DEVELOPMENT AND EVALUATION OF IRON-BASED FOOD PRODUCTS FOR ADOLESCENTS WITH IRON-DEFICIENCY ANAEMIA

PROJECT SUBMITTED

In Partial Fulfilment of the Requirement for the Award of the Degree of

B.Sc NUTRITION AND DIETETICS

BY

AHLAM RAZI. ALFIYA ALI, ASHLY MATHEW, SONA LAZAR, TREESA SYEONA, ZEMERA NINAN

SB22ND003, SB22ND007, SB22ND012, SB22ND044, SB2ND047, SB22ND50

DEPARTMENT OF CLINICAL NUTRITION AND DIETETICS

ST. TERESA 'S COLLEGE (AUTONOMOUS)

ERNAKULAM

MARCH 2025

CERTIFIED AS BONAFIDE RESEARCH WORK

Signature of Internal Examiner **Signature of External Examiner**

DECLARATION

I hereby declare that the project entitled "**DEVELOPMENT AND EVALUATION OF IRON-BASED FOOD PRODUCTS FOR ADOLESCENTS WITH IRON DEFICIENCY ANAEMIA"** submitted in partial fulfilment of the requirement for the award of the degree of B.Sc. Nutrition and Dietetics is a record of original research work done by me under the supervision and guidance of Dr.Soumya, Assistant Professor. Department of Clinical Nutrition and Dietetics, Women's Study Centre, St. Teresa's College (Autonomous), Ernakulam and has not been submitted in part or full of any other degree/diploma/fellowship or the similar titles to any candidate of any other. university.

Ahlam Razi
Alfiya Ali
Ashly Mathew
Sona Lazar
Treesa Syona
Zemera Ninan

Place:
Date:

CERTIFICATE

I hereby certify that the project entitled " **DEVELOPMENT AND EVALUATION OF IRON-RICH FOOD PRODUCTS FOR ADOLESCENTS WITH IRON DEFICIENCY ANAEMIA**" submitted in partial fulfilment of the requirement for the award of the degree of B.Sc. Nutrition and Dietetics is a record of original work done by Ms. Ahlam Razi, Ms. Alfiya Ali, Ms. Ashly Mathew, Ms. Sona Lazar, Ms. Treesa Syona, and Ms. Zemera Ninan during the study under my guidance and supervision.

Signature of the HOD	**Signature of the Research Guide and designation**
	Guide with designation
Ms. Surya M Kottram. Head of the department	Dr. Soumya P S Assistant Professor
Department of Clinical Nutrition and Dietetics	Department of Clinical Nutrition and Dietetics
St. Teresa's college. (Autonomous), Ernakulam	St Teresa's college (Autonomous), Ernakulam

ACKNOWLEDGEMENT

First and foremost, we would like to praise and thank God, the Almighty, who has granted us countless blessings, knowledge, and the opportunity to complete this thesis.

We are sincerely grateful to Rev. Sr. Nilima CSST, Provincial Superior and Manager, Rev. Sr. Francis Ann CSST, Director; Dr. Alphonsa Vijaya Joseph, Principal, St. Teresa's College (Autonomous), Ernakulam and Dr. Kala M.S., Dean of Self-financing Stream, for granting me the opportunity to undertake this project and for fostering an environment of academic excellence.
We express our sincere thanks to Mrs. Lekha Sreenivas, Co-ordinator of Women's Study Centre, St. Teresa's College, Ernakulam, for her constant encouragement and advice

We would love to express our sincere gratitude to Ms. Surya M Kottaram, Head of the Department, for the constant support and advice.

We are deeply indebted to my guide, Dr. Soumya P.S., Assistant Professor, Department of Clinical Nutrition and Dietetics, for her constant guidance and supervision and for providing the necessary information regarding the thesis activities. Her insightful feedback pushed me to sharpen my thinking and brought my work to a higher level.

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABSTRACT

The study titled "Development and Evaluation of Iron-Based Food Products for Adolescents with Iron Deficiency Anaemia" aimed to create convenient and nutrient-rich food products using iron-rich ingredients. Six products, namely Baked Beetroot Chips, Beetroot-Moringa soup, Beetroot-Dates Squash, Chickpea Cookies, Chickpea-Dates Spread, Spinach -Dates Jelly, were developed and evaluated for their sensory attributes, nutritional composition and shelf life. Anaemia is a common heamatological condition characterized by a decrease in the number of red blood cells (RBCs) or heamoglobin concentration, leading to reduced oxygen delivery to tissues.

Through organoleptic evaluation, the best variation of each product was selected based on taste, texture, aroma, flavour and overall sensory appeal. The nutrient analysis revealed that the incorporated products offered a well-balanced composition of carbohydrates, protein and dietary fibre. Essential minerals such as iron and vitamin c were found in significant amounts. By analysis of the iron-based food products it is noticed that the lowest iron content in Baked Beetroot Chips (1.35 mg) and highest iron content in Beetroot-Moringa Soup (10.18 mg) and for the vitamin C content of the given food products it was found that highest vitamin C content on Spinach-Dates jelly and lowest one is the Chickpea Cookies. However, further nutritional analysis is needed to gain a comprehensive understanding of the complete nutrient profile. The products were designed to be palatable, culturally acceptable and nutritionally effective. Sensory evaluation was conducted among adolescents to assess acceptability.

Overall, the study showcased the potential of incorporating these iron-based products in the development of convenient and nutrient-rich food products to improve the overall status. These products offer a good balance of Macro nutrients and essential minerals. This study highlights the potential of using affordable, iron-rich foods as a dietary strategy to improve iron status among adolescents, offering a practical solution for managing IDA through sustainable nutrition interventions.

(Key words: Baked Beetroot Chips, Beetroot-Moringa soup, Beetroot-Dates Squash, Chickpea Cookies, Chickpea-Dates spread, Spinach -Dates Jelly)

1. INTRODUCTION

"Iron deficiency remains the most common nutritional deficiency in the world, affecting energy, cognition, and overall health—yet it is also one of the most preventable."

- Dr. Robert Murray, a nutrition expert

WHO defines anaemia as a prevalent and significant global public health concern, characterized by a reduction in the number of red blood cells or heamoglobin concentration leading to a decreased capacity of the blood to transport oxygen to the body's tissues. Symptoms manifest as fatigue, weakness, dizziness and shortness of breath, which can severely impact an individual's overall well-being and productivity.

The primary causes of anaemia are multifaceted and include nutrient deficiencies due to inadequate diets or poor absorption, infections such as malaria, tuberculosis and HIV, chronic diseases, gynaecological and obstetric conditions and inherited red blood cell disorders. Among these, iron deficiency stands out as the most common nutritional cause followed by deficiencies in folate, vitamins B12 and A.

Anaemia disproportionately affects vulnerable populations, including young children, menstruating adolescent girls and women and pregnant and postpartum women. According to the World Health Organization (WHO), approximately 40% of children aged 6–59 months, 37% of pregnant women and 30% of women aged 15–49 worldwide suffer from anaemia.

This project aims to explore the prevalence, causes and impacts of anaemia, focusing on dietary interventions and nutritional strategies to prevent and manage the condition. Through this study, we aim to raise awareness and propose effective solutions to combat anaemia, thereby improving public health and enhancing the quality of life for affected populations.

Anaemia is characterized by a deficiency of red blood cells or haemoglobin, leading to reduced oxygen transport throughout the body. It is a widespread public health concern, particularly affecting children, adolescent girls and women of reproductive age. The most common cause of anaemia is iron deficiency, which can result from poor dietary intake, inadequate absorption or increased demand for iron due to conditions such as pregnancy or chronic diseases.

A well-balanced diet plays a crucial role in preventing and managing iron deficiency anaemia. Foods rich in iron, such as chickpeas, beetroot, spinach and dates can help improve haemoglobin levels and overall blood health. Chickpeas provide a good source of non-heme iron and folate, both essential for red blood cell formation. However, since non-heme iron is less easily absorbed, pairing it with vitamin C-rich foods like lemon or tomatoes can enhance its bioavailability. Beetroot, although containing a moderate amount of iron, is rich in folate and nitrates which support red blood cell production and improve oxygen circulation. Spinach, one of the most iron-rich plant-based foods, also contains folate and vitamin C, but its oxalate content can hinder iron absorption unless cooked properly. Dates contribute iron along with vitamin C and natural sugars, providing an energy boost while supporting iron absorption and red blood cell function.

Hence, the present study entitled "Development and Evaluation of Iron-Based Food Products for Adolescents with Iron Deficiency Anaemia" was undertaken with the objectives of:

1. To select and standardize iron-rich ingredients for food development.
2. To develop iron-based food products.
3. To evaluate the sensory qualities of the snacks using the 9-point Hedonic Scale.
4. To calculate the nutritional value per serving of the food.
5. To analyse the cost of the developed products.

2. REVIEW OF LITERATURE

The literature pertaining to the study "Development and Evaluation of Iron-Rich Snack Products for Adolescents with Iron Deficiency Anaemia" is presented under the following heads:

2.1 PREVALENCE OF ANAEMIA

2.1.1 Prevalence of Anaemia on a Global Scale

The global prevalence of anaemia for all age groups was 22.8% (95% CI: 22.6–23.1) in 2019, showing a decrease from 27.0% (26.7–27.2) in 1990. Despite the decline in prevalence over the years, the total number of anaemia cases increased from 1.42 billion (1.41–1.43) in 1990 to 1.74 billion (1.72–1.76) in 2019. The highest prevalence was noted among children under five years, with a combined prevalence of 39.7% (39.0–40.4) in 2019. Notably, 54.1% (53.8–54.4) of anaemia cases globally were categorized as mild, 42.5% (42.2–42.7) as moderate, and 3.4% (3.3–3.5) as severe. Anaemia was responsible for 58.6 million years lived with disability in 2019. The highest burden of anaemia was reported in Western Sub-Saharan Africa, South Asia and Central Sub-Saharan Africa. The top three causes of anaemia globally were dietary iron deficiency, vitamin A deficiency, and beta-thalassemia trait (Gardner et al.,2020).

A meta-analysis involving 1,244,747 participants revealed that the overall prevalence of anaemia in pregnant women was 36.8% (95% CI: 31.5–42.4%). The prevalence of mild anaemia in this group was highest at 70.8% (95% CI: 58.1–81) and the third trimester of pregnancy saw the highest prevalence at 48.8% (95% CI: 38.7–58.9%). The highest prevalence was observed in African countries, where it stood at 41.7% (95% CI: 32.3–49.4) (Karami et al., 2022).

Previous studies on anaemia have often been geographically limited and have lacked in-depth analysis of severity and etiology. A study covering 187 countries from 1990 to 2010 estimated anaemia severity (mild, moderate, and severe) across 20 age groups and both sexes. The study indicated that in 2010, global anaemia prevalence stood at 32.9%, causing 68.36 million years lived with disability (8.8% of the total burden for all conditions). This study also highlighted a reduction in prevalence over the years, with a more significant reduction in males than in females. However, the burden remained highest in South Asia, Central, West and East Sub-Saharan Africa. Iron-deficiency anaemia was the leading cause globally, with other notable contributors being malaria, schistosomiasis and chronic kidney disease. Haemoglobinopathies were also significant contributors to anaemia in various populations. The highest burden of anaemia was in children under the age of five, who were the only group showing negative trends in prevalence from 1990 to 2010 (Kassebaum et al., 2014).

Data from a global survey covering 48.8% of the global population revealed a global anaemia prevalence of 24.8% (95% CI: 22.9–26.7), affecting 1.62 billion people. Among specific populations, preschool-aged children had the highest prevalence at 47.4% (95% CI: 45.7–49.1), followed by pregnant women at 41.8% (95% CI: 39.9–43.8) and non-pregnant women at 30.2% (95% CI: 28.7–31.6). The number of affected individuals included 293 million preschool-aged children, 56 million pregnant women and 468 million non-pregnant women (McLean et al., 2009).

A review of nine eligible studies found that the global prevalence of anaemia in patients with anorexia nervosa was 44.8% (95% CI: 25.7–65.7). The prevalence based on hematocrit and haemoglobin levels was 48% (95% CI: 19.9–77.4) and 43.4% (95% CI: 18.6–72), respectively. Meta-regression analysis indicated that with an increase in sample size and year of publication, the global prevalence of anaemia in anorexia nervosa patients showed varied trends (Salari et al., 2025).

In a study involving 47 LMICs between 2010 and 2018, the overall prevalence of anaemia among children under 5 years was 56.5% (95% CI: 56.2–56.8). The prevalence of anaemia was significantly higher among younger children aged 6–35 months, with an adjusted odds ratio (OR) of 1.38 (95% CI: 1.36–1.39, $P < 0.001$) compared to older children aged 36–59 months.

For women of reproductive age in 46 LMICs, the overall prevalence was 40.4% (95% CI: 40.1–40.7). Pregnant women, particularly in the third trimester (adjusted OR 1.55, 95% CI: 1.48–1.62, P < 0.001) and second trimester (adjusted OR 1.51, 95% CI: 1.45–1.58, P < 0.001), were more likely to have anaemia compared to those in the first trimester. Although there was a decrease in anaemia prevalence between 2000-2009 and 2010-2018, the current prevalence remained high, especially for children and pregnant women (Sun et al., 2021).

In Uganda, a study using data from the 2006 Demographic Health Survey and the 2009 Malaria Indicator Survey revealed that over 60% of children under 5 years of age were anaemic, with more than half testing positive for malaria. Children with concurrent malaria infections, particularly those in households without mosquito nets were more likely to suffer from anaemia. This highlighted the combined burden of malaria and anaemia in this population, emphasizing the need for prevention and treatment of both conditions to reduce anaemia's toll (Menon et al., 2015).

2.1.2 Prevalence of Anaemia in India

Anaemia is one of the most significant nutritional problems globally, primarily caused by iron deficiency. While it affects all age groups, its prevalence is particularly high among women of childbearing age. Studies have highlighted that anaemia is more common in developing nations, largely due to low socioeconomic status and limited access to healthcare services (Chandrakumari et al., 2019).

In developing countries, adolescents are particularly vulnerable to nutritional challenges, with adolescent girls being more susceptible to anaemia. Anaemia in this demographic is regarded as one of the greatest nutritional concerns in these regions. India, in particular, has reported a high prevalence of anaemia among adolescent girls, a rate higher than that observed in other developing nations (Chandrakumari et al., 2019).

Adolescence, defined by the World Health Organization as the period between 10 and 19 years of age, is a critical phase of transition from childhood to adulthood. This stage is characterized by rapid physical growth, increased physical activity, and significant psychological and behavioural changes, all of which necessitate additional nutritional requirements. Recent statistics indicate that there are approximately 1.2 billion adolescents worldwide, making up about one-fifth of the global population. Of this, developing countries account for about 5 million adolescents and in India, adolescents constitute about 21% of the total population (Chandrakumari et al., 2019).

In India, the prevalence of anaemia among adolescent girls has been on the rise, particularly since the onset of menstruation. This increases the vulnerability of adolescent girls to nutritional anaemia. In rural areas, early marriages and pregnancies during the late adolescent years further exacerbate the risk of anaemia and low birth weight in babies. The adolescent period, marked by the onset of menstruation, increases the nutritional demands for iron, making this group more prone to developing anaemia (Chandrakumari et al., 2019).

Although several studies have focused on anaemia among pregnant women and children, fewer studies have examined the prevalence of anaemia among adolescent girls. A study aimed at understanding the prevalence of anaemia among adolescent girls in a rural area of South India found that the overall prevalence of anaemia was 48.63% (n = 124). Of these, the majority (55.64%, n = 69) had mild anaemia. The study revealed that 188 of the 255 participants (73.73%) were in the early adolescent age group (10–14 years). Anaemia was particularly prevalent among late adolescents and those from lower socioeconomic backgrounds (Chandrakumari et al., 2019).

2.1.3 Prevalence of Anaemia in Kerala

Anaemia is a significant public health issue in India and Kerala, despite its relatively better health indicators is not exempt. It is characterized by a reduced level of haemoglobin in the blood, leading to fatigue, weakness and increased susceptibility to disease. In Kerala, anaemia affects various segments of the population, including women, children, adolescents and the elderly, often due to nutritional deficiencies and socioeconomic factors.

According to the National Family Health Survey (NFHS-5) conducted between 2019 and 2021, 36.3% of women aged 15 to 49 years in Kerala were found to be anaemic, marking a slight increase from 34.2% in NFHS-4. Although this is significantly lower than the national average of 57% for the same demographic, it still indicates a pressing need for intervention and education about iron intake and women's health. (James et al., 2021).

This age-specific trend underlines the biological and nutritional vulnerabilities of early adolescence. Programs such as weekly iron-folic acid supplementation in schools, alongside nutrition education and menstrual hygiene awareness, can help curb this growing issue.

A cross-sectional study conducted in a rural area of Kerala reported a 26.3% prevalence of anaemia among adolescent girls, with 94% having mild anaemia. The study also found that younger adolescents (aged 10–14 years) had a higher prevalence (39.5%) compared to older adolescents (15–19 years), reflecting a critical need for early dietary interventions and health education in schools (Sreelatha et al., 2021).

Pregnant women have increased iron demands due to foetal development and blood volume expansion, making them particularly susceptible to anaemia. Routine antenatal care including iron supplementation and dietary counselling, plays a critical role in managing anaemia during pregnancy.

Among pregnant women in Kerala, a study reported a prevalence of 40% anaemia, with most cases being mild. The study further highlighted that women who had their first delivery at or before the age of 25 were significantly more likely to be anaemic. These findings emphasize the impact of reproductive health, maternal age and nutrition on anaemia during pregnancy (Rajendran et al., 2022).

The higher anaemia prevalence among elderly women can be attributed to post-menopausal hormonal changes and possible chronic illnesses. There is a need for targeted geriatric nutrition programs and regular screening to manage anaemia among the elderly, especially in underserved urban regions.

In the elderly population of Kerala, particularly in urban slums of Kochi, anaemia is also widespread. A study revealed that 60.6% of elderly individuals were anaemic, with a higher prevalence in women (66%) than men (49%). Dietary habits, including low consumption of green leafy vegetables and legumes, were significantly associated with anaemia in this age group (Thomas et al., 2020).

In children, iron deficiency impacts cognitive development, immunity and growth. Therefore, early interventions including iron supplementation, deworming and caregiver education are crucial to reduce anaemia burden in this vulnerable age group.

Although Kerala's children under five generally fare better than national averages, anaemia remains a concern. National data from NFHS-5 indicated that 67.1% of children aged 6–59 months across India are anaemic, up from 58.6% in NFHS-4. While Kerala's rates are relatively lower, the trend suggests the need for focused nutritional supplementation and awareness among caregivers (Bhagat et al., 2021).

2.2 GENERAL FOOD HABITS

The Indian meal pattern is affected by the kinds of foods available. For example, rice is grown in certain parts of the country, and it forms the staple in those regions. Similarly, wheat, jawar (barley), bajra(millet), makka (corn), and ragi (finger millet) are used as staples where they are the major crops. The kinds and amount of food eaten are affected by the money that can be spent for food. The family's meal pattern is dictated by geographic region, religion, and community and family practices that have developed over several generations (1995).

In a study by Green et al. (2016), it is noted that traditional nutrient-by-nutrient analyses may miss the real-world combinations in which foods are consumed, and that India's rising burden of diabetes and cardiovascular disease makes a whole-diet approach urgent. They set out to identify and characterise common dietary patterns reported in India and to examine their links with diet-related non-communicable diseases (NCDs) by systematically reviewing both published and "grey" literature. Searches spanned multiple databases and grey-literature sources, yielding eight studies that together described eleven distinct dietary-pattern models. Analytical approaches: Included data-driven methods such as principal component analysis (PCA), factor analysis, k-means clustering and latent class analysis, each aiming to group foods typically eaten together or by similar consumer profiles. Predominantly Vegetarian Patterns are high in cereals, pulses, fruits, and vegetables. "Western" or Energy-Dense Patterns are characterised by higher intakes of fats, sugars, sweets/snacks and greater inclusion of meat. Large inter-regional differences in pattern prevalence. Some evidence of diet shifts over time; however, no consistent sex or age-based distinctions emerged. High-fat patterns were linked to higher body mass index (BMI). Patterns rich in sweets and snacks showed a stronger association with diabetes risk compared to traditional rice-and-pulse diets. Relationships with other NCD markers (e.g., blood lipids, blood pressure) were inconsistent or under-explored. Dietary-pattern analysis offers a nuanced view of Indian eating behaviours and their health impacts. Current evidence is sparse and hampered by heterogeneous data sources, small sample frames and varying statistical methods. More nationally representative surveys using standardized pattern-derivation methods are needed to inform policy and public health interventions.

Reddy (2010) offers a comprehensive analysis of dietary patterns and nutritional intake across the state's three distinct regions: Coastal Andhra, Rayalaseema, and Telangana. The research utilized data from the 61st round of the National Sample Survey (2003–04), encompassing 5,550 rural households across 432 villages.

Across all regions, diets were predominantly cereal-based, contributing approximately 74% of energy, 67% of proteins, and 10% of fats. Despite this, 30–45% of the population remained undernourished, indicating that reliance on cereals alone was insufficient for meeting nutritional requirements. The Coastal region exhibited higher consumption of high-value food items such as fruits, vegetables, milk, and meat products compared to Rayalaseema and Telangana. This suggests better dietary diversity and potential micronutrient intake in the Coastal area. Undernutrition was more prevalent among landless individuals, Scheduled Castes (SC), Scheduled Tribes (ST), and economically disadvantaged groups. For instance, calorie intake per consumer unit was 2,288 Kcal for SCs, 2,437 Kcal for STs, and 2,658 Kcal for other social groups. Nutrient intake, particularly calories, proteins and fats, increased with landholding size. Households with larger landholdings had better access to diverse foods, leading to improved nutritional status. Lower-income groups allocated a higher percentage of their income to food. For example, very poor households in Rayalaseema spent approximately 70.5% of their income on food, compared to 50.5% by richer households.

2.2.1 Food Habits- India

India's culinary traditions reflect its diverse cultural, ethnic and geographical backgrounds. The variety in food habits across different regions is shaped by historical, agricultural and climatic factors. In the northern part of India, wheat-based foods such as chapati, roti and naan form the dietary staples, typically served with lentils, vegetables and meat curries. In contrast, South India predominantly relies on rice as a staple grain, with accompanying dishes like sambar, rasam, and coconut-based curries. These regional distinctions are not merely culinary but are deeply tied to the socio-cultural fabric and the agricultural practices of the areas.

Religion and tradition significantly influence Indian food habits. Many communities follow vegetarian diets due to religious beliefs, particularly those practicing Hinduism, Jainism and Buddhism. The preparation and consumption of food often involve rituals passed down through generations. Spices and herbs such as turmeric, cumin, coriander and asafoetida are commonly used in Indian cuisine, not only to enhance flavours but also for their medicinal and health-promoting properties. Traditional cooking techniques, such as slow cooking in clay pots and fermentation, are utilized to retain the nutritional value of food while improving taste.

The impact of globalization has been noticeable in urban India, where international cuisines have found a place in the food culture. This has led to the rise of fusion foods combining traditional Indian ingredients with global flavours. In addition, the growing awareness of health and nutrition has shifted consumer preferences toward organic foods, plant-based diets and low-calorie alternatives. Despite these modern influences, traditional home-cooked meals continue to form the backbone of daily life for many families, balancing the old with the new in the nation’s food habits.

2.2.2 Food Habits in Kerala

Kerala’s cuisine is distinct for its use of locally sourced ingredients, which include rice as the primary staple food. Rice is consumed in various forms such as boiled rice, rice flour, and rice-based snacks. Coconut is another key ingredient in Kerala’s culinary repertoire, used in numerous forms such as grated coconut, coconut milk and coconut oil. The liberal use of coconut imparts a creamy texture to many dishes, enhancing their richness. Kerala’s cuisine also incorporates a variety of spices, including black pepper, cardamom, cloves and cinnamon, many of which are grown locally and have historical significance due to the state's role in the spice trade.

Given Kerala’s extensive coastline and backwaters, seafood plays a prominent role in its cuisine. Fish, prawns, mussels and crab are commonly consumed, often cooked in spiced gravies or grilled with simple seasonings. One of the signature dishes of Kerala is the Kerala fish curry, which typically features a base of coconut milk or tamarind, flavored with a blend of spices. Non-vegetarian dishes, including chicken, beef, and mutton, are also popular, reflecting the state’s diverse religious and cultural practices.

The state’s traditional meal, known as the "sadya," is a grand vegetarian feast typically served on a banana leaf during festivals and special occasions. The sadya includes an array of dishes such as avial, thoran, olan, sambar and payasam, which are arranged and served in a specific order. Kerala is also known for its variety of snacks and breakfast items, with popular dishes including appam (soft rice pancakes with a spongy center), puttu (steamed rice flour cylinders layered with coconut) and idiyappam (rice noodle cakes).

Kerala’s food habits emphasize a balanced diet incorporating carbohydrates, proteins, fats and fibre, sourced from fresh, seasonal, and locally grown ingredients. The use of coconut oil and spices contributes not only to the flavour but also to health benefits, including antimicrobial and antioxidant properties. This dietary pattern is a reflection of the state's agrarian lifestyle, where physical activity and locally grown produce are integral to a culture of nutritious and sustainable eating.

2.3 IRON-BASED FOOD PRODUCTS

Murlidhar et al. (2017) discussed that beetroots (Beta vulgaris L.) are a rich source of potent antioxidants and minerals including magnesium, sodium and potassium. It contains betaine, which is important for cardiovascular health. Beetroots are low in calories (about 45 Kcal per 100 g) and have zero cholesterol. The study was conducted to improve the nutritional qualities of cookies with incorporation of different levels of beetroot powder ie 0, 5, 7, 10, 15 and 20%, and examined for its physical and chemical composition. The proximate composition of cookies enriched with beetroot powder from 5 to 20% indicated that protein was increased from 7.39 to 9.12%, crude fibre 0.95 to 1.90% and ash content 0.93 to1. 89%. The incorporation of beetroot powder in cookies lowered the lightness (L*) and yellowness (b*) but increased redness (a*) of cookies. The hardness of the cookies was increased with increasing the level of beetroot powder. Sensory evaluation of cookies concluded that the cookies prepared with addition of 10% beetroot powder were more acceptable as compared to others.

According to, Małgorzata and Andrzej (2017) red and processed meats are the main sources of iron in the diet. Adequate intake of this nutrient is essential for the proper development and functioning of the human body, and its deficiencies are associated mainly with the occurrence of anaemia, which is one of the most widespread nutritional problems in the world. However, excessive intake of iron can be detrimental to health. Studies have shown that high consumption of red meat and its products, and thereby iron, particularly in the form of heme, increases the risk of non-communicable diseases, including cancers, type II diabetes and cardiovascular disease. Due to the high nutritional value, the presence of red meat in the diet is preferable, but according to World Cancer Research Fund International its consumption should not exceed 500 g per week. Furthermore, there are several potential ways to suppress the toxic effects of heme iron in the diet.

Chhorn Lim et al. (2001) explained that iron is a trace mineral of fundamental importance for most higher animals, including fish, because of its functions in oxidation-reduction activity and oxygen transport. In biological systems, iron can exist in the ferrous (Fe2+) or ferric (Fe3+) state, and this permits iron to donate or accept electrons and thus participate in the oxidation-reduction reactions, including those involved in oxygen transport. It occurs in the animal body as a component of the respiratory pigment (heme compounds), such as haemoglobin in red blood cells and myoglobin in muscle, as well as the heme enzymes such as peroxidase, catalase, and cytochromes. The remainder of the iron in the body is found in nonheme compounds such as transferrin (siderophilin), lactoferrin, ferritin, and hemosiderin (Harper 1973; Kaneko 1980). Transferrin, which is the principal protein carrier of iron in the blood, plays an important role in iron metabolism. Ferritin and hemosiderin are iron storage compounds found in the liver, spleen, and bone marrow. Fish can absorb soluble iron from water across the gill membrane (Roeder and Roeder 1966); however, intestinal mucosa is considered the major site of iron absorption (Lall 1989). Diet is considered the major source of iron because of low concentrations of soluble iron in natural waters (NRC 1993). The dietary requirements of iron for optimum growth and prevention of various deficiency signs have been demonstrated for several fish species, including red sea bream, Chrysophrys major (Sakamoto and Yone 1976, 1978b); yellowtail, Seriola quinqueradiata (Ikeda, Ozaki, and Uematsu 1973); common carp, Cyprinus carpio (Sakamoto and Yone 1978a); eel, Anguilla japonica (Nose and Arai 1979); Atlantic salmon, Salmo salar (Lall and Hines 1987; Andersen, Maage, and Julshamn 1996)

Rybicka et al. (2021) emphasized that dried fruits are an excellent alternative to unhealthy snacks. Twelve commercially available dried fruits were selected: dates, raisins, prunes, Goji berry, chokeberry, rose hip, sea buckthorn, berberis, physalis, haritaki, noni and juniper. The nutritional value in terms of moisture, ash, protein, fat, carbohydrate, dietary fibre, energy value, mineral composition, antioxidant activity and tannins was compared. It is a novelty in the literature in relation to the particular analytes (e.g., minerals, tannins) and/or fruits (e.g., berberis, noni, haritaki). Especially rich in protein were Goji berry (13.3%), sea buckthorn (9.3%), noni (8.9%) and physalis (8.0%); in fat − sea buckthorn (11.2%); in dietary fibre (4.4–53.0%) − most of analyzed products. High antioxidant capacity was noticed for haritaki, berberis, rose hip, Goji berry, and physalis. An important source of minerals was 100 g of: noni (345 mg of Ca; 251 mg of Mg), rose hip (844 mg of Ca; 207 mg of Mg), juniper (564 mg of Ca), sea buckthorn (58 mg of Fe), berberis (24 mg of Fe) and haritaki (14 mg of Fe). The nutritionally attractive dried fruits have the potential for wider application in food formulations.

According to De (2020) adequate nutrients are required for all cells to develop immune systems. Seeds are rich in proteins, healthy fats, fibres and minerals such as magnesium potassium, calcium, iron and zinc and contain vitamins such as B1, B2, B3 and vitamin E. Commonly edible seeds used in human diet are pumpkin seeds, opium seeds, flax seeds, sesame seeds, sunflower seeds, mustard seeds, amaranth seeds, oat seeds, barley seeds, black rice seeds, brown rice seeds, quinoa seeds, nigella seeds and millet seeds. Nuts are rich in high calorific value, unsaturated fatty acids, dietary fibres, proteins, antioxidants, vitamins E, B6, folic acid, niacin and minerals such as magnesium, zinc, iron, copper, selenium, phosphorus and potassium and low in saturated fats and cholesterol. Popular edible nuts include almonds, cashew nuts, Brazil nuts, pistachio nuts, walnuts and pea nuts. Among vitamins, E, D and B6; minerals including zinc, selenium and amino acids like glutamine play a vital role on developing immune systems in the body. Of all the popular nut varieties, pistachios have the most iron, containing 14mg per 100g – nearly 4 times the amount of almonds, brazils or cashews. They are also a great source of protein, vitamin E, calcium and magnesium, making pistachios the ideal healthy snack.

Masuda (2015) explained that ferritin, a multimeric iron storage protein distributed in almost all living kingdoms, has been highlighted recently as a nutritional iron source in plant-derived foodstuffs, because ferritin iron is suggested to have high bioavailability. In soybean seeds, ferritin contributes largely to the net iron content. Here, the oligomeric states and iron contents of soybean ferritin during food processing (especially tofu gel formation) were analyzed. Ferritin was purified from tofu gel as an iron-containing oligomer (approximately 1000 Fe atoms per oligomer), which was composed of two types of subunits similar to the native soybean seed ferritin. Circular dichroism spectra also showed no differences in α-helical structure between native soybean ferritin and tofu ferritin. The present data demonstrate that ferritin was stable during the heat treatment (boiling procedure) in food processing, although partial denaturation was observed at temperatures higher than 80 °C.

Singh et al.(2001) explains that six green leafy vegetables and herbs – spinach, amaranth, bengal gram, cauliflower, mint, coriander and carrots – were analyzed for moisture, protein, ascorbic acid, β-carotene, total iron, ionizable iron (as % of total iron) in vitro iron (% of total iron), copper, manganese and zinc. Moisture content of the leaves and carrots varied from 75.1 percent (bengal gram) to 95.4 percent (carrot) and protein from 9.83 percent (carrots) to 30.9 (mint). Ascorbic acid, β-carotene, total iron and ionizable iron contents were at a maximum in case of bengal gram leaves whereas level of ionizable iron and in vitro iron as a percent of total iron was highest in carrots. Copper, manganese and zinc contents were maximum in spinach. Spinach, Swiss chard, and lamb's lettuce are some vegetables that contain high amounts of iron. Iron deficiency is common across many people, with females of childbearing age having the highest prevalence rate, followed by 9% of young children aged 12–36 months.

Deepika Dhawan and Sheel Sharma (2015) explained that the beetroot flour was then used to develop food products incorporating it, followed by sensory evaluation of them. The results of the study accord appropriate proximate value and high antioxidant potential to beetroot flour. The products developed were Beetroot Barfi and Beetroot Kanjhi having 1%, 2%, 3%, and 4% incorporation of beetroot flour. The results indicate that the Beetroot Barfi having 1% and Beetroot Kanjhi having 4% incorporation of beetroot flour was accepted as well as their respective standard. The study is expected to extend the use of beetroot, a commonly grown yet marginalized foodstuff, in the form of its flour blended food products to provide nutrients and health-enhancing phytochemicals to the masses.

2.4 RELATIONSHIP BETWEEN IRON-BASED FOOD PRODUCTS AND ANAEMIA

Purba et al. (2021) conducted a study aiming to determine the effect of beetroot juice and red spinach juice on increasing haemoglobin (Hb) levels in anemic adolescent girls. Using a quasi-experimental pretest-posttest non-equivalent control group design with twenty participants in each group, the study found that after two weeks of beetroot juice intervention, the mean Hb levels increased from 11.47 g/dL to 12.02 g/dL, with the increase being statistically significant ($p < 0.05$). Similarly, after the red spinach juice intervention, Hb levels increased from 11.4 g/dL to 12.08 g/dL, also with statistical significance ($p < 0.05$). The findings emphasize that beetroot and red spinach, being rich sources of iron and vitamin C, can play an important role in combating iron deficiency anaemia, which is prevalent among adolescents due to poor dietary habits and inadequate nutritional intake.

In another study, Eman and Omayma (2021) examined the effect of functional beetroot pomace biscuits on anaemia in albino rats. The research found that beetroot pomace was rich in iron (129.17 mg/100 g), potassium (2396.13 mg/100 g), and sodium (1114.3 mg/100 g). It was observed that increasing beetroot pomace in the biscuit formulation led to significant rises in mineral content, particularly iron, where values in biscuits containing 15% and 20% beetroot pomace doubled compared to the control. The iron concentration in these biscuits exceeded the recommended daily intake, suggesting their potential effectiveness in anaemia prevention and treatment.

Marlyne and Hamadou (2022) studied the anti-anemic potential of beetroot (Beta vulgaris), pineapple (Ananas comosus), and papaya (Carica papaya) juice in phenylhydrazine-treated Wistar rats. The study demonstrated that the juice blend had higher iron (1.29 mg/100 mL), calcium (6.03 mg/100 mL), and magnesium (7.87 mg/100 mL) concentrations compared to pure beetroot juice and beetroot-pineapple combinations. Iron plays a crucial role in anaemia prevention, cellular immunity, and respiratory exchange. Furthermore, vitamin C content in the juice (50.85 mg/100 mL) was higher than that found in other beverages like mandarin and corossol, enhancing iron absorption and protecting cells against oxidative stress.

Kristin and Novrika (2021) examined the effect of green spinach leaf consumption on haemoglobin levels in pregnant women with mild anaemia. The results indicated that among 28 pregnant women who consumed green spinach, an average increase of 0.2–0.4 g% in haemoglobin levels was observed. The findings suggest that incorporating green leafy vegetables like spinach can significantly improve haemoglobin status, particularly in vulnerable populations such as pregnant women.

Zhang et al. (2007). Through haemoglobin regeneration efficiency (HRE) and apparent iron absorption methods, the study showed that spinach iron was well-utilized by rats, with HRE values of 0.41, 0.53, and 0.36, and corresponding apparent iron absorption values of 0.48, 0.59, and 0.37 for severely anaemic, mildly anaemic, and non-anaemic groups, respectively. These results affirm the potential of spinach as an effective dietary source of iron.

Ghatpande et al.(2018) studied the relationship between fruit and green leafy vegetable consumption and iron status among adolescent girls. It was found that 28.2% of the girls were anaemic and 65.9% were iron-deficient. Girls who did not consume guava had a 3.8-fold increased risk of low serum iron levels, and those who consumed amaranth had significantly higher serum hepcidin and ferritin levels. The study highlights the essential role of regular consumption of vitamin C-rich fruits and green leafy vegetables in improving iron status among adolescent girls.

Lailatul et al. (2022) revealed that the median haemoglobin level before consuming dates was 10.8 g/dL, which increased to 11.9 g/dL after a seven-day intervention where participants consumed seven dates daily. Conducted among 30 adolescent female students aged 15–18 years at an Islamic boarding school in East Java, Indonesia, the study concluded that date fruit consumption effectively increased haemoglobin levels.

Devi et al. (2022) assessed the effectiveness of a honey, dates, and amla mix on the level of fatigue among adolescent girls with iron deficiency anaemia. The intervention combining these three extracts led to an improvement in haemoglobin levels, which subsequently reduced fatigue and enhanced the quality of life among the participants. This simple, natural intervention holds potential for regular use, especially in rural areas.

Rahman et al. (2021), a study investigating the dietary pattern, nutritional status, anaemia prevalence, and anaemia-related knowledge among urban adolescent college girls in Bangladesh (2021) found that 23% of participants were anaemic (Hb <12 g/dL). Around 17% had low serum iron, and 23% showed evidence of iron-deficient erythropoiesis. Although 65% of participants knew anaemia causes, 73.8% were unaware of the sources of iron-rich foods. This gap in nutritional knowledge underscores the need for targeted dietary education to combat anaemia among adolescents.

3. MATERIALS AND METHODS

The present study, entitled "Development of Iron-Based Food Products for Adolescents with Iron Deficiency Anaemia," was conducted, and the methodology adopted is discussed under the following headings:

3.1 Selection and Collection of Raw Materials

- 3.1.1 Collection of raw materials
- 3.1.2 Preparation of ingredients for the development of iron-based food products

3.2 Development of Iron-based food products

- 3.2.1 Baked Beetroot Chips
- 3.2.2 Beetroot-Dates Squash
- 3.2.3 Beetroot-Moringa Soup Mix
- 3.2.4 Chickpea Cookies
- 3.2.5 Chickpea-Dates Spread
- 3.2.6 Spinach-Dates Jelly

3.3 Standardization of the Iron-Based food products

3.4 Quality Evaluation of the developed products

- 3.4.1 Score Card

3.5 Nutritive value analysis of the developed products

3.6 Cost analysis of the iron-based food products

3.1 SELECTION AND COLLECTION OF RAW MATERIALS

3.1.1 Collection of raw materials

Beetroot, dates, spinach, and chickpeas are nutritious ingredients rich in essential vitamins, minerals, and antioxidants. Their combination contributes to a balanced diet and promotes overall health

Fresh and firm beetroot with smooth skin and deep red colour was selected and collected from the local vegetable market. Tender and vibrant green spinach leaves, free from yellowing and wilting, were sourced from the local farmers' market. Fully ripened dates with a soft texture and uniform brown colour were selected and collected from a local grocery store. Clean and uniform dried chickpeas, free from insect damage and impurities, were collected from the local supermarket.

3.1.2 Preparation of ingredients for the development of Iron-Based Food Products

Collect fresh moringa leaves from the local market and wash thoroughly under running water to remove dirt and impurities. Dry the leaves under the sun until completely moisture-free. Once dried, grind the leaves into a fine powder using an electric grinder and store the powder in an airtight container.

Select fresh, tender carrots from the local market and wash them properly under running water. Peel the outer skin and slice the carrots into thin pieces. Dry the carrot slices in the sun until fully dried. Grind the dried slices into a fine powder using an electric mixer and store in an airtight container.

Mature coconuts are collected from the local market. The coconuts are broken open, and the white kernel is separated, grated, and then squeezed to extract fresh coconut milk. The milk is filtered through a muslin cloth to remove any solid particles and collected for immediate use.

Select fresh, firm beetroot from the local vegetable market. Wash thoroughly under running water to remove any soil or impurities. Peel and slice the beetroot into thin pieces. Dry the slices in the sunlight until they become crisp. Grind the dried beetroot into fine powder and store in an airtight container.

3.2 DEVELOPMENT OF IRON-BASED FOOD PRODUCTS

3.2.1 Baked Beetroot Chips

Ingredients (10 Servings)

- Beetroot – 100 g
- olive oil - 15 ml
- Salt – 5 g
- Optional: pepper, garlic powder, paprika, rosemary

Preparation

- Preheat oven to 300°F (150°C).
- Slice washed, peeled beets thinly (1/16").
- Soak slices 10 min in cold water, then pat dry.
- Toss with oil, salt, and seasonings.
- Arrange on parchment-lined tray, no overlap.
- Bake 30–40 min, flipping halfway. Watch closely near end.
- Cool for 5–10 min to crisp up.

Plate 1: ingredients for baked beetroot chips

3.2.2 Beetroot-Dates Squash

Ingredients (10 servings)

- Beetroot-60g

- Dates-40g
- Apple-30g
- Lemon -5g
- Ginger-2g

Preparation

- Wash all fresh produce thoroughly under running water to remove dirt, pesticides, and impurities.
- Peel and chop the beetroots into small cubes to allow even cooking. In a saucepan, add 2 cups of water and bring it to a boil. Add the chopped beets to the boiling water and simmer for 10–15 minutes until they become soft.
- Turn off the heat and let the beets cool slightly before blending. This prevents heat damage to the blender and preserves nutrients.
- Transfer the cooked beets along with the boiled water, into a blender. Add the chopped apple, dates, and grated ginger. Blend on high speed until the mixture becomes smooth and thick.
- Strain the mixture using a fine mesh sieve or muslin cloth. Press down with a spoon to extract maximum liquid. Discard or repurpose the beet pulp in baking or smoothies.
- Stir in lemon juice to enhance freshness and aid iron absorption. Add cinnamon powder for warmth and extra flavour. Mix well to evenly distribute the flavours.
- Transfer the prepared beetroot squash into a glass or food-grade container. Refrigerate for at least 1 hour before serving for a refreshing, cool drink. Serve chilled, optionally garnished with mint leaves or a slice of lemon.
- Storage and Shelf-Life Refrigeration: Store in an airtight container for up to 2 days to retain freshness. For Longer Shelf Life: Pasteurize the drink by heating it to 80°C for 10 minutes, then cool and store in sterilized bottles.
- Store in airtight, food-grade glass bottles for better shelf life. Keep refrigerated and consume within 2-3 weeks for best quality.

Plate 2: Ingredients for Beetroot-Dates Squash

3.2.3 Beetroot-Moringa Soup

Ingredients (10 servings)

- Beetroot powder – 60 g
- Drumstick (Moringa) leaf powder – 30 g
- Tomato sauce – 150 g (approx. 10 tbsp)
- Carrot powder – 20 g
- Garlic powder – 10 g
- Black pepper powder – 7.5 g
- Salt – 4 g
- Ginger powder – 4 g
- Roasted onion powder – 15 g
- Jaggery powder – 5 g
- Fresh coconut milk – 2½ cups
- Butter – 5 tsp
- Water – 7½ cups

Preparation

- Heat 2 cups of water in a large saucepan. Add the tomato sauce and let it simmer for 1–2 minutes.
- Mix all dry ingredients (beetroot powder, moringa powder, carrot powder, garlic powder, black pepper, salt, ginger powder, roasted onion powder, jaggery powder) in a bowl.
- Add the dry mix to the tomato base, stirring continuously.
- Add 2½ cups of fresh coconut milk and mix well.

- Gradually add the remaining 5½ cups of water while stirring. Let the soup simmer for 4–5 minutes until slightly thickened.
- Add 5 tsp of butter, stir well, and remove from heat.
- Serve hot. Optionally garnish with coriander leaves or a few drops of lemon juice.

Plate 3: Ingredients for Beetroot-Moringa Soup Mix

3.2.4 Chickpea Cookies

Ingredients (10 Servings)

- Chickpeas -150g
- Wheat flour-100g
- Honey-10g
- Peanut butter -20g
- Cocoa powder -30g
- Baking powder -2g
- Dark chocolate -5g
- Butter-10g
- Milk-50ml

Preparation

- Rinse ½ cup dried chickpeas and soak them in water overnight. Drain the soaking water. Add chickpeas to a pot, cover with fresh water, and boil for 45–60 minutes until very soft. Use a blender to mash the chickpeas into a smooth paste.
- Preheat oven to 170°C (340°F). Line a baking tray with parchment paper.
- In a bowl, beat the softened butter and honey until creamy and well combined.
- Add mashed chickpeas (or chickpea flour), vanilla extract, and mix well.
- In another bowl, sift together wheat flour, baking powder, cinnamon (if using), and salt.
- Combine wet and dry ingredients, mixing into a soft dough. If it's too dry, add milk 1 tablespoon at a time until it holds together.
- Scoop out small portions of dough, roll into balls, flatten slightly, and place on the tray.
- Bake for 12–15 minutes or until lightly golden at the edges.

Plate 4: Ingredients for Chickpea Cookies

3.2.5 Chickpea-Dates Spread

Ingredients (10 servings)

- Cooked chickpeas -100 g
- Dates -60 g
- Peanut butter-20g

- Biscoff cookie powder -10 g
- Honey-10 g
- Vanilla extract- 3 ml
- Salt – a pinch
- Milk (to blend)

Preparation

- Put chickpeas, dates, peanut butter, Biscoff powder, honey, and salt to a food processor or blender.
- Blend until smooth, scraping down the sides as needed.
- Add milk gradually to reach your desired consistency.
- Taste and adjust sweetness or salt as needed.
- Store in an airtight container in the fridge for up to a week.

Plate 5: Ingredients for Chickpea-Dates Spread

3.2.6 Spinach-Dates Jelly

Ingredients (10 servings)

- Spinach – 60 g
- Dates – 60 g

- Agar-agar – 5 g
- Lemon juice – 10 g
- Honey – 15 g

Preparation

- Wash and chop the spinach. Blanch it briefly in hot water for a few minutes.
- In a blender, blend the spinach with water until smooth. Adjust the amount of water. Add dates and blend along until smooth
- In a saucepan, dissolve the agar-agar powder in 1 cup of water. Bring to a boil and stir continuously. Let it simmer for about 2-3 minutes until the agar is fully dissolved.
- Add the lemon juice to the saucepan with the agar mixture. Stir well to combine.
- Add the spinach-dates puree to the saucepan and mix everything well together. Let it cook for another 1-2 minutes on low heat.
- Pour the mixture into moulds or a shallow pan and let it cool to room temperature. After that, place it in the refrigerator to set for2-3 hours.
- Once the jelly is set, cut it into pieces and serve chilled.

Plate 6: Ingredients for Spinach-Dates Jelly

3.3 STANDARDIZATION OF IRON-BASED FOOD PRODUCTS

3.3.1 Proportion of Ingredients for the Developed Iron-Based Food Products

For the development of functional food products, different proportions were standardized for each item. In the preparation of baked beetroot chips, beetroot was kept constant at 100 g in all treatments, with T1 containing 10 g pepper, T2 containing 10 g salt, T3 containing 5 g honey, and T0 containing 10 g salt. In the beetroot dates squash, beetroot and dates were varied as follows: T1 (60 g beetroot and 40 g dates), T2 (70 g beetroot and 30 g dates), and T3 (80 g beetroot and 20 g dates), while T0 included 100 g beetroot and 0 g dates. For the beetroot soup mix, beetroot and moringa were added in the following proportions: T1 (8 g beetroot and 10 g moringa), T2 (12 g beetroot and 6 g moringa), and T3 (10 g beetroot and 10 g moringa), with T0 having no addition of beetroot or moringa. In the formulation of chickpea cookies, the compositions were T1 (175 g chickpea and 75 g wheat flour), T2 (75 g chickpea and 175 g wheat flour), and T3 (125 g chickpea and 125 g wheat flour), while the control (T0) consisted of 0 g chickpea and 250 g wheat flour. In the preparation of chickpea dates spread, chickpea and dates were combined in varying ratios: T1 (120 g chickpea and 60 g dates), T2 (90 g chickpea and 90 g dates), and T3 (60 g chickpea and 120 g dates), with T0 as the control containing 0 g chickpea and 0 g dates. Finally, for the spinach-dates jelly, spinach and dates were combined in the ratios of T1 (100 g spinach and 20 g dates), T2 (80 g spinach and 40 g dates), and T3 (60 g spinach and 60 g dates), with the control T0 having 120 g spinach and 0 g dates.

Table 1: Proportion of Ingredients for the Developed Iron-Based Food Products

BAKED BEETROOT CHIPS		
TREATMENT	INGREDIENTS (%)	
	BEETROOT	SEASONINGS
T_{1BB}	90.91%	9.09% (PEPPER)
T_{2BB}	90.91%	9.09% (CHILLI FLAKES)
T_{3BB}	95.24%	4.76% (HONEY)
T_{0BB} (Control)	90.91%	9.09% (SALT)

BEETROOT-DATES SQUASH		
TREATMENT	INGREDIENTS (%)	
	BEETROOT	DATES
T_{1BD}	60%	40%
T_{2BD}	70%	30%
T_{3BD}	80%	20%
T_{0BD} (Control)	BEETROOT - 100%	
BEETROOT-MORINGA SOUP MIX		
TREATMENT	INGREDIENTS (%)	
	BEETROOT	MORINGA
T_{1BM}	44.44%	55.56%
T_{2BM}	66.67%%	33.33%
T_{3BM}	50%	50%
T_{0BM} (Control)	CARROT- 100%	
CHICKPEA COOKIES		
TREATMENT	INGREDIENTS (%)	
	CHICKPEA	WHEAT FLOUR
T_{1CC}	70%	30%
T_{2CC}	30%	70%
T_{3CC}	50%	50%
T_{0CC} (Control)	WHEAT FLOUR- 100%	
CHICKPEA-DATES SPREAD		
TREATMENT	INGREDIENTS (%)	
	CHICKPEA	WHEAT FLOUR
T_{1CD}	66.67%	33.33%
T_{2CD}	50%	50%

T_{3CD}	33.33%	66.67%
T_{0CD} (Control)	PEANUT BUTTER – 100%	
SPINACH-DATES JELLY		
TREATMENT	INGREDIENTS (%)	
	SPINACH	DATES
T_{1SD}	83.33%	16.67%
T_{2SD}	66.67%	33.33%
T_{3SD}	50%	50%
T_{0SD} (Control)	SPINACH – 100%	

3.4 QUALITY EVALUATION OF THE DEVELOPED PRODUCTS

Sensory evaluation has been defined as a scientific discipline used to evoke, measure, analyse, and interpret human reactions to meet sensory characteristics as perceived by sight, smell, taste, touch, and hearing by the Institute of Food Technologists (IFT)

From the six products developed — Beetroot Squash, Spinach Jelly, Baked Beetroot Chips, Beetroot and Moringa Soup Mix, Chickpea-Dates Spread, and Chickpea Cookies with three variations and a control — the most acceptable variant for each product was selected by a panel of judges based on sensory attributes including appearance, colour, flavour, taste, texture, and overall acceptability.

Sensory evaluation of the developed products was carried out by 10 panel of judges, with a 9-Hedonic scale.

3.4.1 Score Card

Score cards consist of particulars such as,

9- like extremely, 8- like very much ,7-like moderately, 6-like slightly, 5-neither Like nor dislike, 4-dislike slightly, 3-dislike moderately, 2-dislike very much,1-dislike extremely

1 stands for poor and 9 stands for excellent.

3.5 NUTRITIONAL VALUE ANALYSIS OF THE DEVELOPED IRON-BASED FOOD PRODUCTS

The nutrients selected for analysing the nutritive value of each food product are based on their high content in each recipe and include energy, protein, fat, carbohydrates, iron, vitamin C, and fibre.

Energy

Energy is the ability to do work or produce heat. In the context of nutrition, it refers to the energy we get from food and beverages, which our bodies use for all activities, including breathing. circulating blood, and moving our muscles. Energy formed in mitochondria of the cell is actually stored in our liver and muscle cells and readily available as glycogen. The energy from the breakdown of food is stored in the body in the form of a high energy compound, adenosine triphosphate (ATP). ATP is also known as the energy currency.

Carbohydrate

Carbohydrates are the main source of energy for the body. They are the sugars, starches, and dietary fibre that occur in plant foods and dairy products. Carbohydrates, or carbs, are sugar molecules. Along with proteins and fats, carbohydrates are one of the three main nutrients found in foods and drinks. Your body breaks down carbohydrates into glucose. Glucose, or blood sugar, is the main source of energy for your body's cells, tissues, and organs. Glucose can be used immediately or stored in the liver and muscles for later use. It is generally recommended that people consume between 45-65% of their total calories in the form of carbohydrates per day.

Protein

Protein is a nutrient your body needs to grow and repair cells and to work properly. Protein is found in a wide range of foods and you must get enough protein in your diet every day. Protein from food comes from plant and animal sources such as: meat and fish, eggs, dairy products, seeds and nuts, legumes like beans and lentils. Proteins are made up of building blocks called amino acids. There are about 20 different amino acids that link together in different combinations. Your body uses them to make new proteins, such as muscle and bone, and other compounds such as enzymes and hormones. It can also use them as an energy source.

Fat

Fat is a source of essential fatty acids, which the body cannot make itself. Fat helps the body absorb vitamin A, vitamin D and vitamin E. These vitamins are fat-soluble, which means they can only be absorbed with the help of fats. Any fat that's not used by your body's cells or turned into energy is converted into body fat. Likewise, unused carbohydrates and proteins are also converted into body fat. All types of fat are high in energy. A gram of fat, whether it's saturated or unsaturated, provides 9kcal (37kJ) of energy compared with 4kcal (17kJ) for carbohydrate and protein.

Iron

Iron is a vital mineral found naturally in many foods, added to certain products, and available as a supplement. It is essential for oxygen transport in the body, as it forms part of haemoglobin in red blood cells and myoglobin in muscles. Iron also supports muscle metabolism, connective tissue health, growth, neurological development, cellular function, and hormone synthesis. Dietary iron exists in two forms: haeme, found in meat, seafood, and poultry, and nonheme, present in plants and fortified foods. The Recommended Dietary Allowances (RDAs) for iron vary by age, sex, pregnancy, and lactation. Infants need 0.27 mg daily, increasing to 11 mg at 7–12 months. Young children require 7–10 mg, while those aged 9–13 need 8 mg. Adolescents require more, with males needing 11 mg and females 15 mg due to menstruation. Pregnant adolescents need 27 mg, while lactating adolescents require 10 mg. Adults aged 19–50 need 8 mg (males) and 18 mg (females), with higher needs during pregnancy (27 mg) and lactation (9 mg). After 51, both men and women require 8 mg daily.

Vitamin C

Vitamin C, or L-ascorbic acid, is a water-soluble vitamin found in certain foods, fortified products, and supplements. Unlike most animals, humans cannot synthesize vitamin C, making it an essential dietary component. It plays a key role in collagen synthesis, protein metabolism, and neurotransmitter production, supporting wound healing and connective tissue health. As a powerful antioxidant, vitamin C helps regenerate other antioxidants like vitamin E and boosts immune function. It also enhances nonheme iron absorption from plant-based foods. Deficiency leads to scurvy, characterized by fatigue, weakened connective tissues, and fragile capillaries.

RDAs for vitamin C vary by age, sex, and physiological conditions. Infants require 40–50 mg daily, children need 15–45 mg, and adolescents require 65–75 mg, with higher needs during pregnancy (80–85 mg) and lactation (115–120 mg). Adults need 90 mg (males) and 75 mg (females), while smokers require an additional 35 mg per day due to increased oxidative stress.

Fibre

Fibre includes the parts of plant foods that the body can't digest or absorb. This makes it different from nutrients such as fats, proteins, and other carbohydrates including starches and sugars. The body breaks down these nutrients and absorbs them. Instead, fibre passes somewhat intact through the stomach, small intestine and colon and out of the body.

Soluble fibre is a type of fibre that dissolves in water. It forms a gel-like material in the stomach that slows down digestion. Insoluble fibre is a type of fibre that doesn't dissolve in water. It supports the movement of material through the digestive system and adds bulk to stool. So it can be helpful for people who have constipation or don't regularly pass stool.

3.6 COST ANALYSIS OF THE DEVELOPED IRON-BASED FOOD PRODUCTS

The aim of this project is to promote iron-rich food products developed using ingredients like beetroot, spinach, and chickpeas, which are commonly available and beneficial for combating iron deficiency, especially anaemia. These ingredients are sourced considering local availability and affordability to make the product accessible and sustainable.

The iron-rich food product was subjected to cost analysis considering variable costs, including the cost of raw materials, processing, packaging, labour, electricity, and fuel. The fixed costs included equipment depreciation and setup charges. This cost analysis helps evaluate the feasibility of introducing the product to the market at a reasonable price while ensuring profitability and scalability.

The total cost is calculated using the following equation:

TCP (Total Cost of Product) = FC (Fixed Cost) + VC (Variable Cost)

4. RESULT AND DISCUSSION

The results of the present study entitled "Development of Iron-Based Food Products for Adolescents with Iron Deficiency Anaemia" are presented in this chapter under the following headings:

4.1 Standardization of the iron-based food products

4.2 Development of Iron-Based Food Products

4.2 Quality Evaluation of Iron-Based Food Products

4.2.1 Sensory Evaluation

4.2.1.1 Baked Beetroot Chips

4.2.1.2 Beetroot-Dates Squash

4.2.1.3 Beetroot-Moringa Soup Mix

4.2.1.4 Chickpea Cookies

4.2.1.5 Chickpea-Dates Spread

4.2.1.6 Spinach-Dates Jelly

4.4 Nutritive Value Calculation of Iron-Based Food Products

4.5 Cost Analysis of developed products

4.1 STANDARDIZATION OF IRON-BASED FOOD PRODUCTS

To standardize the formulation of various functional food products, different ingredient proportions were used for each preparation. In the preparation of baked beetroot chips, beetroot was kept constant at 100 g across all treatments, with T1 containing 10 g pepper, T2 containing 10 g chilli flakes, T3 containing 5 g honey, and T0 (Control) containing 10 g salt. In the development of beetroot dates squash, beetroot and dates were varied as follows: T1 (60 g beetroot and 40 g dates), T2 (70 g beetroot and 30 g dates) and T3 (80 g beetroot and 20 g dates), while T0 (Control) included 100 g beetroot and 0 g dates. For the preparation of beetroot soup mix, beetroot and moringa were added in the following proportions: T1 (8 g beetroot and 10 g moringa), T2 (12 g beetroot and 6 g moringa) and T3 (10 g beetroot and 10 g moringa), with T0 (Control) having no addition of beetroot or moringa. In the formulation of chickpea cookies, the compositions were T1 (175 g chickpea and 75 g wheat flour), T2 (75 g chickpea and 175 g wheat flour), and T3 (125 g chickpea and 125 g wheat flour), while the control (T0) consisted of 0 g chickpea and 250 g wheat flour. In the preparation of chickpea dates spread, chickpea and dates were combined in varying ratios: T1 (120 g chickpea and 60 g dates), T2 (90 g chickpea and 90 g dates) and T3 (60 g chickpea and 120 g dates), with T0 serving as the control containing 0 g chickpea and 0 g dates. Finally, for the spinach-dates jelly, spinach and dates were combined in the ratios of T1 (100 g spinach and 20 g dates), T2 (80 g spinach and 40 g dates) and T3 (60 g spinach and 60 g dates), with the control (T0) containing 120 g spinach and 0 g dates.

4.2 DEVELOPMENT OF IRON-BASED PRODUCTS

Baked beetroot chips

Baked beetroot chips are a healthy, colourful snack made by thinly slicing fresh beets and baking them until they're crispy. They're naturally sweet and earthy in flavour and when baked, they retain more nutrients like fibre, potassium and antioxidants. Beetroot is naturally rich in iron, folate (vitamin B9) and vitamin C. Folate (vitamin B9) is crucial for DNA synthesis and the production of new blood cells. A lack of folate leads to megaloblastic anaemia, where red blood cells are abnormally large and inefficient at carrying oxygen. All nutrients are important for preventing and managing anaemia. Iron is a mineral that's crucial for making haemoglobin, the protein in red blood cells that carries oxygen. Beetroot contains a moderate amount of non-haeme iron (plant-based iron). While non-haeme iron isn't absorbed as easily as iron from meat, the vitamin C in beets helps improve its absorption. The black pepper used in this variation gives it its spicy flavour. It improves digestion and enhances the absorption of nutrients like iron, selenium, and curcumin (from turmeric). Black pepper is rich in antioxidants that help protect your cells from oxidative stress. It may help reduce low-grade inflammation linked to chronic diseases. T1 (beetroot and salt) is the permissible variation of baked beetroot chips.

Beetroot-Dates squash

Beetroot squash made with beetroot, apple, ginger, lemon and dates is a powerhouse of nutrients that directly support blood health. Beetroot itself is rich in iron and folate, two critical nutrients for the production of healthy red blood cells. It also contains vitamin C, which helps in iron absorption and natural nitrates that improve blood circulation and oxygen delivery, addressing common symptoms of anaemia such as fatigue and weakness. Apples also offer dietary fibre, which supports gut health. Lemon not only enhances the flavour but also provides a strong antioxidant punch. Dates enrich the squash with natural iron, fibre, and energy-boosting sugars, making the drink more filling and energising for individuals struggling with anaemia-related tiredness. Meanwhile, ginger improves digestion and reduces inflammation, ensuring that the body can effectively absorb and utilise the nutrients provided by the drink. Together, these ingredients create a naturally sweet, refreshing, and highly beneficial squash that supports red blood cell formation, improves iron absorption, and strengthens overall blood health. T1 (beetroot, dates, apples, lemon and ginger) is the permissible variation of beetroot squash

Beetroot-Moringa soup mix

The beetroot soup mix made from beetroot powder, moringa powder, carrot powder, tomato sauce, garlic powder, roasted onion powder and coconut milk is a highly nutritious blend that strongly supports blood health, particularly in the context of managing anaemia. Beetroot powder is rich in iron, folate and nitrates, which are essential for red blood cell production, oxygen transport and improving circulation, all critical in combating anaemia. Moringa powder is a superfood exceptionally high in iron, vitamin C and other essential micronutrients that boost haemoglobin levels and enhance iron absorption. Carrot powder contributes additional iron, along with beta-carotene (vitamin A), which supports the health of blood and immune cells. Tomato sauce offers a strong dose of vitamin C and antioxidants like lycopene, helping to increase the absorption of non-haeme iron from plant sources. Garlic powder and roasted onion powder both provide sulphur compounds and flavonoids that improve blood circulation and may support better nutrient absorption. Coconut milk adds healthy fats necessary for the absorption of fat-soluble vitamins (like vitamin A from carrots) and provides energy to help fight the fatigue often associated with anaemia. T2 (beetroot powder, moringa powder, carrot powder, tomato sauce, garlic powder, roasted onion powder and coconut milk) is the permissible variation of baked beetroot chips.

Chickpea cookies

These nutritious, iron-rich chickpea cookies are a delicious way to support recovery from anaemia. Made with chickpea flour, whole wheat flour and a touch of cocoa powder, they are packed with plant-based iron, fibre and essential minerals. Chickpea flour offers a high iron content and protein, while wheat flour adds energy-boosting carbohydrates and additional nutrients. Cocoa powder not only enriches the flavour but also contributes natural iron and antioxidants. Perfect for a healthy snack, these cookies help improve iron levels naturally while satisfying your sweet tooth. Among the 4 variants of chickpea cookies, such as T1, T2, T3, and T0 with different proportions of the ingredients, T3 was the most acceptable one.

Chickpea-dates spread

A nutritious, iron-rich spread was formulated using chickpeas, dates, peanut butter and honey, aiming to create a healthy and delicious option for all age groups. Four variations — T0, T1, T2, and T3 — were prepared by adjusting the proportions of the ingredients. Among these, T3 was found to be the most acceptable based on taste, texture, and overall sensory evaluation. This spread offers multiple nutritional benefits: chickpeas are an excellent source of plant-based protein, fibre, and iron; dates provide natural sweetness along with essential minerals like iron, potassium and magnesium; peanut butter contributes healthy fats and additional protein; and honey acts as a natural sweetener with antioxidant properties. Together, these ingredients make the spread not only a tasty choice but also a highly nutritious one, promoting energy, improved digestion, and better iron absorption.

Spinach-dates jelly

A healthy, iron-rich spinach and dates jelly was formulated by combining nutrient-packed spinach with naturally sweet dates. Four variations — T0, T1, T2, and T3 — were prepared by altering the ingredient proportions to find the most appealing combination. Sensory evaluation revealed that T3 was the most preferred sample for its flavour, consistency, and overall acceptability. Rich in iron, fibre, and essential vitamins, this jelly offers significant nutritional benefits. Spinach enhances the iron and antioxidant content, promoting better blood health and immunity, while dates contribute natural sugars, potassium, and dietary fibre, making the jelly a wholesome and energy-boosting option.

Plate 7: Baked Beetroot Chips

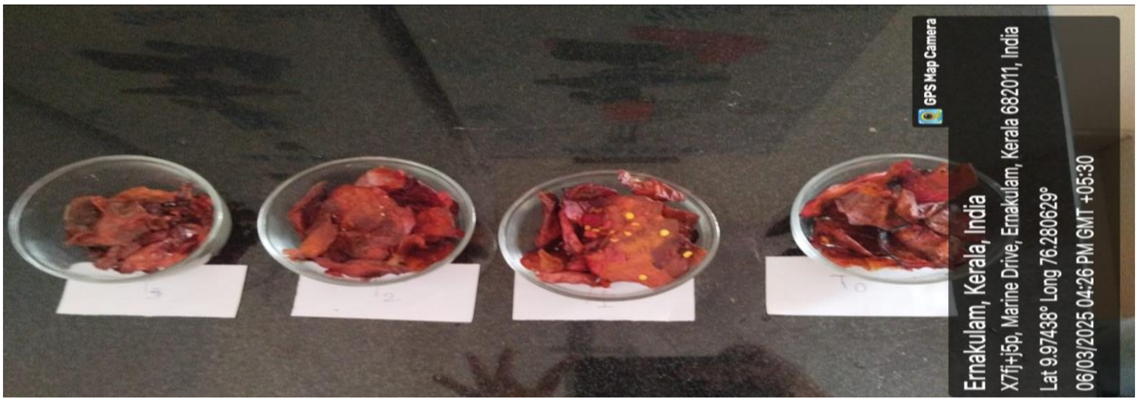


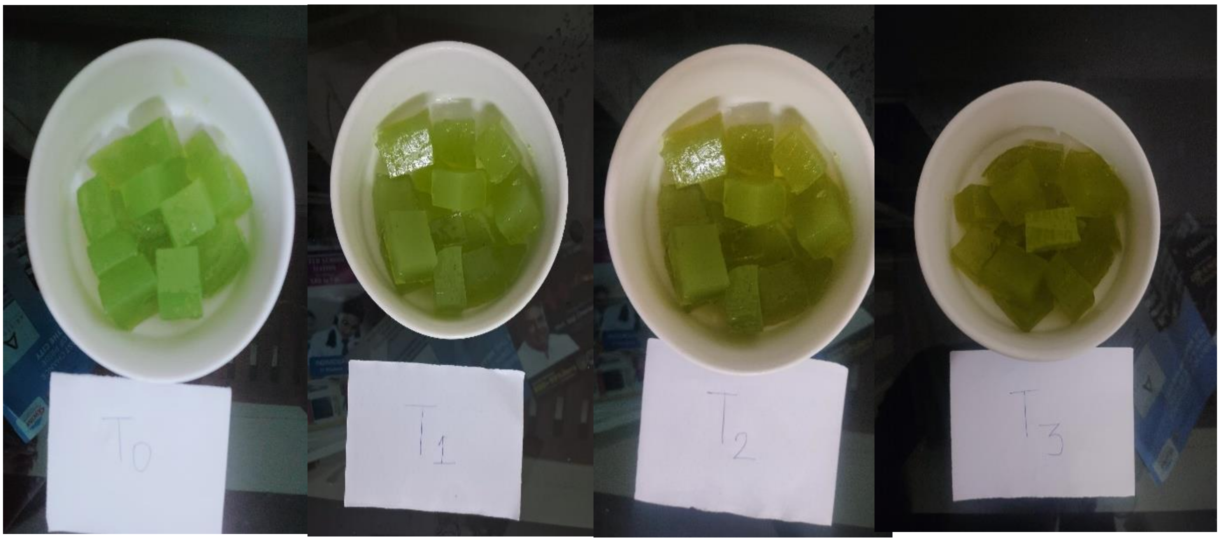
Plate 8: Beetroot-Dates Squash

Plate 9: Beetroot-Moringa Soup Mix

Plate 10: Chickpea Cookies

Plate 11: Chickpea-Dates Spread

Plate 12: Spinach-Dates Jelly



4.3 QUALITY EVALUATION OF IRON-BASED FOOD PRODUCTS

4.3.1 Sensory Evaluation

Sensory analysis combines various disciplines to better understand the sensory qualities of items and how consumers react to them. Sensory evaluation scores are the mean scores of 10 judges who were selected to evaluate the developed product. The different parameters like appearance, aroma, texture, taste, colour and overall acceptability for the developed product were scored by a panel of judges using 9 9-point Hedonic rating scale. The maximum score that could be attained for each attribute was 9. Sensory scores of 3 variations of each Iron-Based food product and the control are given below.

4.3.1.1 Baked Beetroot Chips

The sensory evaluation scores obtained for Baked Beetroot Chips are given in Table 2.

Table 2: Sensory Evaluation of Baked Beetroot Chips

TREATMENT	APPEARANCE (MS)	COLOUR (MS)	FLAVOUR (MS)	TEXTURE (MS)	TASTE (MS)	OAA (MS)
T_{1BB}	**7.6**	**7.7**	**7.3**	**7.3**	**8.1**	**8.0**
T_{2BB}	7.3	7.8	7.8	7.0	8.0	7.9
T_{3BB}	6.5	6.4	6.4	6.4	6.3	6.6
T_{0BB}	7.7	7.5	7.3	7.3	7.6	7.7

MS- Mean Score, T0- Control, BB- Baked Beetroot Chips

The appearance of any food is one of the most important features, especially when it is linked to other aspects of food quality. Every raw food and manufactured product has an acceptable range of appearance that is determined by the factors associated with the consumer. Three variations of beetroot chips and a control were scored to select the best one. On analysis, the data sensory evaluation revealed that the mean score for the appearance of baked beetroot chips ranged between 6.5-7.7. It was found that T1 ranked first with a mean score of 7.6 and least rank T3 with a mean score of 6.5. But control was superior to the variants, with a mean score of 7.7. (Table. 2)

For food, colour and appearance are often the first attributes to determine quality. As per sensory evaluation, it was revealed that the mean score for the colour of baked beetroot chips ranged from 7.7 to 7.9. T2 ranks first with a mean score of 7.8, and T1 and T3 with a mean score of 7.7. But the control is superior to the variants, with a mean score of 7.9. (Table. 2)

Flavour is the substance that enhances the quality of the product. As per the sensory evaluation, it was revealed that the least ranked T3 had a mean score of 6.4, and the highest ranked T2 had a mean score of 7.8. (Table. 2)

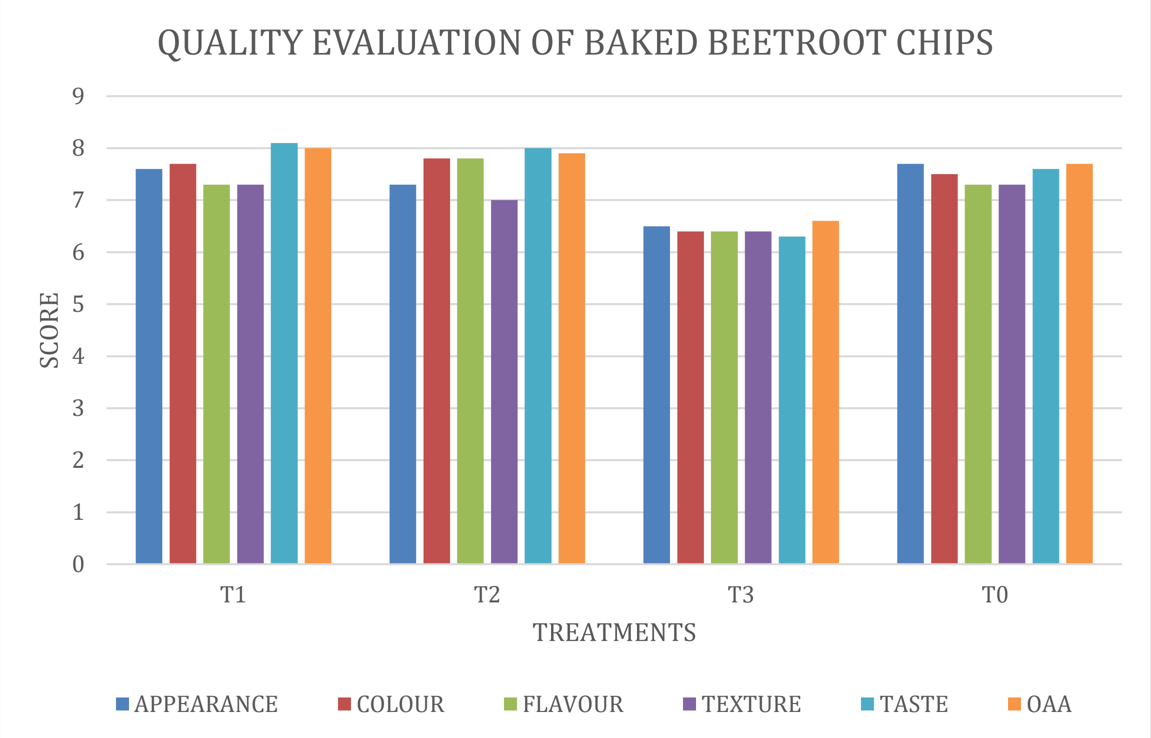
From the sensory analysis, it was revealed that T1 ranked first with a mean score of 7.3. T3 had a low mean score of 6.4. Control also had the same mean score as T1. (Table 2)

Taste is a chemical sensation caused by a taste stimulus that hits a taste receptor. Regarding the taste sensation, it was found that the mean score range is between 6.3- 8.1. T1 claimed the first rank with a mean score of 8.1, and the lowest is T3 with a score of 6.3. (Table. 2)

Assessing the overall acceptance, the proportion of T1 is superior to other variations and the control. (Table. 2)

According to studies by Singh & Patel, 2020; Wang et al., 2021, baked beetroot chips have emerged as a healthier snack alternative to fried versions, retaining significant levels of antioxidants and dietary fibre. Studies emphasize the importance of optimizing baking conditions to preserve beetroot’s vibrant colour and nutrients (Sharma et al., 2022; Nguyen & Chao, 2023). Consumer acceptance is higher when light seasoning is added (Adams & Kumar, 2022), and there is a rising trend towards vegetable-based snacks in the health food market (Johnson et al., 2023).

Fig. 1: Quality Evaluation of Baked Beetroot Chips



4.3.1.2 Beetroot-Dates Squash

The sensory evaluation scores obtained for Beetroot-Dates Squash are given in Table 3.

Table 3: Sensory Evaluation of Beetroot-Dates Squash

TREATMENT	APPEARANCE (MS)	COLOUR (MS)	FLAVOUR (MS)	AROMA (MS)	TASTE (MS)	OAA (MS)
T_{1BD}	**8.5**	**8.5**	**6.9**	**8.1**	**6.5**	**7.2**
T_{2BD}	7.5	8.4	7.0	7.6	7.1	7.0
T_{3BD}	7.8	8.1	6.0	6.6	5.3	6.0
T_{0BD}	7.2	7.3	4.1	5.7	3.8	4.4

MS- Mean Score, T0- Control, BD- Beetroot-Dates Squash

The appearance of any food is one of the most important features, especially when it is linked to other aspects of food quality. Every raw food and manufactured product has an acceptable range of appearance that is determined by the factors associated with the consumer. Three variations of Beetroot Squash and a control were scored to select the best one. On analysis, the data sensory evaluation revealed that the mean score for the appearance of beetroot-dates squash ranged between 7.5-8.5, it was obtained that T1 ranked first with a mean score of 8.5, and least rank T2 with a mean score of 7.5. The variants, especially T1, is attractive than the control. (Table. 3)

For food, colour and appearance are often the first attributes to determine quality. As per sensory evaluation, it was revealed that the mean score for colour for Beetroot Squash ranged from 8.1 to 8.5. T1 ranks first with a mean score of 8.5, on par with T3 8.1 mean score. Beetroot Squash is more appetizing than the control. (Table. 3)

Flavour is the substance that enhances the quality of the product. As per the sensory evaluation, it was revealed that the least ranked T3 had a mean score of 6.0, and the highest ranked T2 had a mean score of 7.0. Beetroot Squash has a better flavour than the control. (Table. 3)

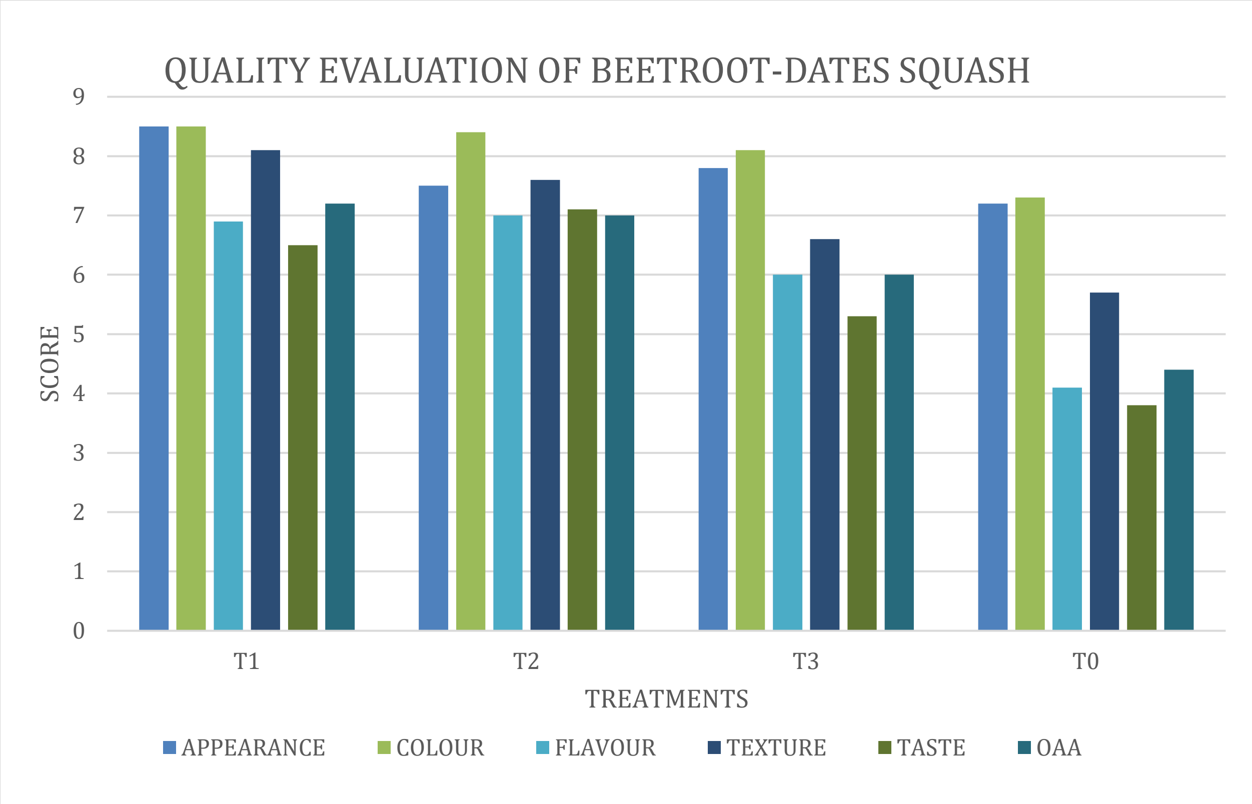
From the sensory analysis, it was revealed that T1 ranked first with a mean score of 8.1. Beetroot Squash is more appetizing than the control. (Table. 3)

Taste is a chemical sensation caused by a taste stimulus that hits a taste receptor. Regarding the taste sensation, it was found that the mean score ranged between 5.3- 7.1. T2 claimed the first rank with a mean score of 7.1, and the lowest is T3. Beetroot Squash tasted better than the control. (Table 3)

Assessing the overall acceptance, the proportion of T1 is superior to other variations and the control. (Table. 4)

Studies by Smith et al., 2021; Lee & Tan, 2019; Chen et al., 2021, shows that beetroot squash, a beverage made from beetroot and sweeteners, has been recognized for its cardiovascular benefits due to its high nitrate content. Studies have shown its potential to reduce blood pressure, improve blood circulation, and boost stamina . Rich in antioxidants like betalains, beetroot squash also offers anti-inflammatory and anticancer properties (Wang & Zhu, 2020), although the added sugar content may slightly moderate these health benefits (Adams et al., 2022).

Fig. 2: Quality Evaluation of Beetroot-Dates squash



4.3.1.3 Beetroot-Moringa Soup Mix

The sensory evaluation scores obtained for Beetroot-Moringa Soup Mix are given in table 4.

Table 4: Sensory Evaluation of Beetroot-Moringa Soup Mix

TREATMENT	APPEARANCE (MS)	COLOUR (MS)	FLAVOUR (MS)	AROMA (MS)	TASTE (MS)	OAA (MS)
T_{1BM}	8.0	7.8	7.9	7.8	7.6	7.8
T_{2BM}	**8.8**	**8.7**	**8.5**	**8.6**	**8.7**	**8.7**
T_{3BM}	7.5	7.2	7.0	7.0	6.8	7.0
T_{0BM}	6.8	6.5	5.5	5.8	5.0	5.7

MS- Mean Score, T0- Control, BM- Beetroot-Moringa Soup Mix

The appearance of any food is one of the most important features, especially when it is linked to other aspects of food quality. Every raw food and manufactured product has an acceptable range of appearance that is determined by the factors associated with the consumer. Three variations of Beetroot Soup Mix and a control were scored to select the best one. On analysis, the sensory evaluation data revealed that the mean score for the appearance ranged between 6.8–8.8. It was obtained that T2 ranked first with a mean score of 8.8, and the least rank was T0 with a mean score of 6.8. Beetroot Soup Mix is attractive compared to the control(Table 4)

For food, colour and appearance are often the first attributes to determine quality. As per sensory evaluation, it was revealed that the mean score for colour for Beetroot Soup Mix ranged from 6.5 to 8.7. T2 ranks first with a mean score of 8.7, and the least score was for T0 with 6.5. Beetroot Soup Mix is more appetizing than the control. (Table. 4)

Flavour is the substance that enhances the quality of the product. As per the sensory evaluation, it was revealed that the least ranked T0 had a mean score of 5.5, and the highest ranked T2 had a mean score of 8.5. Beetroot Soup Mix has a better flavour than the control. (Table. 4)

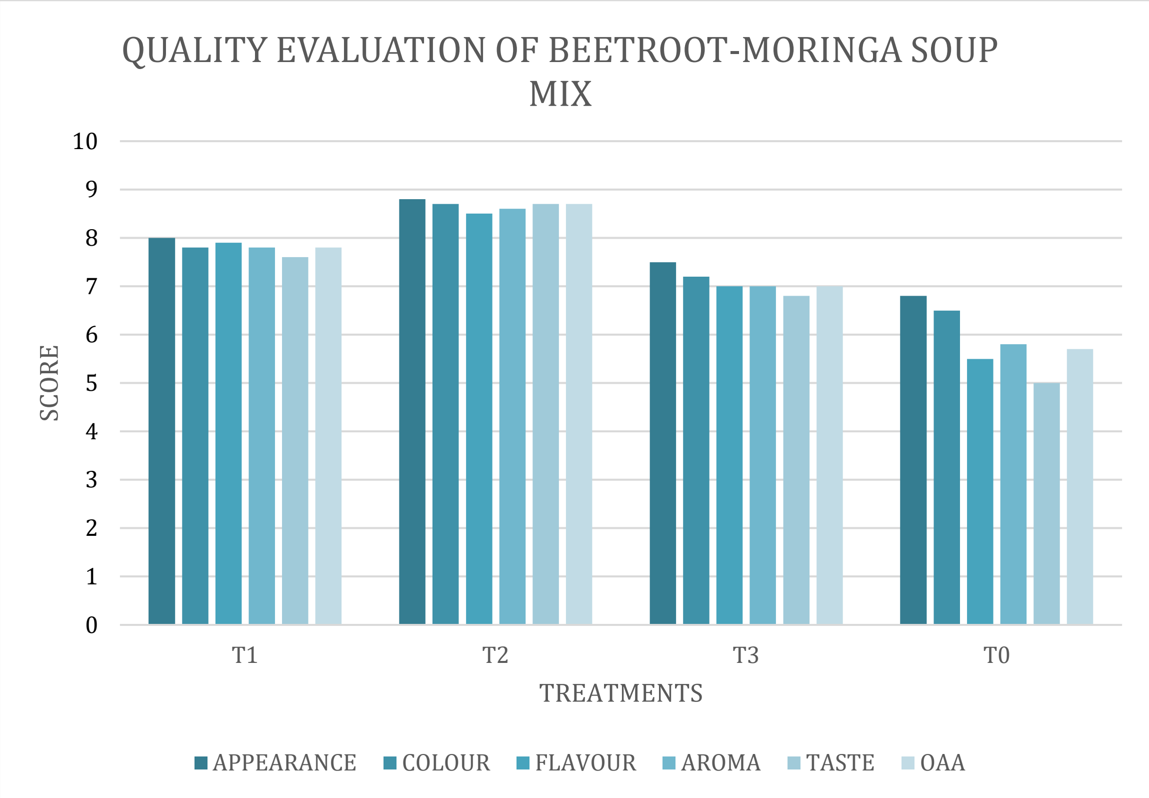
From the sensory analysis, it was revealed that T2 ranked first with a mean score of 8.6. Beetroot Soup Mix is more appetizing than the control. (Table. 4)

Taste is the ultimate factor influencing consumer preference. The Beetroot Soup Mix had a taste profile that combined the natural sweetness of beetroot and jaggery with a mild spicy kick from black pepper and ginger. T2 achieved the highest taste score of 8.7, suggesting that the careful balancing of ingredients and proper simmering led to a full-bodied, satisfying flavour superior to all other treatments. (Table. 4)

Assessing the overall acceptability, the proportion of T2 is superior to other variations and the control. (Table. 3)

Recent innovations in beetroot soup mixes have enhanced their nutritional appeal. Trindade et al. (2023) developed a microencapsulated beetroot soup enriched with nitrate and betalains, preserving quality for 90 days. Similarly, Hiregoudar, Bhavana, and Rajesh (2023) formulated a pulse-enriched beetroot soup mix with improved protein and fibre content, emphasizing its sensory and nutritional advantages.

Fig. 3: Quality Evaluation of Beetroot- Moringa Soup Mix



4.3.1.4 Chickpea Cookies

The sensory evaluation scores obtained for Baked Beetroot Chips are given in Table 5.

Table 5: Sensory Evaluation of Chickpea Cookies

TREATMENT	APPEARANCE (MS)	COLOUR (MS)	FLAVOUR (MS)	TEXTURE (MS)	TASTE (MS)	OAA (MS)
T_{1CC}	7.6	7.8	7.1	7	6.9	7.1
T_{2CC}	7.9	7.9	7.6	7.4	7.5	7.7
T_{3CC}	**8.1**	**8.2**	**8.4**	**7.8**	**8.3**	**8.4**
T_{0CC}	8	8	7.6	7.3	7.7	7.8

MS- Mean Score, T0- Control, CC- Chickpea Cookies

The appearance of any food is one of the most important features, especially when it is linked to other aspects of food quality. Every raw food and manufactured product has an acceptable range of appearance that is determined by the factors associated with the consumer. Three variations of Chickpea cookies and a control were scored to select the best one. On analysis, the sensory evaluation data revealed that the mean score for the appearance ranged between

7.6-8.1. It was obtained that T3 ranked first with a mean score of 8.1, and the least rank was T1 with a mean score of 7.6. Chickpea cookies are attractive compared to the control. (Table. 5)

For food, colour and appearance are often the first attributes to determine quality. As per sensory evaluation, it was revealed that the mean score for colour for Chickpea cookies ranged from 7.8 to 8.2. T3 ranks first with a mean score of 8.2, on par with T1 7.8 mean score. Chickpea cookies are more appetizing than the control. (Table. 5)

Flavour is the substance that enhances the quality of the product. As per the sensory evaluation, it was revealed that the least ranked T1 had a mean score of 7.1, and the highest ranked T3 had a mean score of 8.4. Chickpea cookie has a better flavour than the control. (Table. 5)

From the sensory analysis, it was revealed that T3 ranked first with a mean score of 7.8. Chickpea cookies are more appetizing than the control. (Table. 5)

Taste is a chemical sensation caused by a taste stimulus that hits a taste receptor. Regarding the taste sensation, it was found that the mean score ranged between 6.9-8.3. T3 claimed the first rank with a mean score of 8.3, and the lowest is T1. The chickpea cookie tasted better than the control. (Table. 5)

Assessing the overall acceptability, the proportion of T3 is superior to other variations and the control. (Table. 5)

According to studies by Patel & Sharma, 2020; Brown & Chen, 2021; Singh et al. (20220) Chickpea cookies offer a protein-rich, gluten-free alternative to traditional cookies, with added benefits of dietary fibre, low glycemic index, and improved satiety. Other Studies show that chickpea cookies are well accepted by consumers, especially when combined with ingredients like oats, honey, or dark chocolate, making them a strong candidate in the growing functional snack market (Johnson & Kumar, 2023).

Fig. 4: Quality Evaluation of Chickpea Cookies

4.3.1.5 Chickpea-Dates Spread

The sensory evaluation scores obtained for Baked Beetroot Chips are given in table 6.

Table 6: Sensory Evaluation of Chickpea-Dates Spread

TREATMENT	APPEARANCE (MS)	COLOUR (MS)	FLAVOUR (MS)	TEXTURE (MS)	TASTE (MS)	OAA (MS)
T_{1CD}	8.1	7.9	6.9	7.9	7.5	7.9
T_{2CD}	8.2	8	7.8	7.7	7.7	7.7
T_{3CD}	**8.6**	**8.8**	**8.7**	**8.7**	**8.7**	**8.7**
T_{0CD}	8.3	8.4	8.6	8.3	8.6	8.5

MS- Mean Score, T0- Control, CD-Chickpea Dates Spread

The appearance of any food is one of the most important features, especially when it is linked to other aspects of food quality. Every raw food and manufactured product has an acceptable range of appearance that is determined by the factors associated with the consumer. Three variations of Chickpea cookies and a control were scored to select the best one. On analysis, the sensory evaluation data revealed that the mean score for the appearance ranged between 8.1-8.6. .It was obtained that T3 ranked first with a mean score of 8.6, and the least rank was T1 with a mean score of 8.1. Chickpea dates spread is attractive compared to the control. (Table. 6)

For food, colour and appearance are often the first attributes to determine quality. As per sensory evaluation, it was revealed that the mean score for colour for Chickpea cookies ranged from 7.9-8.8. T3 ranks first with a mean score of 8.8, on par with T1, a 7.9 mean score. Chickpea dates spread is more appetizing than the control. (Table. 6)

Flavour is the substance that enhances the quality of the product. As per the sensory evaluation, it was revealed that the least ranked T1 had a mean score of 6.9 and the highest ranked T3 had a mean score of 8.7. Chickpea dates spread has a better flavour than the control. (Table. 6)

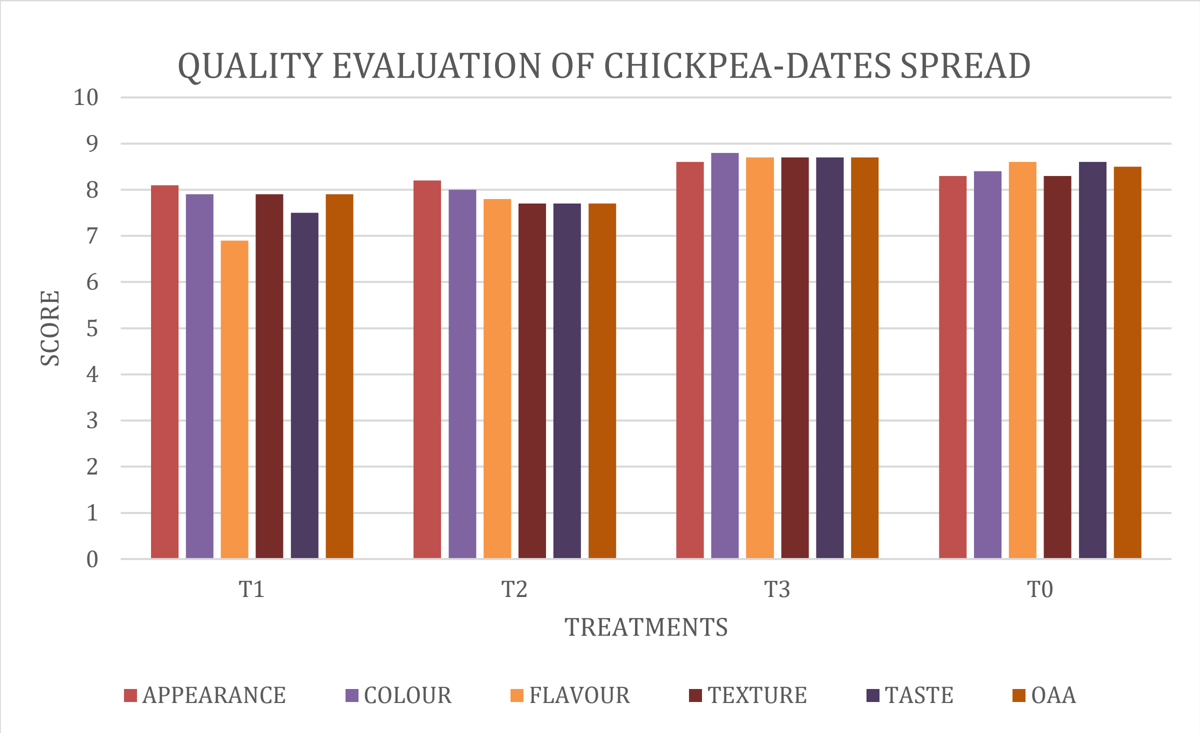
From the sensory analysis, it was revealed that T3 ranked first with mean score 8.7. Chickpea dates spread is more appetizing than the control. (Table. 6)

Taste is a chemical sensation caused by a taste stimulus that hits a taste receptor. Regarding the taste sensation, it was found that the mean score range between 7.5-8.7. T3 claimed the first rank with a mean score of 8.7 and the lowest is T1. Chickpea dates spread tasted better than the control. (Table. 6)

Assessing the overall acceptability, the proportion of T3 is superior to other variations and the control. (Table. 6)

Chickpea-dates spread has been explored as a plant-based, functional alternative to traditional spreads. Combining chickpea flour and dates results in a product rich in fibre, protein, and essential minerals (Alavi et al., 2022). Research by Rashid et al. (2021) found that chickpea-date spreads maintain excellent texture and stability during storage, while Singh and Sharma (2020) emphasized its market potential due to the blend of nutty and sweet flavours.

Fig.5: Quality Evaluation of Chickpea-Dates Spread



4.3.1.6 Spinach-Dates Jelly

The sensory evaluation scores obtained for Spinach-Dates jelly are given in Table 7.

Table 7: Sensory Evaluation of Spinach-Dates jelly

TREATMENT	APPEARANCE (MS)	COLOUR (MS)	FLAVOUR (MS)	TEXTURE (MS)	TASTE (MS)	OAA (MS)
T_{1SD}	6.9	7.1	6.3	6.5	5.1	5.8
T_{2SD}	7.6	7.5	6.1	6.8	5.3	6.1
T_{3SD}	**8**	**7.8**	**6.5**	**7.5**	**6**	**6.9**
T_{0SD}	5	6.3	4	4.6	3.3	5

MS- Mean Score, T0- Control, SD- Spinach-Dates jelly

The appearance of any food is one of the most important features, especially when it is linked to other aspects of food quality. Every raw food and manufactured product has an acceptable range of appearance that is determined by the factors associated with the consumer. Three variations of Spinach-Dates jelly and a control were scored to select the best one. On analysis, the data sensory evaluation revealed that the mean score for the appearance of Spinach-Dates jelly ranged between 6.9-8, it was obtained that T3 ranked first with a mean score of 8, and least rank T1 with a mean score of 6.9. Spinach-Dates jelly is attractive than the control. (Table. 7)

For food, colour and appearance are often the first attributes to determine quality. As per sensory evaluation, it was revealed that the mean score for colour for Spinach-Dates jelly ranged from 7.1 to 7.8. T3 ranks first with a mean score of 7.8, on par with T1 7.1 mean score. Spinach-Dates jelly is more appetizing than the control. (Table. 7)

Flavour is the substance that enhances the quality of the product. As per the sensory evaluation, it was revealed that the least ranked T2 had a mean score of 6.1 and the highest ranked T3 had a mean score of 6.5. Spinach-Dates jelly has a better flavour than the control. (Table. 7)

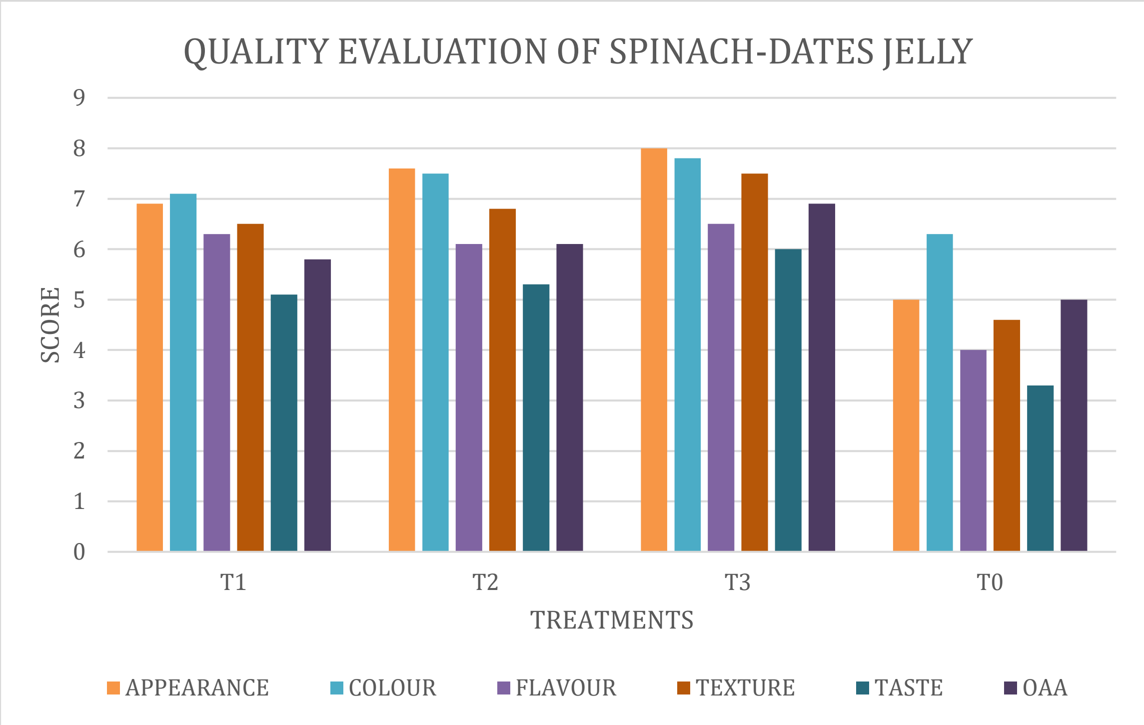
From the sensory analysis, it was revealed that T3 ranked first with a mean score of 7.5. Spinach-Dates jelly is more appetizing than the control. (Table. 7)

Taste is a chemical sensation caused by a taste stimulus that hits a taste receptor. Regarding the taste sensation, it was found that the mean score ranged between 5.1- 6. T3 claimed the first rank with a mean score of 6, and the lowest is T1. Spinach-Dates jelly tasted better than the control. (Table. 7)

Assessing the overall acceptability, the proportion of T3 is superior to other variations and the control. (Table. 7)

Spinach-Dates Jelly is an innovative functional food product combining the nutritional richness of spinach and the natural sweetness of dates. Spinach is a good source of vitamins A, C, K, folate, iron, and calcium, while dates contribute natural sugars, fibre, potassium, and magnesium (Smith et al., 2022; Johnson & Lee, 2020). Research highlights that the combination offers antioxidant benefits, supports digestive health, and helps regulate blood sugar, making it a nutritious alternative to traditional jellies (Brown & Wang, 2021; Nguyen et al., 2023; Chen & Tan, 2022).

Fig.6: Quality Evaluation of Spinach-Dates Jelly



4.4 NUTRITIVE VALUE CALCULATION OF IRON-BASED FOOD PRODUCTS

Table 8: Nutritive value calculation of Iron-Based food products

Name of food	Energy (kcal)	CHO (g)	Protein (g)	Fat (g)	Iron (mg)	Vit C (mg)
Baked Beetroot Chips	192	9.75	4.2	15.37	1.35	5.26
Beetroot-Moringa soup	454	39.3	7.7	13.0	10.18	17.0
Beetroot-Dates Squash	171	48.13	2.3	0.47	2.97	8.52
Chickpea Cookies	737	126.0	25.0	14.0	8.00	2.0

Chickpea-Dates Spread	519	89.9	15.8	14.9	4.0	1.4
Spinach -Dates Jelly	246	64.48	3.56	0.63	2.55	13.3

Macro nutrients and micro nutrients of 6 iron-based products are mentioned here.

Among these food products, chickpea cookies have the highest calorie (737 kcal), and the lowest one is Beetroot-Dates Squash (171 kcal). Almost all food products have a sufficient amount of carbohydrates, but the highest of these is Chickpea Cookies (126 g), and the lowest one is Baked Beetroot Chips (9.75 g).

The highest protein content is noticed in Chickpea Cookies (25 g), and the lowest of these is in Beetroot-Dates Squash (2.3 g). Other Products have a protein content between 4.2 to 15.8 g. Among these iron-based products, the lowest fat content is present in Beetroot-Dates Squash and Spinach-Dates Jelly (0.47 and 0.63 g), and the highest is in Baked beetroot chips.

Among the given iron-based food products it is noticed that the lowest iron content in Baked Beetroot Chips (1.35 mg) and highest iron content in Beetroot-Moringa Soup (10.18 mg) and for the vitamin C content of the given food products it was found that highest vitamin C content on Spinach-Dates jelly and lowest one is the Chickpea Cookies.

Nutritive calculation helps us understand the exact amount of energy and nutrients present in different foods. By measuring the carbohydrates, proteins, fats, vitamins, and minerals, we can calculate how healthy and balanced a food item or meal is. Overall, nutritional calculation is a useful tool for making better and more informed food choices.

4.5 COST ANALYSIS OF DEVELOPED PRODUCTS

The cost analysis of Spinach-Dates Jelly was carried out based on the price of various commodities. This includes the cost of spinach, dates, beetroot, chickpeas, moringa leaves, and utensils, as well as labour and fuel charges.

Table 9: Cost analysis of the developed products

FOOD PRODUCTS	TOTAL COST (Rs)
Spinach dates jelly	120
Beetroot-Dates Squash	135
Beetroot-Moringa Soup mix	85
Baked beetroot chips	130
Chickpea cookies	165
Chickpea dates spread	250

The table depicts the expenses incurred for the developed products. The highest cost was recorded for chickpea date spread (Rs. 250/-) followed by chickpea cookie (Rs. 165/-), beetroot squash (Rs. 135/-), and baked beetroot chips (Rs. 130/-), Spinach dates jelly (Rs. 120/-) and beetroot soup mix (Rs. 85/-) were comparatively less expensive.

When compared among the products, beetroot soup mix was the most cost-effective, while chickpea date spread was relatively expensive, possibly due to the high cost of chickpeas and dates. Overall, cost variation depends on the ingredients and the processes involved in product development.

Michaelsen and Friis (2021) highlighted that iron deficiency, which affects about one-third of the global population, necessitates effective and economical dietary iron fortification solutions. Clinical studies have shown that iron-fortified foods are effective in preventing iron deficiency, though they may cause side effects. Therefore, it is crucial to develop iron-rich ingredients that offer high bioavailability, stability, and low cost. Furthermore, advanced processing technologies for fortification are essential. Common foods such as cereals, dairy, and bakery products remain the best vehicles for effective iron delivery.

Plessow et al. (2016) assessed the cost-effectiveness of price subsidies on fortified packaged infant cereals (F-PICs) in reducing iron deficiency anaemia (IDA) in urban India. The study found that price subsidies targeting poorer households were particularly cost-effective, with interventions saving costs by reducing future production losses and improving health outcomes. The cost per DALY averted ranged from 909 to 3649 USD, with interventions focused on lower socio-economic groups yielding the highest benefits.

Qureshy et al. (2023) conducted a benefit-cost analysis on iron fortification of rice in India. Their study showed a benefit-cost ratio of 8.2, with most benefits derived from improved learning outcomes in children. While the fortification model was economically promising, the authors emphasized the need for further evidence on the impact of improved iron biomarkers on cognition and productivity.

5. SUMMARY AND CONCLUSION

The summary of the present study, entitled “Development and Quality Evaluation of Iron-Rich Products for Adolescents”, was an attempt to combat iron deficiency anaemia, especially among adolescents. The study was also aimed at developing new value-added products rich in iron using natural ingredients like beetroot, spinach, moringa, and chickpea to improve the nutritive quality of foods.

Beetroot, spinach, moringa, and chickpea are natural sources of iron and other essential nutrients. The aim was to develop products incorporating these ingredients to increase their usage in the food industry and provide a nutritional benefit to adolescents. In this study, the nutritional analysis of the developed iron-rich products was conducted to evaluate their contribution towards dietary iron intake and their potential health benefits.

Raw materials such as beetroot, spinach, and moringa were purchased from the local market in Ernakulam, while dates and chickpeas were collected from a nearby grocery store. Fresh moringa leaves, carrots, coconuts, and beetroot were collected from the local market. The moringa leaves were washed, sun-dried, ground into powder, and stored. Carrots were washed, peeled, sliced, sun-dried, powdered, and stored. Mature coconuts were processed to extract fresh coconut milk by grating, squeezing, and filtering the kernel. Beetroot was washed, peeled, sliced, sun-dried, powdered, and stored for further use.

Six products were developed with three different treatments, T1, T2, and T3 which had the same base ingredients (beetroot, spinach, moringa, and chickpea) but varied proportions of the main components or additional ingredients to enhance iron content and sensory qualities. The developed products were compared with a control sample.

With regard to organoleptic qualities, six iron-rich products were developed in three different variations each, and the most acceptable variant for each product was identified through sensory evaluation. In beetroot soup mix, the 2:1 ratio variant was found to be the most preferred, exhibiting favourable taste, texture, and appearance. For spinach-dates jelly, the 1:1 ratio showed the highest acceptability with balanced sweetness and desirable consistency. Among the chickpea-based products, chickpea cookies prepared in a 1:1 ratio were highly accepted for their crisp texture and appealing flavour, while the chickpea-dates spread at a 2:1 ratio was rated best for its smooth texture and pleasant sweetness. In the case of beetroot-dates squash, the 3:2 ratio variant received the highest overall scores for its attractive colour, flavour, and mouthfeel. Based on the organoleptic evaluation, the selected products were beetroot soup mix (2:1), spinach-dates jelly (1:1), chickpea cookies (1:1), chickpea-dates spread (2:1), and beetroot-dates squash (3:2).

The analysis of the six iron-based food products revealed significant variations in their macro- and micronutrient content. Among the products, Chickpea Cookies exhibited the highest caloric value (737 kcal), while Beetroot-Dates Squash had the lowest (171 kcal). Carbohydrate content was adequate across all products, with Chickpea Cookies recording the highest amount (126 g) and Baked Beetroot Chips the lowest (12.7 g).

In terms of protein, Chickpea Cookies again stood out with the highest content (25 g), whereas Beetroot-Dates Squash contained the least (2.3 g). The other products showed protein levels ranging from 4.2 to 15.8 g. Fat content varied notably, with the lowest observed in Beetroot-Dates Squash (0.47 g) and Spinach-Dates Jelly (0.63 g), and the highest in Baked Beetroot Chips.

Regarding micronutrients, the iron content was found to be highest in Beetroot-Moringa Soup (10.18 mg) and lowest in Spinach-Dates Jelly (2.55 mg). Vitamin C content showed an inverse trend, with Spinach-Dates Jelly having the highest amount and Chickpea Cookies the lowest.

Cost analysis of the developed products in comparison to each other. Compared with other iron-rich products, Chickpea Dates Spread is comparatively costly with a total cost of(Rs. 250) as the product consists of chickpeas, dates, peanut butter, and Biscoff cookie powder additionally. Among the developed products, Chickpea Dates Spread recorded the highest cost on par with Chickpea Cookies (Rs. 165), followed by Beetroot Squash (Rs. 135) and Baked Beetroot Chips (Rs. 130). The least cost was observed for Beetroot Soup Mix (Rs. 85), followed by Spinach-Dates Jelly (Rs. 120). Overall, the iron-rich developed products showed slight variation in cost depending on the type and quantity of ingredients used and the complexity of the processing.

In this study, six iron-rich products were developed to combat iron deficiency anaemia, especially among adolescents. The products formulated included baked beetroot chips, beetroot-dates squash, beetroot-moringa soup, chickpea cookies, chickpea-dates spread, and spinach-dates jelly. Locally available iron-rich ingredients such as beetroot, spinach, moringa leaves, chickpeas, and dates were utilized to enhance the nutritional profile of the products. No artificial preservatives were added to ensure the products remained natural and health-focused.

The incorporation of vegetables, legumes, and fruits not only improved the iron content but also enhanced the organoleptic qualities of the developed products, making them more acceptable to consumers. Development of such iron-rich functional foods can significantly contribute to improving iron intake, especially in vulnerable populations.

Beetroot and spinach are natural sources of iron and antioxidants, while chickpeas provide plant-based protein and additional minerals. Dates contribute natural sweetness and are rich in iron and fibre, enhancing both taste and nutritional value. Combining these ingredients into various forms like snacks, beverages, and spreads offers diversity in consumption and can help address dietary iron gaps effectively.

These products can also be incorporated into regular diets and can serve as a healthier alternative to conventional snacks. Future studies could focus on the therapeutic evaluation of these iron-rich products and their impact on improving haemoglobin levels and reducing anaemia prevalence among targeted groups.

BIBLIOGRAPHY

Monono, E. M., Wiesenborn, D. P., Vargas-Ramirez, J. M., & Zhou, R. (2019). Preserving Juice from Industrial Beets Using Organic Acids. Transactions of the ASABE, 62(1), 177–185.

Theba, T., Nayi, P., & Ravani, A. (2024). Beetroot-based blended juice: Process development, physico-chemical analysis and optimization of novel health drink. Food Chemistry Advances

Assessment of yield and nutritional composition of fruit of wild date palm (Phoenix sylvestris Roxb.) cultivars' (2017) international journal of Biosciences (ijB), pp. 85–91. doi: 10.12692/ijb/11.4.85-91

Kinyoki, D. K., Ross, J. M., Lazzar-Atwood, A., Munro, S. B., Schaeffer, L. E., Abbas, K. M., ... Hay, S. I. (2023). Global burden of anaemia in 204 countries and territories, 1990–2021: A systematic analysis for the Global Burden of Disease Study 2021. The Lancet Global Health,

Beal, T., Tumilowicz, A., Sutrisna, A., Izwardy, D., & Neufeld, L. M. (2022). A review of anaemia in adolescent girls: Etiology, consequences, and interventions. The Journal of Nutrition, 152(1), 15S–30S.

Kejo, D., Petrucka, P. M., Martin, H., Kimanya, M. E., & Mosha, T. C. (2018). Prevalence and predictors of anaemia among children under 5 years of age in Arusha District, Tanzania. BMC Pregnancy and Childbirth, 18(1), 387.

McCance, R. A., & Widdowson, E. M. (2019). The Composition of Foods. Cambridge: Royal Society of Chemistry.

Christian, P., Smith, E. R., & the Global Nutrition Series Group. (2018). Adolescent undernutrition: Global burden, physiology, and nutritional risks. The Lancet Child & Adolescent Health, 2(10), 683–692.

Balarajan, Y., Ramakrishnan, U., Özaltin, E., Shankar, A. H., & Subramanian, S. V. (2011). Anaemia in low-income and middle-income countries. The Lancet, 378(9809), 2123-2135.

Rahman, M. M., Abe, S. K., Kanda, M., Narita, S., Rahman, M. S., Bilano, V., ... Ota, E. (2016). Maternal anaemia and risk of adverse birth and health outcomes in low- and middle-income countries: Systematic review and meta-analysis.

Siddiq, M., Nasir, M., Ravi, R., & Butt, M. S. (2009). Effect of defatted maize germ and chickpea flours on the quality of wheat-based cookies. Journal of Food Processing and Preservation.

Hurrell, R. F., Reddy, M. B., Juillerat, M. A., & Cook, J. D. (2006). Degradation of phytic acid in cereal porridges improves iron absorption by human subjects. The American Journal of Clinical Nutrition.

McLean, E. et al. (2009) 'Worldwide prevalence of anaemia, WHO Vitamin and Mineral Nutrition

Information System, 1993–2005', Public Health Nutrition

Ahmani, A. H. et al. (2014) 'Therapeutic effects of date fruits (Phoenix dactylifera) in the prevention of diseases via modulation of anti-inflammatory, anti-oxidant and

anti-tumour activity', International journal of clinical and experimental medicine

Biondo, P. B. F. et al. (2014) 'evaluation of beetroot (Beta vulgaris l.) leaves during its developmental stages: a chemical composition study', Food Science and Technology, pp. 94–101. doi: 10.1590/s0101 20612014005000007.

Plants Journal. (2022). Chickpea (Cicer arietinum L.) Biology and Biotechnology: From Domestication to Biofortification and Biopharming. https://www.mdpi.com/2223-7747/11/21/2926

Frontiers in Nutrition. (2023). Nutritional composition, health benefits and bio-active compounds of chickpea (Cicer arietinum L.). https://www.frontiersin.org/articles/10.3389/fnut.2023.1218468/full

ScienceDirect. (2021). Nutritional constituent and health benefits of chickpea (Cicer arietinum L.): A review. https://www.sciencedirect.com/science/article/abs/pii/S0963996921006906

Boukid, F. (2021). Chickpea (Cicer arietinum L.) protein as a prospective plant-based ingredient: a review. International Journal of Food Science & Technology, 56(11), 5435–5444. https://doi.org/10.1111/ijfs.15046

Jahan, T. A., Vandenberg, A., Glahn, R. P., Tyler, R. T., Reaney, M. J. T., & Tar'an, B. (2019). Iron fortification and bioavailability of chickpea (Cicer arietinum L.) seeds and flour. Nutrients, 11(9), 2240. https://doi.org/10.3390/nu11092240

Sari, M. I., & Sari, N. (2021). Pulse probiotic superfood as iron status improvement agent in active women—A review. Nutrients, 13(4), 1276. https://doi.org/10.3390/nu13041276

Hurrell, R. F., Reddy, M. B., Juillerat, M. A., & Cook, J. D. (2006). Degradation of phytic acid in cereal porridges improves iron absorption by human subjects. The American Journal of Clinical Nutrition, 77(5), 1213–1219. https://doi.org/10.1093/ajcn/77.5.1213

Media Gizi Mikro Indonesia. (n.d.). The Effect of Date Fruits (Phoenix dactylifera L) Intervention to Increase Haemoglobin Levels in Female Adolescents - UNIDA Gontor Repository. https://repo.unida.gontor.ac.id/1749/

Effect of Green Spinach Leaves on Haemoglobin Levels in Pregnant Women with Mild Anaemia Natalia, K., Silalahi, N., Insani, S. D., & Sinambela, M. (2020). Effect of green spinach leaves giving against haemoglobin levels increased in pregnant women with mild anaemia. In *Proceedings of the International Conference on Health Informatics and Medical Application Technology (ICHIMAT 2019)* (pp. 28–35). SCITEPRESS. https://www.scitepress.org/Papers/2019/94621/94621.pdf:contentReference[oaicite:1]{index=1}

The Effect of Date Fruits Intervention on Haemoglobin Levels in Female Adolescents. Fathimah, F. (2022). The effect of date fruits (Phoenix dactylifera L) intervention to increase haemoglobin levels in female adolescents. Jurnal Efek Pemberian Buah Kurma, 13(2), 97–104. https://repo.unida.gontor.ac.id/1749/:contentReference[oaicite:5]{index=5}

Natalia, K., Silalahi, N., Insani, S. D., & Sinambela, M. (2019). *Effect of green spinach leaves giving against haemoglobin levels increased in pregnant women with mild anaemia*. Proceedings of the International Conference on Health Informatics and Medical Application Technology (ICHIMAT 2019). SCITEPRESS. https://www.scitepress.org/Papers/2019/94621/94621.pdf

Article on Taylor & Francis: (2018). *Journal of the American College of Nutrition*. https://www.tandfonline.com/doi/abs/10.1080/07315724.2018.1492470

Singh, N., & Sengupta, R. (2020). Multigrain beetroot crisps: A healthy snacking option. *Asian Journal of Medicine and Health, 18*(3), 19–25. https://doi.org/10.9734/ajmah/2020/v18i330189JAMHS

Krajka-Kuźniak, V., Szaefer, H., Bartoszek, A., & Baer-Dubowska, W. (2008). In vitro effects of beetroot juice and chips on oxidative metabolism and apoptosis in neutrophils from obese individuals. *Phytotherapy Research, 22*(1), 49–55. https://doi.org/10.1002/ptr.2535 Europe PMC

Ramos, J. A., Furlaneto, K. A., de Mendonça, V. Z., Mariano-Nasser, F. A. C., Lundgren, G. A., Fujita, E., & Vieites, R. L. (2017). Influence of cooking methods on bioactive compounds in beetroot. *Semina: Ciências Agrárias, 38*(3), 1295–1302. https://doi.org/10.5433/1679-0359.2017v38n3p1295UNESP Institutional Repository+2UEL Journals Portal+2ResearchGate+2

Özcan, M. M., & Al Juhaimi, F. Y. (2023). Changes in bioactive compounds, antioxidant activity, and polyphenols of red beetroots dehydrated in oven, microwave, and infrared systems. *JSFA Reports, 3*(1), e161. https://doi.org/10.1002/jsf2.161

American Dietetic Association, Dietitians of Canada, & American College of Sports Medicine. (2016). Position of the Academy of Nutrition and Dietetics: Nutrition and athletic performance. Journal of the Academy of Nutrition and Dietetics, 116(3), 501–528. https://doi.org/10.1016/j.jand.2015.12.006

Gopalan, C., Rama Sastri, B. V., & Balasubramanian, S. C. (2021). Indian Food Composition Tables (IFCT). National Institute of Nutrition, ICMR.

Jeukendrup, A., & Gleeson, M. (2019). Sport Nutrition: An Introduction to Energy Production and Performance (3rd ed.). Human Kinetics.

Mohanraj, R., & Sivasankar, S. (2014). Influence of beetroot (Beta vulgaris) and moringa (Moringa oleifera) on iron status and haemoglobin levels. International Journal of Food and Nutritional Sciences, 3(5), 87–92.

Rao, P. U. (1993). Nutrient composition and biological evaluation of Moringa oleifera leaves. Plant Foods for Human Nutrition, 42(1), 1–6. https://doi.org/10.1007/BF02196008

Sathe, S. K., & Kshirsagar, A. (2018). Product development and sensory evaluation of instant soup premix enriched with drumstick leaves. Journal of Pharmacognosy and Phytochemistry, 7(5), 372–376.

Sivakumar, R., & Karunya, K. (2020). Development and evaluation of instant soup mix using dehydrated vegetables. The Pharma Innovation Journal, 9(11), 244–248

Kamble, K. S., & Mote, G. V. (2019). Process development of instant Moringa pod soup powder supplemented with herbs. Journal of Pharmacognosy and Phytochemistry, 8(3), 3281–3286.

Banigo, E. B., Kiin-Kabari, D. B., & Owuno, F. (2015). Physicochemical and sensory evaluation of soy/carrot drinks flavoured with beetroot. African Journal of Food Science and Technology, 6(5)

APPENDIX

HEDONIC RATING SCALE

TREATMENTS	**PARTICULATES**					
	Appearance	**Colour**	**Flavour**	**Texture/Aroma**	**Taste**	**Overall acceptability**
T_1						
T_2						
T_3						
T_0						

***Kindly indicate your rating between 1-9 (1 stands for poor and 9 stands for excellent)**

Like extremely 9

Like very much 8

Like moderately 7

Like slightly 6

Neither like nor dislike 5

Dislike slightly 4

Dislike moderately 3

Dislike very much 2

Dislike extremely 1

NAME:

SIGNATURE: