscript indicates no significant difference within row and column
Exp 1: Experimental 1, Exp 2: Experimental 2, Exp 3: Experimental 3

Table: 4.23 Hedonic score of control and experimental Thepla

Sample	Appearance	Texture	Flavour	Taste	After taste	Overall acceptability
Control	1.83 ± 1.11^{a}	2.00±1.17^{a}	2.28±1.68^{a}	2.06±1.43^{a}	2.00±1.35^{a}	2.11 ±1.41^{a}
Exp 1 **(10% RAL)**	2.42 ± 1.27^{ab}	2.58±1.40^{a}	2.91±1.34^{a}	3.00±1.33^{b}	3.06±1.33^{b}	2.97 ±1.18^{b}
Exp 2 **(20% RAL)**	2.25±1.13^{ab}	2.56±1.50^{a}	2.83±1.36^{a}	2.78±1.22^{b}	2.75±1.42^{b}	2.67±1.10^{ab}
Exp 3 **(30% RAL)**	2.61 ±1.42^{b}	2.36±1.31^{a}	2.94±1.45^{a}	2.86±1.44^{b}	2.69±1.41^{b}	2.86 ± 1.40^{b}
F-value	2.568	1.423	1.649	3.475	3.763	3.223
P-value	0.057 ^{NS}	0.239 ^{NS}	0.181 ^{NS}	0.018 *	0.012*	0.025*

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NS indicates no significant difference at $p > 0.05$
Same alphabetical superscript indicates no significant difference within row and column
Exp 1: Experimental 1, Exp 2: Experimental 2, Exp 3: Experimental 3

was obtained by experimental 1 chilla (3.06) which was liked very much whereas the other samples were liked moderately. 10% red amaranth leaves incorporated chilla obtained the highest taste score (3.25) followed by 20% red amaranth leaves incorporated chilla (3.50), control chilla (3.50) and 30% red amaranth leaves incorporated chilla (3.28). The after taste of the chilla ranged from 2.89 to 3.11. The highest overall acceptability was obtained by experimental 1 chilla (2.94) and the lowest overall acceptability was observed between the control and experimental 3 chilla.

Table 4.25 describes the hedonic sensory score of control and experimental Dosa. The appearance score of control and experimental Dosa ranged from 1.47 to 1.75. The control Dosa score the highest texture score (1.56), followed by experimental 3 dosa (1.67), experimental 1 dosa (1.72) and experimental 2 dosa (1.89). The Flavour score of control and experimental Dosa range from 1.61 to 2.00. The highest score was obtained by control dosa (1.61). This was liked very much whereas the other samples were liked moderately. Control Dosa obtained the highest taste score (1.72) followed by 20% red amaranth leaves incorporated Dosa (2.11), 30% red amaranth leaves incorporated dosa (1.92) and 10% red amaranth leaves incorporated Dosa (1.83). The after taste of the Dosa ranged from 1.78 to 2.33. The highest overall acceptability was obtained by control Dosa (1.64) and the lowest overall acceptability was observed between the experimental 1 and experimental 3 dosa.

Table 4.26 shows the hedonic sensory score of control and experimental Handvo. The appearance score of control and experimental Handvo ranged from 1.64 to 2.42. The experimental 2 Handvo score the highest texture score (2.00), followed by experimental 3 handvo (2.36), experimental 1 handvo (2.28) and Control handvo (2.06). The Flavour score of control handvo and experimental Handvo range from 1.89 to 2.44. The highest score was obtained by experimental 2 handvo (1.89). This was liked very much whereas the other samples were liked moderately. Experimental 2 Handvo obtained the highest taste score (1.92) followed by control handvo (2.06), 30% red amaranth leaves incorporated Handvo (2.56) and 10% red amaranth leaves incorporated handvo (2.31). The after taste of the Handvo ranged from 2.06 to 2.92. The highest overall acceptability was obtained by control Handvo (1.64) and the lowest overall acceptability was observed between the experimental 2 and experimental 3 handvo.

Table: 4.24 Hedonic score of control and experimental Chilla

Sample	Appearance	Texture	Flavour	Taste	After taste	Overall acceptability
Control	2.86± 1.22[a]	2.72±1.45[a]	3.22±1.40[a]	3.50± 1.36[a]	3.11± 1.41[a]	3.39± 1.40[a]
Exp 1 **(10% RAL)**	2.47± 1.50[a]	2.36±1.64[a]	3.06±1.55[a]	3.25± 1.68[a]	2.92±1.76[a]	2.94± 1.82[a]
Exp 2 **(20% RAL)**	2.86± 1.22[a]	2.72±1.45[a]	3.22±1.40[a]	3.50± 1.36[a]	3.06± 1.37[a]	3.36± 1.36[a]
Exp 3 **(30% RAL)**	2.72± 1.30[a]	2.50±1.21[a]	3.31±1.24[a]	3.28± 1.42[a]	2.89± 1.45[a]	3.14± 1.3[a]
F-value	0.698	0.545	0.202	0.314	0.183	0.709
P-value	0.555 [NS]	0.652 [NS]	0.895 [NS]	0.815 [NS]	0.908 [NS]	0.548 [NS]

Values are Mean ± SD scores of a hedonic scoring test by a panel of 36 members
* indicates significant difference at $p \leq 0.05$
NS indicates no significant difference at $p > 0.05$
Same alphabetical superscript indicates no significant difference within row and column
Exp 1: Experimental 1, Exp 2: Experimental 2, Exp 3: Experimental 3

Table: 4.25 Hedonic score of control and experimental Dosa

Sample	Appearance	Texture	Flavour	Taste	After taste	Overall acceptability
Control	1.47± 0.654[a]	1.56±0.69[a]	1.61±0.64[a]	1.72±0.91[a]	1.78±1.14[a]	1.64 ± 0.762[a]
Exp 1 **(10% RAL)**	1.53± 0.696[a]	1.72±0.84[a]	1.69±0.78[a]	1.83±0.97[a]	2.08±1.05[a]	1.86 ± 0.931[a]
Exp 2 **(20% RAL)**	1.75± 1.052[a]	1.89±1.11[a]	2.00±1.24[a]	2.11±1.26[a]	2.33±1.28[a]	2.14 ± 1.150[a]
Exp 3 **(30% RAL)**	1.64± 0.899[a]	1.67±0.92[a]	1.83±0.91[a]	1.92±1.02[a]	2.19±1.43[a]	2.17 ± 1.384[a]
F-value	0.773	0.841	1.226	0.879	1.311	1.920
P-value	0.511 [NS]	0.474 [NS]	0.303 [NS]	0.454 [NS]	0.273 [NS]	0.129 [NS]

Values are Mean ± SD scores of a hedonic scoring test by a panel of 36 members
* indicates significant difference at $p \leq 0.05$
NS indicates no significant difference at $p > 0.05$
Same alphabetical superscript indicates no significant difference within row and column
Exp 1: Experimental 1, Exp 2: Experimental 2, Exp 3: Experimental 3

Table: 4.26 Hedonic score of control and experimental Handvo

Sample	Appearance	Texture	Flavour	Taste	After taste	Overall acceptability
Control	1.64± 0.961[a]	2.06±1.04[a]	2.17±1.10[a]	2.06±0.95[ab]	2.11±0.97[a]	2.03 ± 1.134[a]
Exp 1 (10% RAL)	2.42±1.204[b]	2.28±1.13[a]	2.28±1.23[a]	2.31±1.19[ab]	2.22±1.35[a]	2.22 ± 1.222[a]
Exp 2 (20% RAL)	1.97±0.97[ab]	2.00±1.01[a]	1.89±0.88[a]	1.92±0.96[a]	2.06±1.28[a]	2.44 ± 3.333[a]
Exp 3 (30% RAL)	2.3 ± 1.348[b]	2.36±1.22[a]	2.44±1.20[a]	2.56±1.25[b]	2.92±1.42[b]	2.42 ± 1.273[a]
F-value	3.463	0.883	1.573	2.368	3.554	0.349
P-value	0.018 *	0.452 NS	0.199 NS	0.073 NS	0.016 *	0.790 NS

Values are Mean ± SD scores of a hedonic scoring test by a panel of 36 members
* indicates significant difference at $p \leq 0.05$
NS indicates no significant difference at $p > 0.05$
Same alphabetical superscript indicates no significant difference within row and column
Exp 1: Experimental 1, Exp 2: Experimental 2, Exp 3: Experimental 3

Table: 4.27 Hedonic score of control and experimental Muthiya

Sample	Appearance	Texture	Flavour	Taste	After taste	Overall acceptability
Control	2.86 ± 1.22[a]	2.72±1.45[a]	3.22±1.40[a]	3.50±1.36[a]	3.11±1.41[a]	3.39 ± 1.40[a]
Exp 1 (10% RAL)	2.47 ± 1.50 [a]	2.36±1.64[a]	3.06±1.55[a]	3.25±1.68[a]	2.92±1.76	2.94 ± 1.82[a]
Exp 2 (20% RAL)	2.86 ± 1.22 [a]	2.72±1.45[a]	3.22±1.40[a]	3.50±1.36[a]	3.06±1.37[a]	3.36 ± 1.36[a]
Exp 3 (30% RAL)	2.72 ± 1.30[a]	2.50±1.21[a]	3.31±1.24[a]	3.28±1.42[a]	2.89±1.45[a]	3.14 ± 1.3[a]
F-value	0.698	0.545	0.202	0.314	0.183	0.709
P-value	0.555 NS	0.652 NS	0.895 NS	0.815 NS	0.908 NS	0.548 NS

Values are Mean ± SD scores of a hedonic scoring test by a panel of 36 members
* indicates significant difference at $p \leq 0.05$
NS indicates no significant difference at $p > 0.05$
Same alphabetical superscript indicates no significant difference within row and column
Exp 1: Experimental 1, Exp 2: Experimental 2, Exp 3: Experimental 3

Table 4.27 represents the hedonic sensory score of control and experimental Muthiya. The appearance score of control and experimental Muthiya ranged from 2.47 to 2.86. The experimental 1 Muthiya score the highest texture score (2.36), followed by experimental 3 muthiya (2.50), experimental 2 muthiya (2.72) and Control muthiya (2.72). The Flavour score of control and experimental Muthiya range from 3.06 to 3.31. The highest score was obtained by experimental 1muthiya (3.06). which was liked very much whereas the other samples were liked moderately. Experimental 1 Muthiya obtained the highest taste score (3.25) followed by control Muthiya (3.50), 30% red amaranth leaves incorporated Muthiya (3.28) and 20% red amaranth leaves incorporated Muthiya (3.50). The after taste of the Muthiya ranged from 2.89 to 3.11. The highest overall acceptability was obtained by experimental 1 Muthiya (2.94) and the lowest overall acceptability was observed between the experimental 2 and control muthiya.

Table: 4.28 depict the hedonic sensory score of control and experimental Kabab. The appearance score of control and experimental Kabab ranged from 2.72 to 3.14. The experimental 1kabab and experimental 2 Kabab score the highest texture score (2.72), followed by experimental 3 kabab (3.14), and Control kabab (2.81). The Flavour score of control and experimental Kabab range from 2.53 to 2.94. The highest score was obtained by experimental 2 kabab (2.53), which was liked moderately. Control Kabab obtained the highest taste score (2.69) followed by experimental 1 Kabab (2.83), 30% red amaranth leaves incorporated Kabab (2.97) and 20% red amaranth leaves incorporated Kabab (2.83). The after taste of the Kabab ranged from 2.69 to 2.97. The highest overall acceptability was obtained by control Kabab (2.81) and the lowest overall acceptability was observed between the experimental 2 and experimental 1 kabab.

Table: 4.29 describe the hedonic sensory score of control and experimental kothimbirwadi. The appearance score of control and experimental kothimbirwadi ranged from 2.33 to 2.61. The experimental 3 kothimbirwadi score the highest texture score (2.33), followed by control kothimbirwadi (2.39), experimental 1 kothimbirwadi (2.47) and experimental 2 kothimbirwadi (2.61). The Flavour score of control and experimental kothimbirwadi range from 2.81 to 3.22. The highest score was obtained by experimental 3 kothimbirwadi (2.81) which was liked very much whereas the other

Table: 4.28 Hedonic score of control and experimental Kabab

Sample	Appearance	Texture	Flavour	Taste	After taste	Overall acceptability
Control	2.81±1.564[a]	2.64±1.31[a]	2.75±1.58[a]	2.69±1.21[a]	2.69±1.47[a]	2.81± 1.390[a]
Exp 1 (10% RAL)	2.72±1.162[a]	2.61±1.22[a]	2.83±1.29[a]	2.83±1.13[a]	2.92±1.13[a]	3.08± 0.967[a]
Exp 2 (20% RAL)	2.72± .365[a]	2.53±1.34[a]	2.89±1.43[a]	2.83±1.15[a]	2.97±1.23[a]	3.08± .339[a]
Exp 3 (30% RAL)	3.14±1.588[a]	2.94±1.56[a]	3.17±1.55[a]	2.97±1.38[a]	2.94±1.65[a]	3.08± 1.663[a]
F-value	0.693	0.639	0.547	0.308	0.302	0.374
P-value	0.558 [NS]	0.591 [NS]	0.651 [NS]	0.820 [NS]	0.824 [NS]	0.772 [NS]

Values are Mean ± SD scores of a hedonic scoring test by a panel of 36 members
* indicates significant difference at $p \leq 0.05$
NS indicates no significant difference at $p > 0.05$
Same alphabetical superscript indicates no significant difference within row and column
Exp 1: Experimental 1, Exp 2: Experimental 2, Exp 3: Experimental 3

Table: 4.29 Hedonic score of control and experimental Kothimbirwadi

Sample	Appearance	Texture	Flavour	Taste	After taste	Overall acceptability
Control	2.39± 1.34[a]	2.72±1.61[a]	2.97±1.54[a]	2.92±1.57[a]	3.42±2.02[a]	2.97 ± 1.58[a]
Exp 1 (10% RAL)	2.47± 1.23[a]	2.78±1.27[a]	2.89±1.26[a]	2.86±1.27[a]	3.06±1.37[a]	2.81 ± 1.19[a]
Exp 2 (20% RAL)	2.61± 1.27[a]	2.92±1.27[a]	3.22±1.35[a]	3.25±1.32[a]	3.42±1.61[a]	3.03 ± 1.38[a]
Exp 3 (30% RAL)	2.33± 1.24[a]	2.64±1.48[a]	2.81±1.56[a]	2.92±1.56[a]	2.86±1.51[a]	2.72 ± 1.49[a]
F-value	0.325	0.245	0.566	0.553	1.013	0.361
P-value	0.807 [NS]	0.865 [NS]	0.638 [NS]	0.647 [NS]	0.389 [NS]	0.781 [NS]

Values are Mean ± SD scores of a hedonic scoring test by a panel of 36 members
* indicates significant difference at $p \leq 0.05$
NS indicates no significant difference at $p > 0.05$
Same alphabetical superscript indicates no significant difference within row and column
Exp 1: Experimental 1, Exp 2: Experimental 2, Exp 3: Experimental 3

samples were liked moderately. 10% red amaranth leaves incorporated kothimbirwadi obtained the highest taste score (2.86) followed by 30% red amaranth leaves incorporated kothimbirwadi (2.92), control kothimbirwadi (2.92) and 20% red amaranth leaves incorporated kothimbirwadi (2.86). The after taste of the kothimbirwadi ranged from 2.86 to 3.42. The highest overall acceptability was obtained by experimental 3 kothimbirwadi (2.72) and the lowest overall acceptability was observed between the control and experimental 2 kothimbirwadi.

Table: 4.30 show the hedonic sensory score of control and experimental thalipeeth. The appearance score of control and experimental Thalipeeth ranged from 1.50 to 2.17. The control Thalipeeth score the highest texture score (1.53), followed by experimental 3 (1.92), experimental 1 (1.94) and experimental 2 (2.06). The Flavour score of control and experimental Thalipeeth range from 1.61 to 2.11. The highest score was obtained by control thalipeeth (1.61), which was liked very much whereas the other samples were liked moderately. Control Thalipeeth obtained the highest taste score (1.64) followed by 30% red amaranth leaves incorporated thalipeeth (1.92), 10% red amaranth leaves incorporated thalipeeth (2.03) and 20% red amaranth leaves incorporated thalipeeth (1.94). The after taste of the Thalipeeth ranged from 1.75 to 2.11. The highest overall acceptability was obtained by control thalipeeth (1.61) and the lowest overall acceptability was observed between the experimental 1 and experimental 2 thalipeeth.

Table: 4.31 represent the hedonic sensory score of control and experimental air-fried namakpara. The appearance score of control and experimental air fried namakpara ranged from 1.86 to 2.19. The experimental 2 air-fried namakpara score the highest texture score (1.97), followed by experimental 3 air-fried namakpara (2.19), control air-fried namakpara (2.28) and Experimental 1 (2.00). The flavour score of control and experimental air-fried namakpara range from 2.03 to 2.75. The highest score was obtained by experimental 1 air-fried namakpara (2.03) which was liked moderately. Experimental 2 air-fried namakpara obtained the highest taste score (2.17) followed by 30% red amaranth leaves incorporated air fried namakpara (2.56), 10% red amaranth leaves incorporated air-fried namakpara (2.22) and control air-fried namakpara (2.72). The after taste of the air-fried namakpara ranged from 2.31 to 3.00. The highest overall acceptability was obtained by experimental 1 air-fried namakpara

Table: 4.30 Hedonic score of control and experimental Thalipeeth

Sample	Appearance	Texture	Flavour	Taste	After taste	Overall acceptability
Control	1.50± 0.81^{a}	1.53±0.84^{a}	1.61±1.02^{a}	1.64±1.01^{a}	1.75±1.025^{a}	1.61 ± 0.803^{a}
Exp 1 **(10% RAL)**	1.81± 0.71^{ab}	1.94±0.86^{b}	1.94±0.86^{a}	2.03±0.87^{a}	1.94±0.924^{a}	2.06± 0.674^{ab}
Exp 2 **(20% RAL)**	2.11± 1.09^{b}	2.06± 1.01^{b}	2.11±0.97^{a}	1.94±0.95^{a}	1.94±1.068^{a}	1.97± 1.000^{ab}
Exp 3 **(30% RAL)**	2.17±0.97^{b}	1.92±0.84^{ab}	2.00±1.24^{a}	1.92±1.02^{a}	2.11±1.304^{a}	2.14 ± 1.175^{b}
F-value	4.150	2.395	1.556	1.088	0.661	2.236
P-value	0.00 ^{NS}	0.071 ^{NS}	0.203 ^{NS}	0.356 ^{NS}	0.577 ^{NS}	0.087 ^{NS}

Values are Mean ± SD scores of a hedonic scoring test by a panel of 36 members
* indicates significant difference at $p \leq 0.05$
NS indicates no significant difference at $p > 0.05$
Same alphabetical superscript indicates no significant difference within row and column
Exp 1: Experimental 1, Exp 2: Experimental 2, Exp 3: Experimental 3

Table: 4.31 Hedonic score of control and experimental air-fried Namakpara

Sample	Appearance	Texture	Flavour	Taste	After taste	Overall acceptability
Control	2.19± 1.03 ^{a}	2.28±1.08^{a}	2.75±1.2^{b}	2.72±1.406^{a}	3.00±1.414^{b}	2.72± .301 ^{a}
Exp 1 **(10% RAL)**	1.86± 0.86 ^{a}	2.00±1.09 ^{a}	2.03±1.05^{a}	2.22±0.832^{a}	2.31 ±1.009^{a}	2.25± .025 ^{a}
Exp 2 **(20% RAL)**	2.00± 0.89 ^{a}	1.97±1.13 ^{a}	2.19±1.21^{ab}	2.17±1.183^{a}	2.39±1.315^{ab}	2.33±1.265 ^{a}
Exp 3 **(30% RAL)**	2.19± 1.14^{a}	2.19±1.09 ^{a}	2.61±1.35^{ab}	2.56±1.482^{a}	2.44 ± 1.44^{ab}	2.42±1.273 ^{a}
F-value	0.968	0.656	2.784	1.631	2.097	1.025
P-value	0.410 ^{NS}	0.0580 ^{NS}	0.043 *	0.185 ^{NS}	0.103 ^{NS}	0.384 ^{NS}

Values are Mean ± SD scores of a hedonic scoring test by a panel of 36 members
* indicates significant difference at $p \leq 0.05$
NS indicates no significant difference at $p > 0.05$
Same alphabetical superscript indicates no significant difference within row and column
Exp 1: Experimental 1, Exp 2: Experimental 2, Exp 3: Experimental 3

(2.25) and the lowest overall acceptability was observed between the control and experimental 3 air-fried namakpara.

Table 4.32 signifies the rankings and scores of various food items across four distinct variations of the 10 recipes developed: control, experimental 1 (10% RAL), experimental 2 (20% RAL), and experimental 3 (30% RAL). In the control group, thalipeeth achieved the highest rank with a score of 1.61, followed closely by dosa at 1.64 and handvo at 2.03. In contrast, khakhra was the lowest-ranked item, receiving a score of 3.53. In experimental 1 (10% RAL), dosa secured the top position with a score of 1.86, which resulted in thalipeeth moving to second place with a score of 2.06. Handvo maintained its third rank in this group with a score of 2.22, while khakhra, still in the lowest position, improved its score to 3.36. In experimental 2 (20% RAL), thalipeeth regained the first rank with a score of 1.97, followed by dosa at 2.14 and air-fried namakpara at 2.33. Notably, khakhra advanced to fifth place, achieving a score of 2.58 and demonstrating substantial improvement compared to its earlier rankings in the control and experimental 1 groups. In the final phase, experimental 3 (30% RAL), thalipeeth retained its position at the top with a score of 2.14, trailed closely by dosa at 2.17 and handvo at 2.42. The rankings suggest that an increase in the percentage of RAL has a significant impact on the scores and rankings of various recipes.

Table 4.32 Relative ranking of Control and Experimental recipes based on the mean Scores of the Hedonic Rating Test

Rank	Control	Experimental 1 (10% RAL)	Experimental 2 (20% RAL)	Experimental 3 (30% RAL)
1	Thalipeeth (1.61)	Dosa (1.86)	Thalipeeth (1.97)	Thalipeeth (2.14)
2	Dosa (1.64)	Thalipeeth (2.06)	Dosa (2.14)	Dosa (2.17)
3	Handvo (2.03)	Handvo (2.22)	Air fried Namakpara (2.33)	Handvo (2.42)
4	Thepla (2.11)	Air fried namakpara (2.25)	Handvo (2.44)	Air fried Namakpara (2.42)
5	Air fried Namakpara (2.72)	Kothimbirwadi (2.81)	Thepla (2.67)	Khakhra (2.58)
6	Kabab (2.81)	Chilla (2.94)	Kothimbirwadi (3.03)	Kothimbirwadi (2.72)
7	Kothimbirwadi (2.97)	Muthiya (2.94)	Kabab (3.08)	Thepla (2.86)
8	Chilla (3.39)	Thepla (2.97)	Khakhra (3.28)	Kabab (3.08)
9	Muthiya (3.39)	Kabab (3.08)	Chilla (3.36)	Chilla (3.14)
10	Khakhra (3.53)	Khakhra (3.36)	Muthiya (3.36)	Muthiya (3.14)

DISCUSSION

The great detoxing capability of ROS in the body of humans, their ability to prevent many chronic illnesses, and their anti-aging capabilities make the antioxidant elements of leafy vegetable amaranth potentially important for consumers. The results indicate that certain tolerant of drought leafy crops. Amaranth, have significant free radical-scavenging properties due to their high levels of vitamins C and E, total flavonoids, all total polyphenols, or antioxidant activity (Sarker, 2020).

In 15 leafy Amaranths species, the quantities of minerals, vitamin C, phenolic and flavonoid compounds, and antioxidant activity levels are assessed. In amaranth leaves, the concentration ranges of Ca, K, Mg, P, and phenolics were 1.5-3.5 mg/g, 5.5-8.8 30 mg/g, 1.8-4.5 mg/g, 0.5-0.9 mg/g, 3.2-5.5 mg gallic acid equivalents/g, and 38-90 μmol Trolox equivalents/g, respectively, for all species (Dulce M. Jiménez-Aguilar, 2024).

Red amaranth leaves are excellent sources of protein, carbs, fiber in the diet, and water intake. The red amaranth leaves were found to contain potassium, calcium, magnesium (24.96, 10.13, 30.01 mg g-1), iron, manganese, copper, zinc (1089.19, 243.59, 25.77, 986.61 μg g-1), β-cyanins, total flavonoids (102.10 RE μg g-1 DW), β-xanthins, betalains (33.30, 33.09, 66.40 μg 100 g-1), carotenoids, total phenolics (172.23 GAE μg g-1 DW), β-carotene (1225.94, 1043.18 μg g-1), vitamin C (955.19 μg g-1), and antioxidant activity (DPPH and ABTS+) (19.97 and 39.09 TEAC μg g-1 DW). Daily diet to achieve nutritional and antioxidant sufficiency, red amaranth leaves may be a viable source of nutrients, antioxidant pigments, minerals, and phytochemicals because these components scavenged ROS and functioned as potential antioxidants (Id & Oba, 2019).

Due to the inclusion of flavonoid and phenolic acids, substances with antioxidant activity, amaranth plant products have the ability to neutralize free radicals (Wolosik & Markowska, 2019).

Greater amounts of antioxidant pigment and phytochemicals, or including vitamin C, TPC, and TFC, were found in amaranthus leafy vegetables with a richer reddish-violet colour (Sarker & Oba, 2019).

Numerous health advantages are linked to the activity of antioxidants, which has been shown to have anti-inflammatory, anti-carcinogenic, hypoglycemia, and anti-inflammatory properties. There currently exist no established recommendations for the daily intake quantities of antioxidant chemicals, flavonoids, or phenolics, despite the fact that their consumption is strongly advised by Dulce M. Jiménez-Aguilar, 2024.

Two nutraceutical plants from Burkina Faso, Amaranthus cruentus and Amaranthus hybridus, were examined for their phytochemical makeup and bioactivities. Polyphenols, tannins, flavonoids, steroids, terpenoids, saponins, and betalains were among the several secondary metabolites found in aerial portions extracted in hydroacetonic, methanolic, and aqueous forms. The most diverse extracts were hydroacetonic ones. The ranges for tannins and flavonoids were 2.83–10.17 mg TAE/100 mg and 0.37–7.06 mg QE/100 mg, respectively, while the range for phenolic content was 7.55–10.18 mg GAE/100 mg. A. cruentus has a greater betacyanin concentration (40.42 mg) than A. hybridus (6.35 mg). Stronger free-radical scavenging (IC_{50}: 56 µg/mL vs. 423 µg/mL) and xanthine oxidase inhibition (38.22% vs. 3.18%) were demonstrated by antioxidant activity assays in A. hybridus extracts, demonstrating its better bioactivity and confirming both species' historical applications as nutraceutical food plants (Nana et al., 2012).

According to genotype and measurement technique, the total phenolic content (TPC) of red leaves of amaranth varies greatly, with levels recorded ranging from 159.62 to 958.19 µg Gallic acid equivalence (GAE)/mg dry extract (DE) (Lee, 2022). There are many phenolic acids, including p-coumaric acid, ferulic acid, and caffeic acid (Sarker & Oba, 2019).

Flavonoids that are such as rutin, quercetin, kaempferol, catechin, and myricetin are found in considerable quantities in red amaranth leaves. These substances support its potent antioxidant properties (Sarker & Oba, 2019). The amount of rutin in red amaranth leaves varies greatly depending on the genotype; some studies have found that it can reach 42.30 mg/g dry weight (Lee, 2022).
In tests like DPPH, (2,2-diphenyl-1-picrylhydrazyl) and ABTS, which (2,2′-azino-bis-(3-ethylbenzothiazoline-6-sulfonic acid)), red amaranth leaves demonstrate potent radical scavenging activity. For instance, according to Kraujalis P et al. (2013), the range of DPPH scavenging activity is 1.03 to 49.22 µg Trolox equivalents (TE)/mg.

Compared to green color genotypes & red color genotypes are an excellent source in colors like betalain (1122.47 ng g^{-1} fW), β-xanthin (585.22 ng g^{-1} fW), β-cyanin (624.75

ng g−1 FW), carotenoids (55.55 mg 100 g−1 FW), TFC (312.64 RE μg g−1 DW), TPC (220.04 GAE μg g−1 DW), and tAc (DPPH and ABTS+) (43.81 and 66.59 TEAC μg g−1 DW) (Oba and Sarker, 2019).

Children are typically given boiling amaranthus roots and leaves as a laxative. Additionally, amaranthus has long been utilized as an antibiotics, anti-diabetic, a diuretic anti-snake a poison anti-gonorrhea, and antileprotic. The sap of a plant is used for an eye wash to treat children's convulsions and ophthalmia. Young children, nursing moms, and people suffering from bowel movements, hemorrhage, fever, anemia, or renal issues are all advised to take amaranthus leaves (Joshi & Chandra Verma, 2020).

The analysis of Red Amaranth Leaves for antioxidant properties is influenced by several factors that can affect the accuracy and consistency of the results. Sample variability arises from natural differences in chemical composition due to growing conditions, maturity, and genetic factors, as well as from storage and handling practices that can lead to degradation of sensitive compounds. The extraction method also plays a crucial role, with solvent selection impacting the types and amounts of compounds extracted, and extraction efficiency varying based on factors like time, temperature, and technique. Additionally, environmental and seasonal factors such as soil quality, sunlight, water availability, and the time of year can further influence the antioxidant content of the leaves. These variables highlight the complexity of accurately measuring antioxidant activity and underscore the need for standardized procedures to ensure reliable results.

The leafy greens, which are also used as vegetables for stir-frying in soup among other recipes, are high in micro components and antioxidants. Amaranth leaves have a greater amount of antioxidants than a variety of common green leafy vegetables. The anti-inflammatory properties of amaranth were examined utilizing a variety of methods, including ferric reducing antioxidant power (FRAP) assays, DPPH and ABTS scavenging, and TPC assessments using the reagent Folin-Ciocalteu (Kraujalis et al., 2013).

Value added goods made from amaranthus, such as leaf squash, pakkavada, and stem-based cutlets and pickles, were developed by NIFTEM, Sonipat.

According to research, adding chaya (*Cnidoscolus aconitifolius*) and amaranth flours to cookies has no effect on how well-liked the finished goods are. Cookies' nutritional value is increased and their amount of bioactive chemicals linked to health impacts is increased when traditional foods like chaya and amaranth are added. Since it has been shown that consuming 25–35 g of fiber daily is linked to a decreased risk of metabolic conditions and coronary artery diseases, cookies were an excellent source of fiber that may enhance consumers' health (Johnst et al., 2022).

Pastas made using amaranth leaves flour (ALF) composite. According to the statistical study, panelists preferred pastas with a low ALF %. Pasta prepared with 35, 50, and 55% AF were all comparable in like ratings for aesthetic features; however, pasta created with 70% AF showed the lowest acceptability for color, surface smoothness, and broken pieces. The panelists rated the formulation with 35% AF as having higher acceptability ratings for taste attributes. Three characteristics of texture, stickiness, hardness, and springiness were assessed. Pasta made using less amaranth flour was the most popular (Cárdenas-Hernández Et Al., 2016).

Samples of instant noodles were created by partially replacing the wheat flour in a typical noodles recipe with one, two, and three percent (w/w) of ALP. Therefore, with the exception of color, every sensory attribute examined for samples containing one, two, and three percent ALP was accepted similarly to the control. The enriched noodles' color was significantly changed by the addition of ALP, which also caused their acceptability to drop to 5.47 of the hedonic rating system (Neither like/dislike) (Qumbisa Et Al., 2020).

Bengal gram dal flour and prepared amaranth grain flour (dry roasted and germinating) were mixed in a 1:1 ratio. The dosa mix's unprocessed amaranth grain flour served as a control. The three experimental instant dosa mixes—UTDM (Untreated amaranth Grain Flour Instant Dosa Mix), DRDM (Dry Roasted Amaranth Grain Flour Instant Dosa Mix), and GDM (Germinated Amaranth Grain Flour Instant Dosa Mix) were made with untreated, dry roasted and germinated amaranth grain flour. For general acceptance, the UTDM, DRDM, and GDM received scores of 7.73 ± 0.59, 8.06 ± 0.07, and 7.8 ± 0.41, respectively. The maximum score of 8.06 for DRDM's overall acceptability was "Like very much." (Nadu & Nadu, 2018).

The bread with 10% amaranth that was cooked for 18 minutes at 220 degrees Celsius had the greatest overall sensory ratings and was approved. Panelists favored breads cooked at 220°C out of the 18 varieties created with 5–30% amaranth flour substitutes and baked at three different temperatures. However, because of the low gluten content and darker color, which affected their sensory appeal, flours with more than 15% amaranth were judged unfit for use in breadmaking. In order to ensure the best quality and acceptance, proximate analyses were limited to loaves made with 5–15% amaranth flour substitutes and cooked at 220°C (Nganthoibi, 2021).

Teff was the key ingredient in each mix, and the flatbread was made by varying the amounts (grams) of Amaranthus leaf & grain flour combined with teffflour in proportions of 2:98, 4:96, 6:94, 8:92, and 10:90 (w/w). The acceptability level of the proportionate flatbread compositions was higher than that of the control (Abera Et Al., 2025).

SUMMARY AND CONCLUSION

In India, the most popular leafy vegetable is cultivated throughout all the seasons. Amaranthus's soft, fresh leaves and stem are very nutrient-dense and taste great when cooked. Red and green variants are also appropriate for use in cooking. In all tropical and sub-tropical areas, amaranthus is abundantly found. As a warm-season crop, leaf amaranth thrives in hot, muggy weather. In temperate locations, it is cultivated in the fall, spring, and summer, but in tropical regions, it is grown all year round. In addition, goods made with amaranth leaf powder are excellent sources of calcium, iron, fiber, and protein. Such value-added product consumption may help improve the population's nutritional condition, particularly for the most vulnerable (Singh et al., 2013).

The present study was planned for antioxidant analysis, product development and sensory evaluation of red amaranth leaves (A*maranthus cruentus L*.) incorporated recipes.

The objective of the study was to carry out the antioxidant analysis, product development and sensory evaluation of Red Amaranth Leaves (*Amaranthus Cruentus L.)* incorporated recipes. The specific objectives of the study were:

1. Antioxidant analysis of Red Amaranth Leaves
2. Development of Red Amaranth Leaves incorporated recipes
3. Sensory evaluation of the recipes developed

The entire study was carried out in 3 phases. They are as follows:

Phase 1: Antioxidant Analysis of Red Amaranth Leaves

Phase 2: Development of 10 Red Amaranth Leaves incorporated recipes

Phase 3: Sensory evaluation of the recipes developed

Phase 1: Antioxidant Analysis of Red Amaranth Leaves

The total phenolic content, flavonoid content, FRAP and DPPH-RSA of the Red Amaranth Leaves (fresh leaves) was determined to be 35.4 mgGAE/100gm, 50.3 mgRE/100gm, 28.3 mgTE/100gm and 389.8 mgTE/100gm respectively.

Phase 2: Development of 10 Red Amaranth Leaves incorporated recipe

The nutrient composition of various recipes supplemented with RAL at levels of 10%, 20%, and 30% revealed significant variations in nutrient composition, highlighting specific recipes that excelled in different aspects. Khakhra consistently showed an energy value of 284 kcal in experimental 3, with the highest protein content at 7.1 g. It also demonstrated improved iron content, peaking at 2.705 mg, and a significant increase in calcium to 80 mg. However, it was the handvo that emerged as the best overall recipe, featuring the highest energy content (457 kcal) and the greatest protein increase to 22.8 g. Additionally, it showcased an impressive rise in vitamin A, reaching 900 mg. Thepla exhibited a slight increase in energy and protein levels while maintaining a good nutrient distribution, including a significant rise in vitamin C to 26 mg, indicating its health benefits. On the other hand, dosa presented the lowest energy and protein levels, with a notable decrease in these nutrients compared to its control. Nevertheless, it excelled in calcium content, increasing to 121 mg. lastly, chilla maintained stable energy values while achieving a significant boost in protein (12.7 g), vitamin C (46 mg), and calcium (140 mg). In summary, while handvo was the most nutrient-dense recipe overall, khakhra excelled in iron content, and chilla demonstrated substantial increases in vitamin C and calcium. Each recipe had unique strengths, making them beneficial additions to a balanced diet.

Phase 3: Sensory evaluation of the recipes developed

Table 5.1 presents the hedonic scores and rankings of various recipes, conducting a comparative analysis of both control and experimental variations based on sensory evaluations. The Control Thalipeeth ranks first with a score of 1.61, followed closely by the Control Dosa, which achieves a score of 1.64. Notably, the experimental recipes incorporating RAL demonstrate elevated hedonic scores, reflecting enhanced sensory appeal. For instance, Experimental 1 (10% RAL) Dosa records a score of 1.86, securing the third position, while Experimental 2 (20% RAL) Thalipeeth attains a score of 1.97, ranking fourth. The Control Handvo is positioned fifth with a score of 2.03, succeeded by Experimental 1 (10% RAL) Thalipeeth in sixth place with a score of 2.06. Moreover, the Control Thepla ranks seventh with a score of 2.11. Experimental recipes with higher RAL concentrations, specifically Experimental 2 (20% RAL) Dosa and Experimental 3 (30% RAL) Thalipeeth and Dosa, achieve scores ranging from 2.14 to 2.17, occupying ranks eight through ten. The results suggest that the incorporation of RAL significantly enhances the sensory quality of traditional recipes, as evidenced by their superior hedonic scores in comparison to the control versions.

Table 5.1 Relative Ranking of the control and experimental recipes (Mean scores of the Hedonic test)

Recipe	Hedonic score	Rank
Control Thalipeeth	1.61	1
Control Dosa	1.64	2
Experimental 1 (10% RAL) Dosa	1.86	3
Experimental 2 (20% RAL) Thalipeeth	1.97	4
Control Handvo	2.03	5
Experimental 1 (10% RAL) Thalipeeth	2.06	6
Control Thepla	2.11	7
Experimental 2 (20% RAL) Dosa	2.14	8
Experimental 3 (30% RAL) Thalipeeth	2.14	9
Experimental 3 (30% RAL) Dosa	2.17	10

Table 5.2 presents the hedonic scores and rankings of experimental recipes that incorporate varying concentrations of RAL (10%, 20%, and 30%), thereby highlighting their sensory appeal. Among the assessed dishes, experimental 1 (10% RAL) dosa ranks first, receiving a hedonic score of 1.86, followed closely by experimental 2 (20% RAL) thalipeeth, which attains a score of 1.97 in the second position. The experimental 1 (10% RAL) thalipeeth secures the third position with a score of 2.06. In comparison, recipes featuring higher concentrations of RAL, such as experimental 2 (20% RAL) dosa and experimental 3 (30% RAL) thalipeeth, both achieve a score of 2.14, thereby ranking fourth and fifth, respectively. The experimental 3 (30% RAL) dosa registers a marginally higher score of 2.17, placing sixth in the rankings. Significantly, air-fried recipes demonstrate the highest hedonic scores, with the experimental 1 (10% RAL) handvo achieving a score of 2.22, positioning it seventh. Following this, experimental 1 (10% RAL) air-fried namakpara obtains a score of 2.25, securing the eighth rank. Scores for air-fried namakpara recipes continue to increase, with experimental 2 (20% RAL) recording a score of 2.33, which ranks 9th. Notably, the score of 2.42 is attained by experimental 3 (30% RAL) air-fried namakpara, which occupies the 10th position.

Table 5.2 Relative Ranking of the experimental recipes (Mean scores of the Hedonic test)

Recipe	Hedonic score	Rank
Experimental 1 (10% RAL) Dosa	1.86	1
Experimental 2 (20% RAL) Thalipeeth	1.97	2
Experimental 1 (10% RAL)Thalipeeth	2.06	3
Experimental 2 (20%RAL) Dosa	2.14	4
Experimental 3 (30% RAL) Thalipeeth	2.14	5
Experimental 3 (30% RAL) Dosa	2.17	6
Experimental 1 (10% RAL) Handvo	2.22	7
Experimental 1 (10% RAL) Air fried Namakpara	2.25	8
Experimental 2 (20% RAL) Air fried Namakpara	2.33	9
Experimental 3 (30% RAL) Air fried Namakpara	2.42	10

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Appendix I

Ethical Certificate

Appendix II

CONSENT FORM SENSORY EVALUATION

STUDY TITLE: ANTIOXIDANT ANALYSIS, PRODUCT DEVELOPMENT AND SENSORY EVALUATION OF RED AMARANTH LEAVES (*Amaranthus Cruentus L.*) INCORPORATED RECIPES

INVESTIGATORS

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PURPOSE OF THE STUDY

Red Amaranth Leaves (*Amaranthus Cruentus L.*) are a significant source of essential nutrients, including proteins, dietary fiber, vitamins, and minerals. They are particularly high in vitamin C, calcium, and iron. Additionally, these leaves contain a variety of antioxidant pigments and phytochemicals such as betalains and carotenoids, which are known for their health benefits.

The nutritional composition of red amaranth makes it a valuable candidate for functional food development. Its rich content of antioxidants can help combat oxidative stress and reduce the risk of chronic diseases. The presence of dietary fiber supports digestive health and may aid in weight management

Research has shown that incorporating Red Amaranth Leaves (*Amaranthus Cruentus L.*) into diets can enhance the nutritional quality of various food products. Its versatility allows it to be used in salads, soups, and baked goods, making it an attractive option for health-conscious consumers seeking to improve their diets with nutrient-dense foods. Overall, red amaranth leaves hold great potential for developing functional food products that address nutritional deficiencies and promote overall health.

BENEFITS AND RISKS

Red Amaranth Leaves (*Amaranthus Cruentus L.*) exhibit significant antioxidant properties, which can help mitigate oxidative stress and its associated chronic diseases. These leaves are particularly rich in antioxidants, including various pigments and phytochemicals, which play a crucial role in scavenging free radicals and reducing cellular damage.

Additionally, the high fiber content of Red Amaranth Leaves (*Amaranthus Cruentus L.*) aids in digestive health and may contribute to weight management by enhancing feelings of fullness. This characteristic makes it a beneficial addition to diets aimed at controlling appetite.

PROTOCOL OF THE STUDY

If you decide to join this study, you will be required to taste Red Amaranth Leaves (*Amaranthus Cruentus L.*) incorporated recipes and carry out the sensory evaluation which will be carried out on different days.

COSTS

The study only requires your time and cooperation. All the costs incurred will be borne by the researcher and there is no financial compensation for your participation in this research.

CONFIDENTIALITY

In the study, your identity will be kept confidential. The results of the study, including laboratory or any other data, may be published for scientific purposes but will not reveal your name or include any identifiable references to you.

RIGHT TO WITHDRAW

Your decision to join this study is voluntary. You may quit at any time, for any reason, without notice. We hope you will take part for the entire study period because we need all the information to draw correct conclusions.

VOLUNTARY CONSENT

Your co-operation is important to the success of this study. Unless many volunteers like you agree to join, this study will not be possible.

INVESTIGATOR'S STATEMENT

I have explained the research program, the purpose of the study and the possible benefits and risks to the participant. The participant was given an opportunity to discuss these procedures and ask any additional questions.

Priyanka Kale

9510936096

PARTICIPANT'S STATEMENT

I certify that I have read, or had read out to me, and that I have understood the description of the study. By signing this form, I am attesting that I have read and understood the information given above.

I give my consent to be included as a subject being carried out by Ms. Priyanka Kale under the guidance of Dr. Revati Shah of the Maharaja University of Baroda to determine the acceptability of Red Amaranth Leaves (*Amaranthus Cruentus L*.) incorporated recipes.

I understand that the study requires the participant to taste Red Amaranth Leaves (*Amaranthus Cruentus L*.) incorporated recipes. I have had a chance to ask questions about the study. I understand that I may ask further questions at any time. I have been explained to my satisfaction the purpose of this study and I am also aware of my right to opt out of the study at any time.

Participant's name and signature:

Mobile Number:

Date:

Appendix III

QUESTIONNAIRE FOR GENERAL INFORMATION

1. **Name:**
2. **Age:**
3. **Sex:**
    - Male
    - Female
    - Other:
4. **Profession:**
    - Teacher
    - M.Sc.Student
    - Ph. D. student
    - Other:
5. **Mobile Number:**
6. **Interested in the qualitative work of sensory evaluation for the Red Amaranth Leaves incorporated recipes?**
    - Yes
    - No
7. **Willing to spend time in sensory evaluation of development recipes?**
    - Yes
    - No
8. **Have any medical history?**
    - Yes
    - No
9. **If yes:**
    - Diabetes
    - Hypertension
    - CHD
    - Other:
10. **Taking any medication? If yes, please mention:**
11. **History of cold/cough in the past three days?**
    - Yes
    - No

12. Allergies in any?

- Yes
- No

13. If yes, please specify:

14. Undergone any surgeries in the past year?

- Yes
- No

15. Habit of:

- Smoking
- Alcohol
- Tobacco
- None

Sensory Evaluation Scorecard

Appendix IV

<u>COMPOSITE SCORE CARD</u>

Name: Date:

Product:

Sensory Attributes	**Possible Score**	**Score**			
		A	**B**	**C**	**D**
1. Appearance	20				
2. Texture	20				
3. Flavour	15				
4. Taste	20				
5. After Taste	5				
6. Overall acceptability	20				
Total	**100**				

Comments:

Sign:

Appendix **V**

HEDONIC RATING TEST

Name: Date:

Product:

Sensory Attributes	Score			
	A	**B**	**C**	**D**
1. Appearance				
2. Texture				
3. Flavour				
4. Taste				
5. After Taste				
6. Overall acceptability				

Score Key:
1 – Like extremely
2 – Like very much
3 – Like moderately
4 – Like slightly
5 – Neither like nor dislike
6 – Dislike slightly
7 – Dislike very much
8 – Dislike moderately
9 – Dislike extremely

Comments:

Sign: