OPTIMIZATION OF WEANING FOOD USING LOCALLY AVAILABLE INGREDIENTS

by

Rakshya Khatiwada

Department of Food Technology

Central Campus of Technology

Institute of Science and Technology

Tribhuvan University, Nepal

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A dissertation submitted to the Department of Food Technology, Central Campus of Technology, Tribhuvan University, in partial fulfillment of the requirements for the degree of B. Tech. in Food Technology

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Rakshya Khatiwada

Department of Food Technology

Central Campus of Technology

Institute of Science and Technology

Tribhuvan University, Nepal

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Tribhuvan University

Institute of Science and Technology

Department of Food Technology

Central Campus of Technology, Dharan

Approval Letter

This ***dissertation*** entitled ***Optimization of Weaning Food Prepared Using Locally Available Ingredients*** presented by **Rakshya Khatiwada** has been accepted as the partial fulfillment of the requirement for the **B. Tech. degree in Food Technology**

<u>Dissertation Committee</u>

1. **Head of department** ______________________________

   (Mrs. Mahalaxmi Pradhananga, Asst. Prof.)

2. **External Examiner** ______________________________

   (Mr……………………………………...)

3. **Supervisor** ______________________________

   (Mr. Aashik Jha, Teaching Asst.)

4. **Internal Examiner** ______________________________

   (Mr………………………………….)

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(Rakshya Khatiwada)

Abstract

Maize, rice, soybean, and moringa leaf powder were selected to formulate a nutrient-dense weaning food using locally available ingredients. Raw materials were processed through sorting, soaking, drying, roasting, grinding, mixing, and sieving to enhance digestibility and reduce antinutritional factors. Linear programming via Excel Solver was applied to optimize ingredient proportions based on nutrient constraints and the addition of maize was carried out for amino acid profile balance. The optimized formulation was analyzed for proximate composition, energy value, and selected micronutrients (iron, calcium, vitamin C). Sensory evaluation was conducted using the McNemar test, and shelf-life was estimated by modeling vitamin C degradation under accelerated storage (45 °C) in LDPE and glass packaging using first-order kinetics.

The optimized weaning food met WHO nutrient recommendations and national standards, with adequate protein, energy, and micronutrient content. Sensory evaluation showed good acceptability ($p < 0.05$). Shelf-life modeling revealed that glass packaging extended vitamin C retention significantly compared to LDPE (estimated shelf life: 281.40 vs.172.20 days). The study confirms that nutrient-dense weaning foods can be developed from simple, affordable ingredients using basic processing and mathematical optimization. This approach offers a practical solution to improve complementary feeding and reduce infant malnutrition in resource-limited settings.

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List of Abbreviations

Abbreviations	Full form
AA	Amino Acid
AOAC	Association of Official Analytical Chemists
AP	Active Packaging
ARA	Arachidonic Acid
ASTM	American Society for Testing and Materials
B.Tech	Bachelor of Technology
BSG	Brewers Spent Grain
CDC	Centers for Disease Control and Prevention
CI	Confidence Interval
CHO	Carbohydrate
DHA	Docosahexaenoic Acid
DFTQC	Department of Food Technolgy and Quality Control
db	Dry Basis
DHA	Docosahexaenoic Acid
DoHS	Department of Health Services
EFSA	European Food Safety Authority
EOLSS	Encylopedia of Life Support Systems
EPA	Eicosapentaenoic Acid

EU	European Union
FAO	Food and Agriculture Organization
g	Gram
GHG	Greenhouse Gas
GRISP	Global Rice Science Partnership
HCl	Hydrochloric Acid
HOD	Head of Department
ICF	Inner City Fund (International Consulting Firm)
IRRI	International Rice Research Institute
ISO	International Organization for Standardization
kg	kilogram
kcal	kilocalorie
LCA	Life Cycle Assessment
LCAs	Life Cycle Assessments
LDPE	Low-Density Polyethylene
LP	Linear Programming
MAM	Modern Acute Malnutrition
MAP	Modified Atmosphere Packaging
mg	Milligram
MOHP	Ministry of Health and Population
NaCL	Sodium Chloride

NPV	Net Protein Value
PDCAAS	Protein Digestibility Corrected Amino Acid Score
PEM	Protein-Energy Malnutrition
PRI	Population Reference Intake
RE	Retinol Equivalent
RUTF	Ready-to-Use Therapeutic Food
SAA	Sulphur Amino Acids
SE	Standard Error
UNICEF	United Nations International Children's Emergency Fund
UNU	United Nations University
USAID	United States Agency for International Development
WFP	World Food Program
WHO	World Health Organization
wb	Wet Basis
χ^2	Chi-Square

Part I

Introduction

1.1 General introduction

Weaning represents a vital developmental stage during which infants transition from exclusive breastfeeding to the intake of complementary foods after six months of age. The nutritional adequacy of weaning diets plays a significant role in supporting infant growth, immune function, and overall health outcomes. In many regions of Nepal, commonly used traditional weaning foods are predominantly cereal-based and are frequently deficient in protein, essential micronutrients, and adequate energy density needed for optimal development. Consequently, infants are at an increased risk of undernutrition, growth retardation, and micronutrient-related disorders. At the global level, childhood malnutrition continues to pose a major public health concern. According to the UNICEF/WHO/World Bank Joint Child Malnutrition Estimates (2023), In 2022, an estimated 148.1 million children under the age of five (22.3%) were affected by stunting, while 45 million (6.8%) experienced wasting and 37 million (5.6%) were classified as overweight, highlighting the coexistence of undernutrition and overnutrition commonly referred to as the triple burden of malnutrition. Although some progress has been made, merely one-third of countries are on course to achieve the 2030 target for reducing stunting, while wasting remains a persistent threat to millions of children globally (UNICEF/WHO/World Bank, 2025).

According to the 2022 Demographic and Health Survey in Nepal, 25% of children under five are stunted, 19% are underweight, and 8% experience wasting. While these figures indicate progress compared to previous decades, they also underscore the ongoing prevalence of nutritional deficiencies among young children Ministry of Health and Population (MOHP)/New ERA/ICF (2022). These statistics highlight the critical need for nutrient-rich complementary foods capable of bridging both macronutrient and micronutrient deficiencies in infants. Recent studies have shown that the combination of locally available cereals and legumes with nutrient-dense ingredients such as soybean and moringa can substantially enhance the protein quality, micronutrient content, and overall nutritional adequacy of weaning diets. The development of scientifically validated, nutrient-rich weaning foods utilizing locally available resources is vital for promoting healthy growth and mitigating malnutrition among infants in Nepal (Zuberi and Sangwan, 2020).

1.2 Statement of problem

Despite improvements at the global level, malnutrition still impacts millions of infants, especially in South Asia. In Nepal, 25% of children under five are stunted, 19% are underweight, and 8% experience wasting (Ministry of Health and Population (MOHP)/New ERA/ICF, 2022). These figures highlight that traditional complementary foods such as rice porridge and maize gruel, though culturally accepted, fail to meet protein and micronutrient requirements (Group, 2019). A lack of lysine in cereals, combined with insufficient intake of iron, calcium, and vitamin A, is a key factor contributing to growth retardation and compromised immune function in infants (Jain *et al.*, 2020; Savarino *et al.*, 2021).

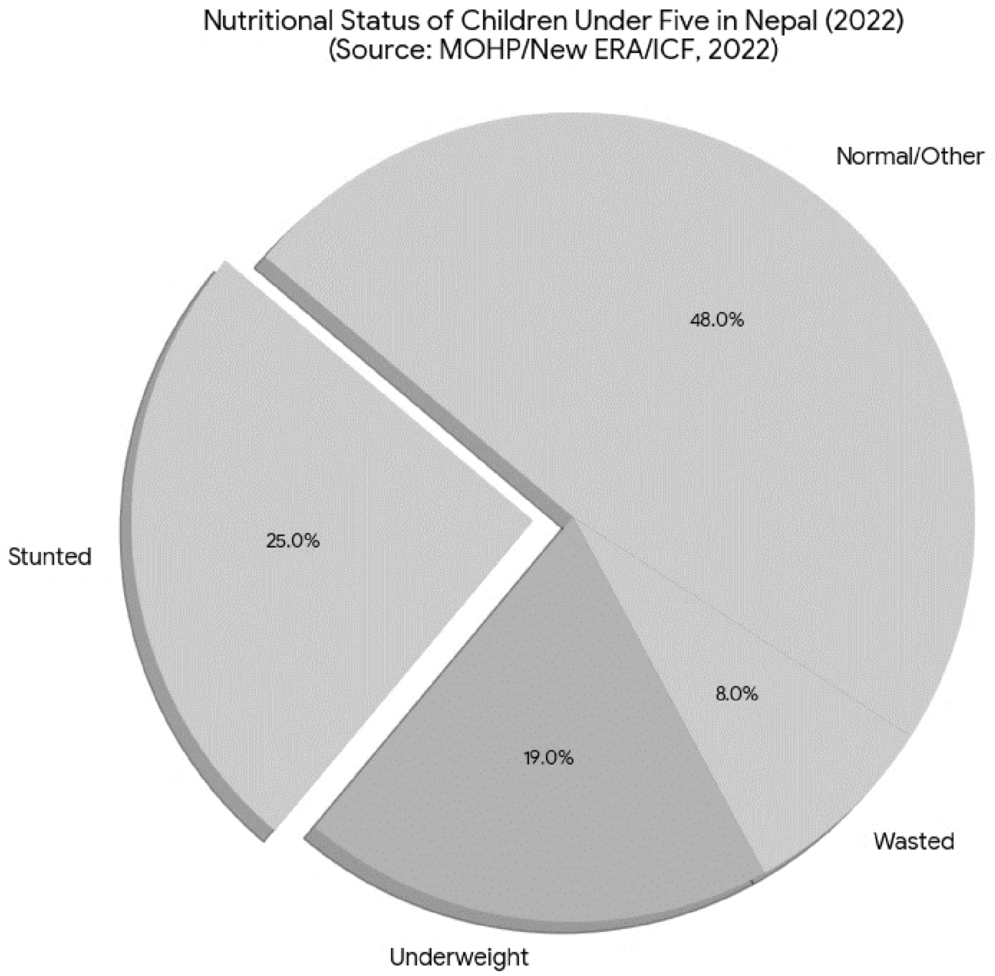


Fig. 1.1 Nutritional Status of Children under Five in Nepal Ministry of Health and Population (MOHP)/New ERA/ICF, 2022).

While commercial weaning foods are available, they are often too expensive for low-income households, resulting in unequal access to nutrient-rich diets. Locally grown crops such as soybean and moringa provide high levels of protein and essential micronutrients but remain underutilized due to limited awareness and the absence of scientifically formulated products (Samtiya *et al.*, 2020). Germination and conventional processing techniques have been demonstrated to enhance digestibility and decrease anti-nutritional compounds, thereby making these ingredients more suitable for infant consumption (Araro *et al.*, 2020). Hence, there is a pressing need for research focused on developing affordable, nutrient-rich weaning foods from locally available ingredients, assessing their nutritional quality in accordance with WHO and WFP standards, and evaluating sensory acceptability to ensure cultural relevance and practical implementation.

1.3 Objective of study

1.3.1 General objective

To develop and evaluate a nutrient-dense weaning food formulated from maize, rice, soybean, and moringa leaf powder.

1.3.2 Specific Objectives

The specific objectives of this study are:

1. To analyze raw ingredients (maize, rice, soybean, moringa) for nutritional composition with recommended standards for infants and young children.
2. To apply linear programming in Excel to optimize ingredient proportions based on nutrient constraints.
3. To determine proximate composition (moisture, protein, ash, fiber) and analyze selected micronutrients (iron, calcium, vitamin C) of the final product.
4. To conduct sensory analysis using McNemar method and Excel-based panelist calculation.
5. To calculate sample size for nutrient testing based on protein variability and 30% allowable error.
6. To assess shelf life using vitamin C retention in glass and LDPE packaging over 14 days at 45 °C.

1.4 Significance of the study

Infant malnutrition continues to be a significant public health issue in Nepal. While traditional complementary foods, such as rice porridge and maize gruel, provide energy, they are often deficient in protein, essential fatty acids, and key micronutrients. Commercial weaning products exist but are frequently too costly for many households. Although locally available ingredients like soybean and moringa offer substantial nutritional benefits, their use in infant diets remains limited due to a lack of awareness and scientific formulation. Consequently, developing and evaluating nutrient-dense weaning foods incorporating maize, rice, soybean, and moringa is essential to address these nutritional deficiencies and enhance infant feeding practices (Zuberi and Sangwan, 2020).

1.5 Limitations of the study

This study was conducted under certain constraints that may limit the scope of its findings:

1. Ingredient scope was restricted to four locally available ingredients (maize, rice, soybean, moringa), excluding other nutrient sources such as fruits, vegetables, or nuts.
2. Only selected micronutrients (iron, calcium, vitamin C) were analyzed; amino acid composition, fatty acid profile, and trace elements were not determined.
3. Shelf-life evaluation focused only on vitamin C degradation; microbial and sensory deterioration were not studied.
4. No microbiological testing was performed to assess product safety and shelf stability.
5. Phytochemical analysis of bioactive compounds (e.g., antioxidants) was not conducted.
6. Sensory evaluation was conducted using adult preferences so,it might not represent infants taste references regarding salt perception as infants have natural preference for bland foods.

PART II

Literature Review

2.1 Background

The nutritional adequacy of complementary foods has received considerable attention, as poorly formulated diets continue to drive malnutrition among infants and young children. Worldwide, stunting and wasting remain significant challenges, with 148 million children under five experiencing stunting and 45 million affected by wasting in 2022 (UNICEF/WHO/World Bank, 2025). In Nepal, 25% of children under five experience stunting, 19% are underweight, and 8% suffer from wasting, highlighting persistent protein and micronutrient deficiencies despite advances in food security (Ministry of Health and Population (MOHP)/New ERA/ICF, 2022). These figures highlight the need for nutrient-dense weaning foods that go beyond traditional cereal-based diets.

Multiple studies have shown that blending cereals with legumes enhances protein quality by complementing limiting amino acids, including lysine and methionine (Savarino *et al.*, 2021). Soyabean is notably high in quality protein and essential minerals, though it is relatively low in methionine, whereas cereals like maize and rice are deficient in lysine. Combining these ingredients creates a more balanced amino acid profile that supports infant growth. Additionally, Moringa oleifera leaves are recognized as a rich source of micronutrients, including calcium, iron, vitamins A and C, and antioxidants, which can enhance immunity and reduce oxidative stress (Jain *et al.*, 2020).

Traditional processing techniques, including germination, soaking, and fermentation, have been demonstrated to enhance digestibility and reduce anti-nutritional compounds such as phytates, tannins, and oxalates, thereby improving the bioavailability of nutrients (Samtiya *et al.*, 2020). Recent research on food formulation has demonstrated that locally available crops can be effectively combined into complementary foods, resulting in enhanced nutrient density and improved functional properties. For example, Araro *et al.* (2020) Studies that developed complementary foods using ingredients such as orange-fleshed sweet potato, teff, and kidney beans have reported notable enhancements in protein digestibility and micronutrient content. These results provide compelling evidence that locally available crops, including maize, rice, soybean, and moringa, can be scientifically formulated into affordable, nutrient-rich weaning foods suitable for infants in Nepal.

2.2 Components of nutrition

2.2.1 Macronutrients

Proteins, fats, and carbohydrates are the main macronutrients in the human diet, supplying the energy required for proper growth and development. Adequate protein consumption during infancy is particularly important for supporting tissue growth and maintaining immune function. According to the European Food Safety Authority (EFSA) (2017), Population Reference Intake (PRI) recommends a protein intake of 1.14 g/kg/day for one-year-old children, which meets the needs of almost all individuals in this age group. Proteins from animal sources, including milk, meat, and eggs, are complete and provide all essential amino acids, while cereals and pulses alone lack certain amino acids. Consequently, the combination of cereals and legumes is essential to obtain a balanced amino acid profile in plant-based diets (Savarino *et al.*, 2021).

Carbohydrates, mainly in the form of starches and sugars, serve as the primary energy source in resource-limited populations, often accounting for up to 80% of total dietary intake. Although fats typically constitute only around 10% of the diet in these populations, they are crucial for the absorption of fat-soluble vitamins and provide essential fatty acids (ARA, EPA, DHA) necessary for brain development during the first two years of life (Kliegman and Geme, 2019).

2.2.2 Micronutrients

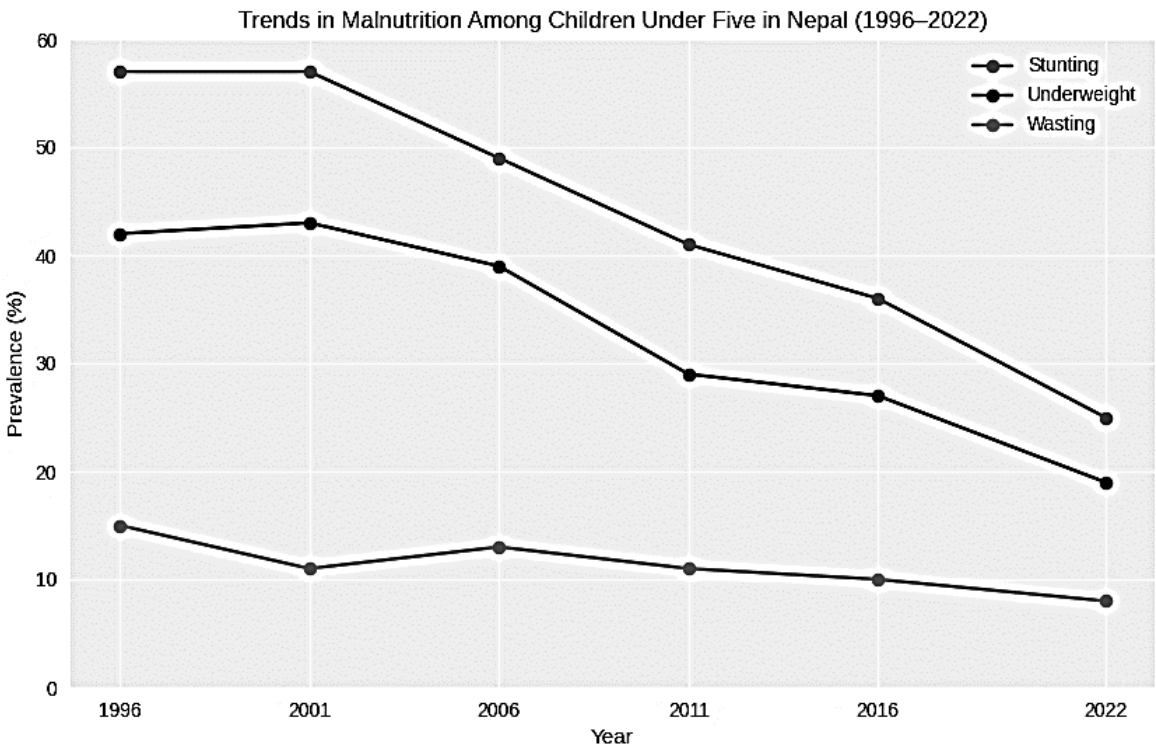
Micronutrients comprising vitamins, minerals, and trace elements—are needed in small quantities but are essential for vital physiological functions, including enzyme activity, tissue integrity, and cellular signaling. According to World Health Organization (2003) more than two billion people globally are affected by deficiencies in critical micronutrients such as vitamin A, iodine, iron, and zinc. At least 30 micronutrients are deemed essential, and since the body cannot produce them, they must be obtained through diet. Insufficient intake of these nutrients during infancy can compromise growth, immune function, and cognitive development.

2.3. Nutritional status

Approximately forty micronutrients are essential for maintaining good health and are classified into two categories. Type I micronutrients, which include iodine, iron, and vitamins A and C, are primarily involved in physiological functions rather than growth. Deficiencies in these nutrients do not necessarily affect anthropometric measures, meaning individuals may appear to grow normally yet still experience deficiencies, which can lead to conditions such as anemia, scurvy, and compromised immunity. Type II micronutrients, including magnesium, sulfur, nitrogen, essential amino acids, phosphorus, zinc, sodium, and chloride, are critical for growth and tissue repair. Although required in small amounts, a proper balance of type II micronutrients is essential for health, and deficiencies in these nutrients among children in Nepal can significantly impair development (UNICEF. *et al.*, 2018).

The nutritional status of children under five is a key indicator of overall health. Adequate nutrition, combined with protection from repeated illnesses and proper care, allows children to reach their full growth potential and be considered well-nourished. Malnutrition contributes to more than half of all child deaths globally. Undernourished children are more susceptible to common childhood illnesses, and survivors often experience repeated infections and impaired growth. Notably, three-quarters of child deaths linked to malnutrition occur in children who are only mildly or moderately malnourished, often showing no visible signs of vulnerability (Adhikari *et al.*, 2021).

In Nepal, malnutrition among children under five has shown a consistent decline over the past two decades as per Ministry of Health and Population (MOHP)/New ERA/ICF (2022) As shown in Fig 2.1, the prevalence of stunting in Nepal declined from 57% in 1996 to 25% in 2022, underweight decreased from 42% to 19%, and wasting fell from 15% to 8%. These positive trends reflect national efforts to improve nutrition, maternal health, and food security. Nevertheless, stunting remains the most widespread form of malnutrition, highlighting persistent chronic nutritional deficiencies. This evidence underscores the need for nutrient-dense weaning foods to sustain and further enhance child health outcomes.



Source : (Henuk, 2018)**.**

Fig. 2.1 Trends in malnutrition (%) among children aged 0–59 months in Nepal from 1996 to 2022.

2.3.1 Protein Energy malnutrition

Protein-energy malnutrition (PEM) is a significant nutritional disorder affecting children under five, resulting from inadequate intake of protein and calories. It can present as marasmus or kwashiorkor, leading to stunted growth, impaired immunity, and elevated child mortality. The risk of PEM is particularly high during the weaning period, when infants transition from exclusive breastfeeding to complementary foods. In many regions, traditional weaning foods are bulky, low in energy density, and of poor protein quality, making it challenging for infants with limited stomach capacity to consume adequate nutrients. Walker (1990), emphasized that inadequacies in traditional weaning diets are a key factor contributing to PEM. To address this, nutrient-dense formulations that combine cereals and legumes have been developed to enhance both protein quality and energy intake.

Pandey and Singh (2019), reported that cereal–legume blends have been shown to provide approximately 21.23% protein and higher energy content compared to traditional porridges, making them effective in preventing PEM. Processing methods such as germination and fermentation further improve digestibility and nutrient bioavailability. Intervention studies demonstrate that children receiving nutrient-dense complementary foods exhibit better growth outcomes and a lower prevalence of PEM. Therefore, the provision of properly formulated weaning foods represents a practical and effective approach to promoting child health and development.

2.4 Raw materials and their nutritive value

2.4.1. Cereals

Cereals constitute the most important staple foods globally, with major varieties including wheat, corn, rice, barley, sorghum, millet, oats, and rye. Botanically, cereals are grasses belonging to the monocot family Poaceae. They serve as staple foods in many countries and are recognized as significant sources of both macronutrients—such as carbohydrates, proteins, fats, and oils—and micronutrients, including vitamins and minerals. Additionally, cereals contain bioactive phytochemicals, such as polyphenols, flavonoids, anthocyanins, and carotenoids, which contribute to their nutritional value (Bisoi *et al.*, 2019).

2.4.1.1 Maize

Maize (Zea mays) is among the most extensively cultivated cereals and functions as a staple food in many regions worldwide. It provides a substantial source of carbohydrates and energy, making it a key component in infant diets. However, maize protein is limited in certain essential amino acids, particularly tryptophan, and contains high levels of leucine, which can hinder the conversion of tryptophan to niacin, thereby increasing the risk of pellagra (Iken and Amusa, 2004).

Table 2.1 Chemical composition of maize flour (per 100 g, (DFTQC) (2012)

	White Maize	**Yellow Maize**
Protein (gm)	9.2	9.2
Iron (mg)	2.4	2.4
Calcium (mg)	20	20
Vitamin C (mg)	0	0
Fiber (g)	1.6	1.6
Moisture (gm)	12	12
CHO (g)	72.1	72.1
Fat (g)	3.9	3.9
Minerals (g)	12.2	1.2
Energy K Cal	360	360
phosphorous mg	256	256
Carotene µg	305	305
Thiamine mg	0.38	0.38

Riboflavin mg	0.11	0.11
Niacin mg	2	2

Source: (Iken and Amusa, 2004).

Other studies report comparable nutritional values, indicating that maize flour contains 6–10% protein, 3–4% fat, and moderate amounts of iron and calcium (Oladapo *et al.*, 2017)(Jati (2023). Maize exhibits moderate functional properties, including water and oil absorption capacities, but also contains anti-nutritional factors such as phytates, oxalates, and tannins. Traditional processing techniques, including roasting, soaking, and germination, can reduce these compounds and enhance digestibility.

2.4.1.2 Rice

Rice (Oryza sativa) is the most widely consumed staple crop globally, forming a daily dietary component for nearly half of the world's population. It accounts for approximately 20% of the global dietary energy supply, with much higher contributions in Asian countries, where rice can provide over 70% of daily caloric intake (GRISP, 2013). Rice is nutritionally appreciated for its easily digestible starch, which makes it particularly suitable for infants and young children. Beyond its carbohydrate content, rice provides moderate levels of protein and small amounts of micronutrients, including thiamine, riboflavin, niacin, and zinc (Megat *et al.*, 2011).

Table 2.2 Chemical composition of raw, milled rice (per 100 g, (DFTQC) (2012)

Protein (gm)	6.8
Iron (mg)	0.7
Calcium (mg)	10

Vitamin C (mg)	0
Fiber (gm)	0.2
Moisture (gm)	13.7
CHO (gm)	78.2
Fat (gm)	0.5
Minerals (gm)	0.6
Energy K Cal	345
phosphorous mg	160
Carotene µg	0
Thiamine mg	0.21
Riboflavin mg	0.06
Niacin mg	1.9

Source: (DFTQC, 2012).

2.4.2 Legumes

2.4.2.1 Soyabean

Soybean (Glycine max) is a legume prized for its high protein and fat content, making it an important component in complementary foods. It contains approximately 35–40% protein and 18–20% fat, along with key minerals such as calcium, iron, and phosphorus (DFTQC, 2012). Soy protein is considered high-quality because it provides most essential amino acids, although it is somewhat limited in methionine. When combined with cereals like maize or rice, soybean effectively improves the overall protein balance of the diet.

Table 2.3 Chemical composition of soybean (per 100 g, (DFTQC) (2012)

Protein (gm)	33.3	33.3	43.2
Iron (mg)	8.5	9.5	10.4
Calcium (mg)	226	213	240
Vitamin C (mg)	0	0	0
Fiber (gm)	4.2	4.3	3.7
Moisture (gm)	10.2	12.1	8.1
CHO (gm)	29.6	31.3	20.9
Fat (gm)	17.7	15	19.5
Minerals (gm)	5	4	4.6

Energy K Cal	411	393	432
phosphorous mg	546	509	690
Carotene μg	10	10	426
Thiamine mg	0.66	0.65	0.73
Riboflavin mg	0.22	0.23	0.39
Niacin mg	2.2	2.8	3.2

Source: (DFTQC, 2012).

Soybean also contains bioactive compounds, including isoflavones, which may confer health benefits. However, it contains anti-nutritional factors, notably trypsin inhibitors, that can hinder protein digestion. Processing techniques such as soaking, germination, and heat treatment effectively reduce these inhibitors and enhance digestibility (Gemede and Ratta, 2014).

2.4.3. Moringa

Moringa (Moringa oleifera), commonly referred to as the drumstick tree, is a perennial plant native to the sub-Himalayan regions of Nepal, India, Pakistan, and Bangladesh. It is increasingly recognized as a nutrient-dense plant with bioactive compounds that can help combat malnutrition. The leaves of Moringa are especially rich in protein, calcium, iron, vitamins A and C, and antioxidants, making them well-suited for inclusion in complementary foods (Jain *et al.*, 2020).

According to Boateng *et al.* (2018), For infants aged 6–12 months, either 5 g/day of pure Moringa leaf powder or 35 g/day of a fortified cereal–legume blend containing Moringa is recommended. The level of moringa leaf powder incorporated in the formulation was adapted from Zakaria *et al.* (2020) who developed an instant complementary food incorporating brown rice, sprouted mung bean, and Moringa oleifera leaf powder at 7–9% of the total dry weight. Their findings indicated that this inclusion level enhanced protein quality, micronutrient density, and overall acceptability. Consequently, a similar proportion was chosen in this study to improve nutritional value while maintaining favorable sensory characteristics.

Table 2.4 Chemical composition of Moringa Leaves (per 100 Grams, (DFTQC) (2012)

Protein (gm)	6.7
Iron (mg)	0.85
Calcium (mg)	440
Vitamin C (mg)	220
Fiber (gm)	16
Moisture (gm)	75.9
CHO (gm)	12.5
Fat (gm)	1.7
Minerals (gm)	2.3

Energy K Cal	92
phosphorous mg	70
Carotene (µg)	6780
Thiamine mg	0.06
Riboflavin mg	0.05
Niacin mg	0.8

Source: (DFTQC, 2012).

In addition to its rich nutrient content, Moringa leaves contain phytochemicals such as flavonoids, phenolics, and carotenoids, which function as natural antioxidants. These compounds not only boost the nutritional value of foods but also enhance the shelf stability of products containing fats (Jain *et al.*, 2020). The inclusion of Moringa leaf powder in weaning foods can thus enhance micronutrient intake, increase antioxidant capacity, and contribute to improved overall health outcomes in infants.

Table 2.5 National Quality Standards for Cereal-Based Food (Nepal Gazette, 2079)

Quality Parameters	Requirement
Moisture, Maximum	8%
Total Fat, Maximum (on dry weight basis)	13%
Total Protein, Minimum (N × 6.25, dry basis)	15%
Total Carbohydrate Maximum (dry basis)	56%
Crude Fiber, Maximum (dry basis)	3%
Total Ash, Maximum (dry basis)	5%
Ash Insoluble in Dilute HCl, Maximum	0.1%
Calcium (mg per 100 g)	500-600mg
Iron (mg per 100 g)	5.8–11.6 mg
Vitamin B_1 (mg per 100 g)	≥ 0.25 mg
Vitamin A (µg RE per 100 g)	200-700 mg
Vitamin D (µg per 100 g)	4–12 µg

Source: (Nepal Government, 2079)

2.5 Standards for Cereal-Based Complementary Foods for Infants Aged 6–24 Months

Cereal-based complementary foods are fundamental to infant nutrition between 6 and 24 months, supplying essential energy and nutrients during this critical period of rapid growth. The Codex Standard for Processed Cereal-Based Foods for Infants and Young Children provide guidelines to ensure these foods meet nutritional requirements (CODEX STAN 74-1981). Cereal-based weaning foods should contain a minimum of 25% cereal on a dry weight basis and provide at least 0.8 kcal/g of energy. Commonly used cereals—such as rice, wheat, maize, sorghum, millet, and oats—are chosen for their digestibility, cultural acceptability, and nutritional contribution. The Codex Standard further requires that protein quality achieve at least 70% of the casein protein efficiency ratio, and that added sugars not exceed 7.5 g per 100 kcal to avoid excessive sweetness while preserving nutritional quality (Codex Alimentarius Commission, 1981).

Complementary feeding starts at six months, as breast milk alone no longer satisfies an infant's nutritional requirements. In the early weaning stage (6–8 months), infants generally consume 5–10 g of dry cereal per meal, typically prepared as thin porridges to suit their limited stomach capacity and developing oral-motor skills. Appropriate cereals for this stage include rice, wheat, maize, and finger millet, often mixed with breast milk or clean water to achieve a semi-liquid consistency (Dewey and Brown, 2003; World Health Organization, 2003). Between 9 and 11 months, infants require thicker, more energy-dense porridges. During this stage, cereal consumption typically rises to 15–20 g of dry cereal per meal, and cereal legume combinations such as wheat–chickpea, rice–lentil, or maize soybean blends are often introduced to enhance protein quality and micronutrient content. Peer-reviewed studies indicate that these blends improve amino acid balance and overall nutritional adequacy (Livingstone and Singh, 1993; Sajilata *et al.*, 2002).

Between 12 and 24 months, children gradually transition to family foods, consuming 25–50 g of dry cereal per meal depending on appetite and energy requirements. Soft, culturally appropriate foods such as rice, chapati, maize porridge, or fermented cereal products are recommended. At this stage, cereals typically provide the primary source of energy, complemented by legumes, vegetables, fruits, and animal-source foods to ensure a diverse and balanced diet (Kabeer *et al.*, 2024; World Health Organization, 2009).

At all stages of complementary feeding, fortifying cereal-based weaning foods with micronutrients is strongly recommended. Nutrients such as iron, zinc, calcium, iodine, and vitamins A, D, C, and B-complex are particularly critical due to their high risk of deficiency in low- and middle-income settings. Reviews of traditional weaning practices in South Asia and Africa consistently indicate that the use of cereal legume blends, combined with fortification and appropriate processing techniques such as malting, fermentation, and roasting significantly enhances nutrient bioavailability and reduces bulk density, making these foods more suitable for infants and young children (Onofiok and Nnanyelugo, 1998)& Nnanyelugo, 1998).

Table 2.6 Key Nutritional Parameter and Literature-Based Nutritional Guidelines for Cereal–Legume Complementary Foods (6–24 Months)

Parameters	Requirement/Amount	Age Group(months)	Citation
Minimum Cereal content	≥25% cereal (dry weight)	6-24	(Codex Alimentarius Commission, 1981)
Energy density	≥0.8 kcal/g	6-24	(Codex Alimentarius Commission, 1981)
Protein Quantity	≥70% of casein PER	6-24	(Codex Alimentarius

			Commission, 1981)
Added sugars (Codex limit)	≤7.5 g/100 kcal	6-24	(Codex Alimentarius Commission, 1981)
Recommended legume types	Recommended legume types	6-24	(Livingstone and Singh, 1993; Onofiok and Nnanyelugo, 1998)
Recommended Cereal types	Rice, wheat, maize, sorghum, millet, oats	6-24	(Kabeer *et al.*, 2024; Sajilata *et al.*, 2002)
Micronutrient fortification	Iron, zinc, calcium, iodine, vitamins A, D, C, B-complex	6-24	(Codex Alimentarius Commission, 1981; World Health Organization, 2009)

Amount per meal	5–10 g dry cereal–legume mix (thin porridge)	6-8	(Dewey and Brown, 2003; World Health Organization, 2003)
Amount per meal	15–20 g dry cereal–legume mix (thicker porridge)	9-11	(Dewey and Brown, 2003; Livingstone and Singh, 1993)
Amount per meal	25–50 g dry cereal–legume mix (soft family foods)	12-24	(Sajilata *et al.*, 2002; World Health Organization, 2009)
Texture progression	Thin → thick → soft family foods	6-24	(World Health Organization, 2003, 2009)
Purpose of cereal–legume combination	Improves amino acid balance and protein quality	6-24	(Livingstone and Singh, 1993; Sajilata *et al.*, 2002)

2.6 Antinutritional factors

Anti-nutritional factors are naturally occurring compounds in plant-based foods that can impede nutrient absorption and utilization. While they may reduce the digestibility and bioavailability of proteins and minerals, traditional processing methods such as soaking, germination, fermentation, and cooking can effectively reduce their levels (Samtiya *et al.*, 2020).

2.6.1 Tannin

Tannins are polyphenolic compounds present in cereals and legumes that bind with proteins and carbohydrates to form insoluble complexes, thereby reducing digestibility. High levels in the diet can impair growth and feed efficiency, whereas moderate levels, typically 1 to 2 percent, are commonly found in beans and cereals (Gemede and Ratta, 2014). Processing techniques such as soaking and cooking help reduce tannin content, thereby enhancing protein availability.

2.6.2 Phytic acid

Phytic acid, or myo inositol hexakisphosphate, is the main phosphorus storage compound in cereals and legumes. It binds tightly to minerals such as calcium, iron, and zinc, forming insoluble complexes that reduce their absorption (Zhang *et al.*, 2020). Techniques such as soaking, sprouting, and lactic acid fermentation effectively lower phytic acid levels, thereby improving mineral bioavailability (Yaseen *et al.*, 2014).

2.6.3 Oxalates

Oxalates are organic acids found in cereals, legumes, and leafy vegetables. They bind to calcium and iron, decreasing their absorption and potentially increasing the risk of kidney stone formation in susceptible individuals (Chai and Liebman, 2005). Boiling and soaking are effective methods for reducing oxalate content in foods (Savage and Klunklin, 2018).

2.6.4 Trypsin inhibitor

Trypsin inhibitors are proteins present in legumes, particularly soyabean, that interfere with proteolytic enzymes such as trypsin and chymotrypsin, thereby reducing protein digestibility. Their presence can result in pancreatic hypertrophy and an increased need for amino acids (Gemede and Ratta, 2014). Heat treatment, germination, and fermentation are effective in inactivating trypsin inhibitors, thereby enhancing protein quality.

2.7 Processing techniques suitable for weaning food

Food processing techniques are used to enhance the nutritional quality, safety, and acceptability of complementary foods. Traditional household methods such as washing, soaking, germination, sieving, and roasting are especially effective in reducing anti-nutritional factors and improving digestibility (Ranganna, 1986; Samtiya *et al.*, 2020).

2.7.1 Sorting

Manual sorting was performed to remove stones, husks, insects, and other foreign materials from raw maize, rice, and soybean grains. This step ensured the safety and quality of the raw ingredients before further processing (Ranganna, 1986).

2.7.2 Washing

Washing cereals and legumes helps remove dust, dirt, and surface contaminants. It also reduces soluble anti-nutritional compounds, such as tannins and saponins, present on the seed coats. Proper washing is essential to ensure the hygienic preparation of infant foods (Ranganna, 1986).

2.7.3 Soaking

Soaking grains and legumes in water softens them, shortens cooking time, and activates endogenous enzymes. This process also leaches out soluble anti-nutritional factors such as phytates, oxalates, and tannins, thereby improving mineral bioavailability. Additionally, soaking enhances the palatability and digestibility of legumes (Gemede and Ratta, 2014).

2.7.4 Drying

Drying is one of the oldest and most widely used food preservation methods. It lowers moisture content and water activity, inhibiting microbial growth and enzymatic spoilage, while extending the shelf life of cereals, legumes, and leafy vegetables (Kumar and Karim, 2017). Besides enhancing stability, drying concentrates nutrients on a weight basis and facilitates further processing, such as milling and roasting (Jain *et al.*, 2020). Several studies have shown that thin layer drying models, such as the Newton, Page, and Henderson–Pabis equations, effectively describe the moisture loss behavior of agricultural products (Adekanye *et al.*, 2023). Controlled oven or tray drying enables reproducible results and precise measurement of drying kinetics, which is essential for optimizing processing conditions and preserving nutrients. Drying also helps reduce certain anti-nutritional factors. Heat treatment during drying can partially inactivate trypsin inhibitors and lower microbial load, while maintaining protein integrity and micronutrient stability when performed at suitable temperatures (Gemede and Ratta, 2014). Therefore, drying serves not only as a preservation method but also as an important experimental tool in food science, connecting moisture reduction to product safety, nutritional quality, and the modeling of drying behavior.

2.7.4.1 Drying of Cereals, legumes and Moringa Leaves

Drying is an essential processing step in the preparation of nutrient-dense complementary foods, as it lowers moisture to safe levels while preserving heat-sensitive nutrients. For Moringa leaves and cereal–legume mixtures, low-temperature drying (45–50 °C) has been shown to better retain vitamin C and carotenoids compared to higher temperatures above 60 °C, which accelerate oxidative degradation (Akoy, 2014; Buzrul, 2023). Drying at 45 °C until a constant weight is reached ensures microbial safety by reducing moisture content below 10 to 12 percent (wet basis), while preserving desirable sensory and functional properties. Regular monitoring of weight at fixed intervals, such as every 30 minutes, aligns with thin layer drying models like Newton, Page, and Henderson–Pabis, which describe the decline in moisture ratio over time (Hussein *et al.*, 2016). Therefore, the selected drying protocol provides a balance between nutrient retention, safety, and practicality for household-level food preparation.

2.7.4.2 Drying kinetics of moringa leaves

The drying kinetics of leafy vegetables have been extensively studied using thin layer models, including the Newton, Page, and Henderson–Pabis equations. These models describe changes in moisture ratio over time and are commonly used to predict drying behavior. Ngo Van Tai *et al.* (2024) reported that the Page model provided the best fit for Moringa leaves dried at 55–70 °C, with effective moisture diffusivity values ranging from 8.36×10^{-12} to 1.22×10^{-11} m^2/s and an activation energy of 20.14 kJ/mol. Similarly, Jain *et al.* (2020) demonstrated that tray drying Moringa leaves at 40–60 °C reduced moisture content to below 10 percent while preserving antioxidant properties. These results support the use of thin layer drying models to evaluate moisture behavior in Moringa leaves, which aligns with the objectives of the present study conducted at 45 °C.

2.7.5 Roasting

Roasting is a food processing method that uses dry heat, at temperatures of at least 150 °C from an open flame, oven, or other heat source, to cook food products evenly. This process enhances palatability, digestibility, and sensory qualities, while inducing desirable structural changes. Roasting also significantly improves flavor through Maillard reactions and surface caramelization (Das *et al.*, 2023b). Roasting cereals and legumes, such as maize and soybean, is a common step in preparing weaning foods. This process improves digestibility, reduces anti-nutritional factors, and enhances flavor (Das *et al.*, 2023a). In the current formulation, Moringa leaves were incorporated without roasting to preserve heat-sensitive nutrients, especially vitamin C (Nguyen and Le, 2021). Similarly, roasting increased the in vitro protein and starch digestibility of weaning foods by 15–21% and 16–19%, respectively. It also enhanced in vitro iron availability by 12–19% (Niraula, 2017).v

2.7.6. Grinding

Grinding is a key size-reduction process used to produce food powders, making the product chemically and microbiologically stable and convenient for use as either a final product or an intermediate ingredient (Pazos *et al.*, 2012). The grinding process encompasses a range of operations using equipment such as mincers, crushers, cutters, mills, grinders, shredders, disintegrators, and homogenizers (Kamdem and Hardy, 1995). Solid food materials are reduced into numerous fine particles through size-reduction techniques. Powders are subsequently produced through the grinding process (Jung *et al.*, 2018).

The moisture content of food materials prior to grinding is a crucial factor, as it influences both the physical characteristics of the materials and the properties of the resulting powder (Ngamnikom and Songsermpong, 2011). Numerous researchers have studied the efficiency of grinding grains and other food materials at different moisture levels. Studies indicate that particle properties are influenced by the structure of the food, which varies with moisture content. Additionally, materials with lower moisture content tend to produce fewer coarse particles, whereas higher moisture levels result in a greater proportion of coarse particles (Moon and Yoon, 2018). Therefore, powders produced from food materials with varying moisture content may exhibit different properties, including particle shape, particle size distribution, and flowability, which refers to the ease with which a powder flows (Jung *et al.*, 2018).

2.7.7. Mixing

Mixing is a fundamental operation in the chemical, pharmaceutical, and food processing industries. It enhances the homogeneity of a system by minimizing non-uniformity or gradients in composition, properties, or temperature (Harnby. *et al.*, 2001). In the food industry, mixing is used not only to combine ingredients but also to modify food structure. A key aspect of food processing is how mixing develops texture and influences the sensory characteristics of the final product (Rielly, 1997). In solid–solid food systems, achieving uniform mixing is especially challenging when one component, such as salt, is present in small amounts. According to the (Encyclopedia of Life Support Systems), the uniformity of a food mixture is evaluated based on the scale of observation, meaning how consistent it appears at the level of consumer use, such as per spoonful. If segregation occurs, some portions may have higher concentrations of salt while others have less, resulting in variations in taste, nutritional content, and safety.

The Encyclopedia of Life Support Systems further highlights that both the intensity and extent of segregation should be measured to ensure even distribution of minor ingredients throughout a product. In the case of weaning foods, this ensures that each spoonful contains the same salt concentration as the overall formulation, preventing portions with too little or too much salt.

2.7.7.1 Taste Adjustment by Salt Addition

Sensory attributes, including taste, aroma, texture, and overall acceptability, are key factors influencing consumer preference and adoption of complementary foods. Salt, in particular, plays an important role in enhancing palatability. Adding salt in moderate amounts improves taste perception and overall acceptability, especially in cereal–legume blends that may otherwise have bland or beany flavors. (Samtiya et al., 2020), reported that seasoning practices, including the addition of salt, significantly improved the sensory scores of nutrient-dense formulations. Similarly, S. Mishra et al. (2020b), highlighted that adding salt can mask undesirable flavors from legumes and enhance overall consumer preference. These findings provide a scientific rationale for assessing the role of salt in weaning food formulations and support the sensory evaluation carried out in the present study.

2.7.8 Sieving

Particle size distribution is a key factor influencing the physicochemical properties of materials in various industries, including food powders, chemicals, colorants, paints, and pharmaceuticals. Sieves and screens are among the oldest and most commonly used tools for separating solids based on particle size (Liu, 2009). Sieving is based on principles from multiple disciplines, including physics and applied fluid mechanics. Its efficiency is influenced by factors such as particle size and shape relative to the sieve openings, mesh size, the quantity of material on the sieve, the direction of sieve motion, and the rate at which particles pass through the mesh (Wang and Flores, 2000).

The Encyclopedia of Life Support Systems emphasized that the uniformity of food powders should be evaluated at the “scale of scrutiny,” meaning consistency should be assessed at the level of consumption. Analytical sieving is commonly used for this purpose, employing a stack of sieves with progressively smaller mesh sizes to separate powders into fractions. Using all sieve sizes ensures that the full particle size range is captured, reducing segregation and enhancing homogeneity. Research in cereal science indicates that sieving efficiency is affected by sieve size, duration, and tapping, which in turn influence the precision of separation and uniformity of fractions (Liu, 2009). In infant foods made from finely milled cereals and legumes, controlling particle size distribution is essential to ensure a smooth texture, good digestibility, and consistent nutrient and salt content. This aligns with (World Health Organization) guidelines that stress uniformity and safety in complementary feeding practices.

2.7.9 Packaging

Packaging is the technology used to enclose and protect products for distribution, storage, sale, and use. It also involves the design, evaluation, and production of packages. Essentially, packaging is a coordinated system for preparing goods for transport, warehousing, logistics, sales, and final consumption. It serves to contain, protect, preserve, transport, inform, and promote products. While preservation is the primary role of packaging, it performs multiple functions that food manufacturers must fully understand (Han, 2014).

The primary packaging materials in the food industry include paper, glass, metal, and plastic, which are often combined in various ways to create different packaging solutions (Marsh and Bugusu, 2007). Food packaging can have direct negative impacts, including the consumption of natural resources, pollution from production processes, littering, landfill accumulation, energy use, and greenhouse gas emissions associated with manufacturing, transportation, and disposal of packaging materials (Boesen *et al.*, 2019). Many modern packaging solutions also utilize advanced technologies, including modified atmosphere packaging (MAP) and active packaging (AP) (Rodriguez-Aguilera and Oliveira, 2009).

(Hemachandra *et al.*, 2024) reviewed 23 life cycle assessments of food packaging and found that plastic is the most frequently studied material, particularly effective for perishable items such as meat, dairy, fruits, and vegetables due to its capacity to extend shelf life and minimize food waste. While plastic predominates, the study emphasizes that packaging selection should be food-specific, with paper and composite materials often adequate for dry products. Extending shelf life was identified as the most important packaging function, closely tied to nutrient preservation. The review also points out gaps in research on biodegradable and intelligent packaging, especially for infant foods, highlighting the need for innovative solutions that balance sustainability with food safety.

2.8 Sensory Evaluation

Sensory science is a multidisciplinary field that employs a range of established and emerging methods to assess human responses to various stimuli. While sensory testing is applied across multiple disciplines, it is particularly prominent in food science. Sensory evaluations are generally classified into two main categories: analytical tests and affective tests. Analytical tests typically focus on the product itself, while affective tests are oriented toward consumer perceptions. Choosing the appropriate type of test is essential to obtain meaningful and actionable results. Peryam and Pilgrim (1957) eveloped the nine-point hedonic scale, a category scaling method that contains nine categories that range from "dislike extremely" to "neutral" to "like extremely." This scale became the gold standard for measuring food acceptability (Moskowitz and Sidel, 1971).

In the late 1970s, the International Organization for Standardization (ISO) and (ASTM International) (formerly known as the American Society for Testing and Materials) began publishing guidelines in sensory analysis covering general principles, terminology, methodology, equipment, and methods tailored to specific food and beverage products. A wide range of sensory tests exists, with new methods developed annually, all grounded in science and the psychophysics of human responses to stimuli. Selecting the appropriate test and applying it correctly is crucial for obtaining meaningful results. Sensory evaluations are broadly classified into two categories: objective tests, which treat humans as measurement instruments, and affective tests, which assess consumer responses such as liking, preference, and emotions (Drake *et al.*, 2023).

2.8.1 Methods of sensory evaluation

According to (Ranganna, 1986), sensory evaluation methods include affective tests such as paired preference, hedonic scaling, ranking, and acceptance tests. Analytical methods are conducted by trained panelists to assess specific product attributes, whereas affective methods involve consumers to evaluate preference and acceptability. Some of the sensory tests employed in this study include:

2.8.1.1 Paired preference test

The paired preference test is a straightforward affective sensory method designed to identify which of two samples is preferred by panelists. As described by (Ranganna, 1986), panelists are presented with two coded samples simultaneously and asked to indicate their preference. This test is especially valuable in product development and quality comparison studies, allowing evaluation of consumer acceptability between different formulations or processing methods. Results are typically analyzed using the binomial test to determine if observed preferences differ significantly from chance. The method is suitable for both trained and untrained panelists.

2.8.1.2 McNemar Test

The McNemar test is applied to assess differences in a dichotomous dependent variable between two related groups. A dichotomous variable has only two categories. This test is analogous to the paired-samples t-test but is used for categorical outcomes rather than continuous variables (University of Sheffield, 2020). The McNemar test has three assumptions that has to be met before running the test:

Assumption 1: You have one categorical dependent variable with two categories (i.e.,a dichotomous variable) and one categorical independent variable with two related groups.

Assumption 2: The two groups of your dependent variable must be mutually exclusive. This means that no groups can overlap: a participant can only be in one of the two groups.

Assumption 3: The cases (e.g., participants) are a random sample from the population of interest.

The McNemar test statistics are calculated using the formula:

$$x^2 = \frac{(|b-c|-1)^2}{b+c}$$

Where:

b = number of panelists who preferred Product B but not Product A

c= number of panelists who preferred Product A but not Product B

2.8.1.3 t- test

The test was employed to determine whether the difference between sample means was statistically significant. Since the population standard deviation (sigma) was unknown, the sample standard deviation (s) was used to estimate variability. The test statistics were calculated using the formula:

$$t = \frac{\bar{X} - \mu}{s\ /\ \sqrt{n}}$$

Where $\bar{X}$ =sample mean, μ = hypothesized population mean

(s) =sample standard deviation, and (n) =sample size.

The resulting value was compared against critical values from the t-distribution table at the 5% level of significance. Degrees of freedom were calculated as (f = n - 1) (Puri, 1989). All statistical computations were performed using Microsoft Excel to ensure accuracy and reproducibility.

2.9 Formulation studies

Numerous formulation studies have shown that locally available crops can significantly enhance the nutritional quality of complementary foods. Araro *et al.* (2020), developed blends of orange-fleshed sweet potato, teff, and kidney beans, demonstrating notable improvements in protein digestibility and micronutrient content compared to traditional cereal-based diets. Consistent evidence from other studies indicates that cereals, legumes, and nutrient-rich crops such as moringa can be formulated into affordable, nutrient-dense complementary foods. These findings strongly support the effectiveness of such formulation strategies in combating malnutrition in resource-limited settings, underscoring the potential of maize, rice, soybean, and moringa blends for Nepalese infants.

2.10 Packaging and Storage of Complementary Foods

Proper packaging and storage of complementary foods are crucial for maintaining nutrient content, ensuring safety, and facilitating accessibility. (UNICEF, 2024) highlighted that the packaging of ready-to-use therapeutic foods (RUTF) plays a vital role in preserving nutrient stability and enabling long-term storage, especially in resource-constrained environments. Isaacs *et al.* (2022) observed that caregivers frequently choose packaged infant foods, including purees and snacks, because of their convenience, safety, and storage stability. This underscores that packaging is not only a matter of practicality but also a critical aspect of complementary feeding, ensuring that food remains safe, acceptable, and nutritionally adequate throughout storage and distribution.

2.11 Statistical analysis

Statistical analysis involves examining trends, patterns, and relationships within quantitative data. It serves as a vital research tool for scientists, governments, businesses, and other organizations. By collecting and interpreting data, statistical analysis uncovers underlying patterns and trends, forming an integral part of data analytics. It is applied in activities such as research interpretation, statistical modeling, and the design of surveys or studies (Remenyi *et al.*, 2011).

2.11.1 Estimation

Estimation is the process of establishing the likely value of a variable. The most direct form of estimation is to establish a single-point value (Remenyi *et al.*, 2011).

Estimation for the work is given by:

Mean $(\overline{X})$± C. L (at 95% confidence level)

Here,' $\bar{X}$' is mean value. 'C.L' is confidence level.

The confidence interval is calculated by:

$$\frac{s^2(n-1)}{x^2_{(n-1);}\alpha/2} < \sigma < \frac{s^2(n-1)}{x^2_{(n-1)};1-\alpha/2}$$

For 95% confidence level, α =0.05

Lower limit, $\alpha/2$=0.025

Upper limit, $1-\alpha/2$ =0.975

2.11.2 Significant test

significant test for the work is given by:

$$t = \frac{x - \mu_0}{\frac{s}{\sqrt{n}}}$$

Here, X' is the observed mean value, $'\mu_0'$ is reference mean value, S' is the standard deviation and 'n' is the sample size.

2.11.3 Chi-Square Test

The chi-square (χ^2) distribution is commonly used in statistical analysis to evaluate the variability of sample data, particularly in relation to population variance. When analyzing a sample of size (n), the expression, $(n-1)s^2 / \sigma^2$ where s^2 is the sample variance and σ^2 is the population variance follows a chi-square distribution. This distribution, like the t-distribution, forms a family of curves defined by degrees of freedom, f = (n – 1). Critical values for the chi-square test are obtained from standard statistical tables, allowing researchers to determine whether a given sample variance significantly deviates from the expected population variance. Such tests are essential for validating the consistency and reliability of experimental data in food science and nutritional studies (Puri, 1989).

2.11.4 t -test

In situations where the population standard deviation (sigma) is unknown, it is estimated using the sample standard deviation (s). When the sample mean $\bar{X}$ is standardized using $s / \sqrt{n},$ the resulting statistic: $t = \frac{\bar{X}-\mu}{s/\sqrt{n}}$ follows t-distribution rather than a standard normal distribution.

The t-distribution is symmetric and bell-shaped, centered at zero, and forms a family of distributions defined by degrees of freedom ((f = n - 1)). Unlike the fixed critical values of the normal distribution (e.g., ±1.96 for 95% confidence), the distribution uses variable critical values such as (t=0.025), which depend on the sample size. For instance, when (n = 15), the degrees of freedom are 14, and the corresponding critical value is $t_{0.025}$=2.1448. As the sample size increases, the t-distribution approaches the standard normal distribution, with critical values converging toward ±1.96 (Puri, 1989).

2.12 Linear Programming (LP)

Linear programming is a mathematical approach used to optimize a linear objective function subject to defined nutritional and acceptability constraints. In the formulation of weaning foods, this technique has been extensively employed to develop cost-effective, nutritionally balanced diets for infants and young children. By representing nutrient requirements and ingredient limitations such as mathematical inequalities, linear programming identifies optimal combinations of locally available foods that satisfy energy, protein, and micronutrient needs. Although the method was introduced over 50 years ago, its application has expanded with the availability of low-cost, high-speed computing, enabling complex nutritional formulations involving hundreds of ingredients to be solved within seconds using spreadsheet-based models (Carvalho *et al.*, 2015; Miow *et al.*, 2025).

2.121 Applications of Linear Programming

1. **Industrial Applications**: The LP is used in industries for product mix-problem, production scheduling, production smoothing, blending problems, transportation problems, production and distribution problems, communication industry.
2. **Management Applications**: LP can be used for portfolio selection, financial mix strategy, profit planning, media selection, travelling salesmen problem, determination of equitable salaries, staffing problem.
3. **Administrative Application**: LP can be used to make decisions for utilizing the available resources.
4. **Non-Industrial Applications of Linear Programming**: Some of the other application of LP is agriculture, environmental protection, urban department and facilities location (Gautam, 2014).

2.12.2 Guidelines on LP model formulation

1. **Define the decision variables**: The first step towards the development of the model is to give the proper definition of the decision variables. The decision variables in the model are denoted by x1, x2, x3….n. In our case, the decision variables are maize, rice, soyabean and Moringa Powder which are denoted by x1, x2 and x3 respectively.
2. **Formulate the objective function**: The second step is to construct the objective function Z, which is a linear equation involving the decision variables that identifies our objective. Here is the objective in our case, Z=x1+ x2+x3
3. **Formulate the constraints**: Formulate all the constraint imposed by the limited resources availability and express the mathematical linear equality/ inequality in terms of decision variables (Gautam, 2014).

2.12.3 Optimization Outcome and Ingredient Sufficiency

The initial linear programming analysis suggested that an optimal formulation could be achieved using only rice, soybean, and moringa leaf powder, as these ingredients met the specified nutrient requirements. Nevertheless, to enhance the amino acid profile and improve protein quality, the proportion of rice was reduced, and maize was added to the formulation. This adjustment provided a more balanced distribution of essential amino acids, particularly lysine and methionine, thereby increasing the overall nutritional adequacy of the weaning food blend (Gautam, 2014).

2.13 Shelf-Life Estimation Using First-Order Kinetics

Shelf-life determination of food products is often based on kinetic modeling of quality deterioration. According to the International Union of Food Science and Technology, (International Union of Food Science and Technology, 2020), most nutrient losses and sensory changes in foods follow either zero-order or first-order kinetics. In first-order reactions, the rate of change is proportional to the concentration of the quality attribute, and the relationship can be expressed as:

$$-dA/dt=kt$$

where A is the concentration of the attribute at time t, and k is the rate constant. Integration of this equation yields:

$$A = A_0 e^{-kt}$$

Shelf life is defined as the time when the attribute decreases to a critical level (A_e), below which the product is no longer acceptable. The expiry date can therefore be calculated as:

$$t_s = \frac{\ln(A - Ae)}{k}$$

This approach has been widely applied in food science to predict the stability of vitamins, flavors, and other sensitive nutrients (Gemede and Ratta, 2014; International Union of Food Science and Technology, 2020). The use of spreadsheet software such as Microsoft Excel allows experimental data to be fitted to first-order models, providing an estimate of the rate constant k, which is then used to calculate the expiry date. Such kinetic modeling provides a scientific basis for shelf-life estimation and ensures that expiry dates are not arbitrary but grounded in quantitative analysis.

Part III

Materials and methods

This part describes the materials selected and the methods used for the formulation and evaluation of the weaning food. Locally available ingredients such as maize, rice, soybean, and moringa leaf powder were chosen based on their nutritional value, availability, and affordability. The raw materials were processed through sorting, soaking, drying, roasting, grinding, mixing, and sieving to improve digestibility and nutrient quality. Linear programming using Microsoft Excel Solver was applied to optimize ingredient proportions according to recommended nutrient requirements. The optimized formulation was analyzed for proximate composition, energy value, and selected micronutrients using standard analytical methods. Sensory evaluation and shelf-life stability studies were also conducted to assess product acceptability and storage quality.

3.1 Materials

3.1.1 Yellow Maize (Zea mays L.)

Yellow maize was procured from local markets in Dharan, Nepal, in Shrawan 13, in accordance with the (DFTQC) (2012) guidelines for marketed food products. The maize was purchased in its marketed form and not directly from farms. Prior to use, visible foreign matter such as stones and insects was manually removed. The grains were washed with water to reduce surface microbial load. Cleaned maize was stored in airtight polyethylene bags at ambient temperature until further processing.

3.1.2 White Soybean (Glycine max L.)

White soybean was obtained from local markets in Dharan, Nepal, in Shrawan 13, following ((DFTQC)) standards for marketed food products. The beans were food-grade and purchased in their marketed form. Manual cleaning was carried out to remove stones and insects, if present, and soaking in water was performed to maximize antinutrient reduction like phytates, oxalates, tannins and polyphenols (Ijarotimi and Ashipa, 2005) The soybeans were stored in airtight polyethylene bags at ambient temperature until use.

3.1.3 Polished Rice (Oryza sativa L.)

Polished rice was purchased from local markets in Dharan, Nepal, in Shrawan 13, in accordance with DFTQC guidelines. The rice was obtained in its marketed form and not directly from farms because brown rice was not available in the local market. Foreign matters such as stones and insects was manually removed before use. The rice grains were not washed with water, consistent with household preparation practices, to prevent nutrient loss. The rice was stored in airtight polyethylene bags at ambient temperature until further processing.

3.1.4 Moringa Leaf Powder (Moringa oleifera Lam.)

Moringa leaf powder was procured from local suppliers in Dharan, Nepal, in Shrawan 13. The powder was food-grade and used directly as obtained, without further cleaning or processing. It was stored in airtight polyethylene bags at ambient temperature until blending with other ingredients. Moringa leaves are recognized for their high nutrient density, particularly β-carotene, iron, calcium, and protein, making them suitable for complementary food formulations (Gopalakrishnan *et al.*, 2016).

3.1.5 Chemicals and Equipment

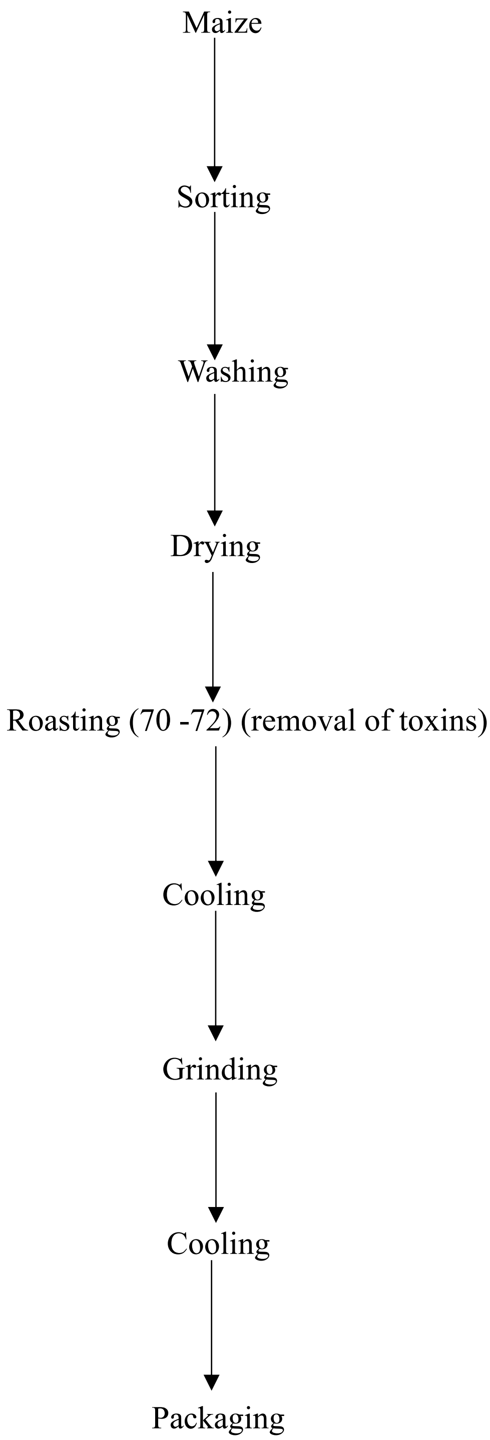
To finalize the process, food-grade NaCl from Dharan, Nepal, was added to the blends for flavor and to assess distribution homogeneity. Essential equipment included laboratory and hot-air ovens for drying and moisture analysis, a grinder for flour production, and stainless-steel or glass containers for handling and storage.

3.2 Methods

3.2.1 Processing of raw materials

3.2.1.1 Maize

After room-temperature washing and air-drying, maize is roasted at 70–72°C, cooled, and ground into flour. This finished flour is cooled again and stored in glass bottles for preservation (Baskota, 2018; Chauliac *et al.*, 1987).



Source: (Chauliac *et al.*, 1987).

Fig. 3.1 Processing method for maize

3.2.1.2 Soyabean

Soybean seeds were cleaned and soaked in 0.5% sodium hydrogen carbonate solution at 30 °C for 2 hours. The soaked seeds were dehulled and oven-dried at 60 °C for 24 hours. Drying was followed by roasting at 70–72 °C, cooling, and milling into flour. The flour was stored in glass containers until further use (Chauliac *et al.*, 1987; Ijarotimi and Ashipa, 2005).

Soyabean

↓

Sorting

↓

Soaking(2hours)

↓

Drying

↓

Roasting (70 -72)(removal of toxins)

↓

Cooling

↓

Grinding

↓

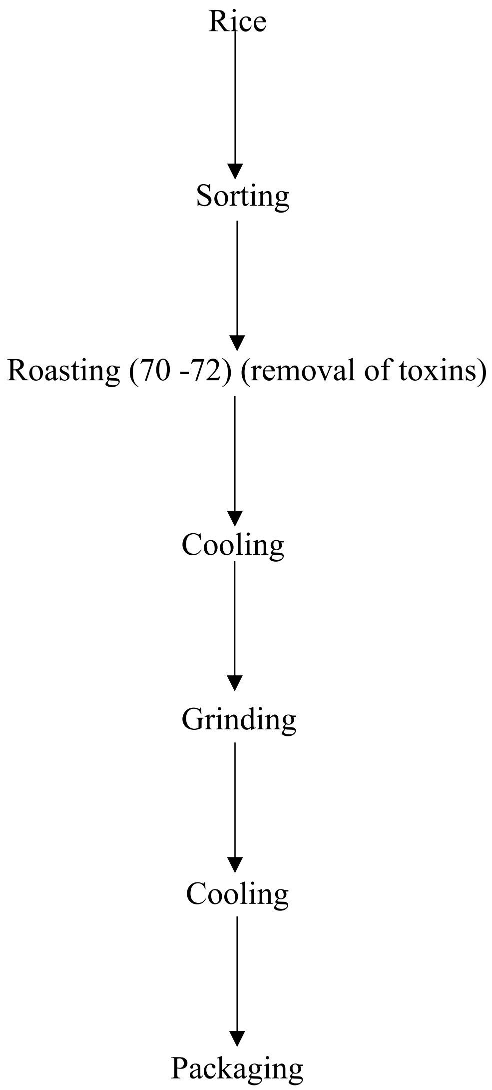
Cooling in room temperature and Packaging

Source: (Chauliac *et al.*, 1987).

Fig. 3.2 Processing method for Soyabean

3.2.1.3 Rice

Rice is sorted to remove impurities such as stones, weed seeds, other grains, broken kernels etc. at room temperature (25- 27 °C). It was then roasted at 70-72°C, cooled at room temperature, grinded using a laboratory grinder, cooled again and the flour was prepared. The prepared flour was then stored in the glass bottle for further use (Chauliac *et al.*, 1987).

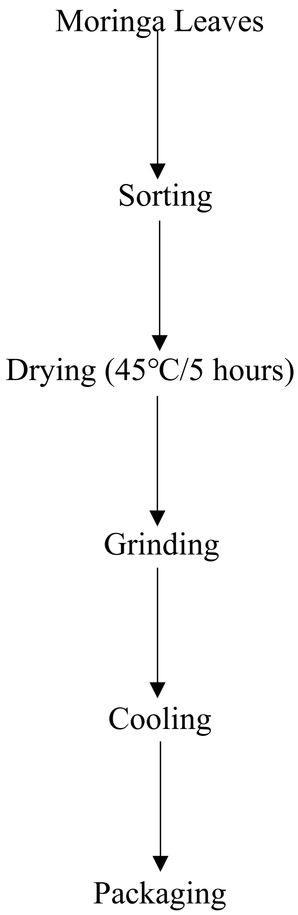


Source: (Chauliac *et al.*, 1987).

Fig. 3.3 Processing method for Rice

3.2.1.4 Moringa Powder

Moringa oleifera leaf powder was prepared using a modification of the method described by (Jain *et al.*, 2020). Moringa leaves were collected, sorted, and then dried in the tray dryer at a temperature of around 45°C for around 5 hours until constant weight. It was then grounded into powder and packaged in LDPE bag and stored for further use.



Source: (Jain *et al.*, 2020).

Fig, 3.4 Processing method for Moringa Leaf Powder

3.2.2 Sieving of Raw Materials

After drying and milling, the flours of maize, rice, soybean, and moringa leaf powder were subjected to sieve analysis to obtain uniform particle size distribution. A stack of laboratory sieves with mesh sizes ranging from coarse (10 mesh) to fine (120 mesh) was arranged sequentially, and the flour samples were placed on the top sieve. The stack was shaken mechanically for a fixed duration to allow proper separation of particles according to size. The fraction retained on each sieve was weighed to determine the particle size distribution of the powders. This analysis provided information on the proportion of course, medium, and fine particles present in the raw materials. Although sieve analysis was performed for academic completeness, only the fine fraction that passed through the 60-mesh sieve was collected for formulation of the weaning food. This particle size was selected because it produces a smooth texture, improves digestibility, and ensures safe consumption by infants, who cannot tolerate coarse particles (Department of Food Technology and Quality Control (DFTQC), 2022). The sieved flour was immediately transferred into airtight containers to prevent moisture uptake and contamination and stored until further use in product formulation.

3.2.3 Physicochemical analysis of product

3.2.3.1 Moisture content

Moisture content of the required raw materials as well as final product was determined by oven-dry method as per AOAC (2005)

3.2.3.2 Crude fat

Crude fat of the required raw materials as well as final product was determined by the Soxhlet extraction technique followed by (AOAC, 2005).

3.2.3.3 Crude protein

The crude protein content of the required raw materials as well as final product was determined following the micro Kjeldahl method (AOAC, 2005).

3.2.3.4 Crude fiber

Fiber content was determined by chemical method according to (Ranganna, 1986).

3.2.3.5 Total ash

The total ash of the required raw materials as well as final product was determined as per (Ranganna, 1986).

3.2.3.6 Determination of Acid-Insoluble Ash

The acid-insoluble ash of the required raw materials as well as final product was determined as per (Ranganna, 1986).

3.2.3.7 Total carbohydrate

The carbohydrate content was estimated by different methods. It was calculated by subtracting the sum of the percentage of moisture, fat, protein, and ash contents from 100% according to (AOAC, 2005).

3.2.3.8 Calcium

Calcium content is determined by volumetric method as per (AOAC, 2005).

3.2.3.9 Vitamin C

Vitamin C content is determined as per (Ranganna, 1986).

3.2.3.10 Iron

Iron content is determined as (Ranganna, 1986).

3.2.4 Determination of energy value

One of the methods specified by FDA is employed. This uses the general factors of 4, 4, and 9 calories per gram of protein, total carbohydrate, and total fat, respectively, to calculate the calorie content of food (Bassey and Edem, 2013).

Total energy = energy from carbohydrates + energy from protein + energy from fat

3.3 Formulation of the flour

Formulation of the flour was done by linear programming method. It was done by the nutritional balance of Protein, Fiber, Iron, Vitamin C and Calcium.

Table 3.1 Linear Programming Table for the Prepared Flour

	Maize	Soyabean	Rice	Moringa Powder
Protein	A1	A2	A3	A4
Iron	B1	B2	B3	B4
Fiber	C1	C2	C3	C4
Vitamin C	D1	D2	D3	D4
Calcium	E1	E2	E3	E4

The quantities are taken into same unit so that the equation will succeed. Thereby:

$$a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 \leq A$$

$$b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 \geq B$$

$$c,x_1 + c_2x_2 + c_3x_3 + c_4x_4 \leq C$$

$$d_1x_1 + d_2x_2 + d_3x_3 + d_4x_4 \geq D$$

$$e_1x_1 + e_2x_2 + e_3x_3 + e_4x_4 \geq E$$

Minimise, $m\varkappa, + nx_2 + o\varkappa_3 + px_4$

$X_1 X_2 X_3 X_4 > 0$, where, X_1 = Maize, X_2 = Soyabean, X_3 = Rice , X_4 = Moringa Powder

m,n,,o and p are the price of per kg of maize, soyabean, rice and moringa leaf powder.

$a_{1,}b_1, c1, d_1$ *and* e_1 are the Protein content, Iron content, Fiber content, Moisture content and Calcium content of maize respectively.

a_2, b_2, c_2, d_2 and e_2 are the Protein content, Iron content, Fiber content, Vitamin C content and Calcium content of soyabean respectively.

$a_3 b_3 c_3 d_3$ and e_3 are the Protein content, Iron content, Fiber content, Vitamin C content and Calcium content of rice respectively.

$a_4 b_4 c_4 d_4$ and e_4 are the Protein content, Iron content, Fiber content, Vitamin C content and Calcium content of Moringa leaf powder respectively.

3.4 Statistical analysis

3.4.1 Determination of sample size

Sample size was calculated by statistical tool (95% confidence level and 5% error). Initially, a preliminary sample size of five was assumed for proximate analysis of the formulated weaning food The data for Protein content was analyzed and sample size was calculated by using those data.

Determination of sample size for the Proximate and Ultimate analysis for the prepared weaning food is given below:

$$n = \frac{t^2 \times s^2}{e^2}$$

where, t= tabulated value, n= number of samples

s= standard deviation, e= marginal error

3.4.2 Estimation

Estimation for the work is given by:

X ± S.E. (at 95% confidence level)

Here, 'X' means mean value and "S.E." is the standard error at 95% confidence level.

The confidence interval is calculated by:

$$\frac{s^2(n-1)}{x^2_{(n-1);}\alpha/2} < \sigma < \frac{s^2(n-1)}{x^2_{(n-1)};1-\alpha/2}$$

For 95% confidence level, α =0.05

Lower limit, $\alpha/2$=0.025

Upper limit, $1 - \alpha/2$ =0.975

3.4.3 Significant test

significant test for the work is given by:

$$t = \frac{x - \mu_0}{\frac{s}{\sqrt{n}}}$$

Here,'X' is the observed mean value, $'\mu_0'$ is reference mean value, 'S' is the standard deviation and 'n' is the sample size.

3.4.4 chi-square (χ^2) test

The chi-square (χ^2) test was applied to evaluate the significance of differences between observed and expected frequencies in the experimental data. The test statistics were calculated using the formula:

$$X^2 = \Sigma \frac{(0 - E)^2}{E}$$

where (O) =Observed value, and (E) the expected values.

Degrees of freedom were determined as (f = n - 1), with (n) being the number of categories. The calculated χ^2 value was compared against tabulated critical values at the 5% level of significance to assess whether the variation observed was statistically significant, (Puri, 1989). All computations were performed using Microsoft Excel, ensuring accuracy and reproducibility of results.

3.4.5 t- test

The t-test was employed to determine whether the difference between sample means was statistically significant. Since the population standard deviation (sigma) was unknown, the sample standard deviation (s) was used to estimate variability. The test statistics were calculated using the formula:

$$t = \frac{\bar{X} - \mu}{s \,/\, \sqrt{n}}$$

Where $\bar{X}$ =sample mean, μ = hypothesized population mean

(s) =sample standard deviation, and (n) =sample size.

The resulting t-value was compared against critical values from the t-distribution table at the 5% level of significance. Degrees of freedom were calculated as (f = n - 1) (Puri, 1989). All statistical computations were performed using Microsoft Excel to ensure accuracy and reproducibility.

3.5 Shelf-Life Estimation by First-Order Kinetics

Shelf life of the formulated weaning food was estimated using first-order kinetic modeling of nutrient degradation. The concentration of the selected quality attribute (Vitamin C) was measured at regular storage intervals. The rate of change was assumed to follow first-order kinetics, expressed as:

$$-\frac{dA}{dt} = kt$$

Experimental data were entered into Microsoft Excel, and the natural logarithm of concentration values (\ln A) was plotted against time. The slope of the regression line provided the rate constant (k). Shelf life was then calculated using the standard first-order equation:

$$t_s = \frac{\ln\left(\frac{A_0}{A_e}\right)}{k}$$

where A_0 is the initial concentration of the nutrient, A_e is the minimum acceptable concentration (critical limit), and k is the rate constant obtained from Excel. This method allowed estimation of the expiry date based on nutrient retention, providing a quantitative measure of product stability (International Union of Food Science and Technology, 2020).

Part IV

Results and discussions

This section presents and discusses the findings related to the proximate composition, micronutrient profile, functional properties, and sensory evaluation of the formulated weaning food samples. The results are systematically organized into clearly defined subsections to ensure logical presentation and ease of interpretation. Each dataset is critically analyzed and compared with established WHO and WFP nutritional standards for complementary foods, as well as with findings reported in relevant previous studies. This comparative approach helps to assess the nutritional adequacy, functional suitability, and overall acceptability of the developed formulations.

4.1 Drying Characteristics

4.1.1 Drying rate curve

In drying, it is necessary to remove free moisture from the surface and also moisture from the interior of the material. If the change in moisture content for a material is determined as a function of time, a smooth curve is obtained from which the rate of drying at any given moisture content may be evaluated. The form of the drying rate curve varies with the structure and type of material. The drying curve (moisture content vs. time) of moringa leaves at 45°C showed a smooth exponential decline, indicating progressive moisture loss during drying. The fitted model equation was $y = 1.3586\, e^{-0.009x}$ with $R^2 = 0.894$, confirming a good fit to the experimental data. Moisture content decreased rapidly in the initial period and then gradually slowed, which is typical of food materials during drying. Similar drying behavior has been reported in leafy vegetables and cereal-legume blends (Mishra *et al.*, 2020).

The drying curve for drying of moringa leaves at 45°C is presented on figure below:

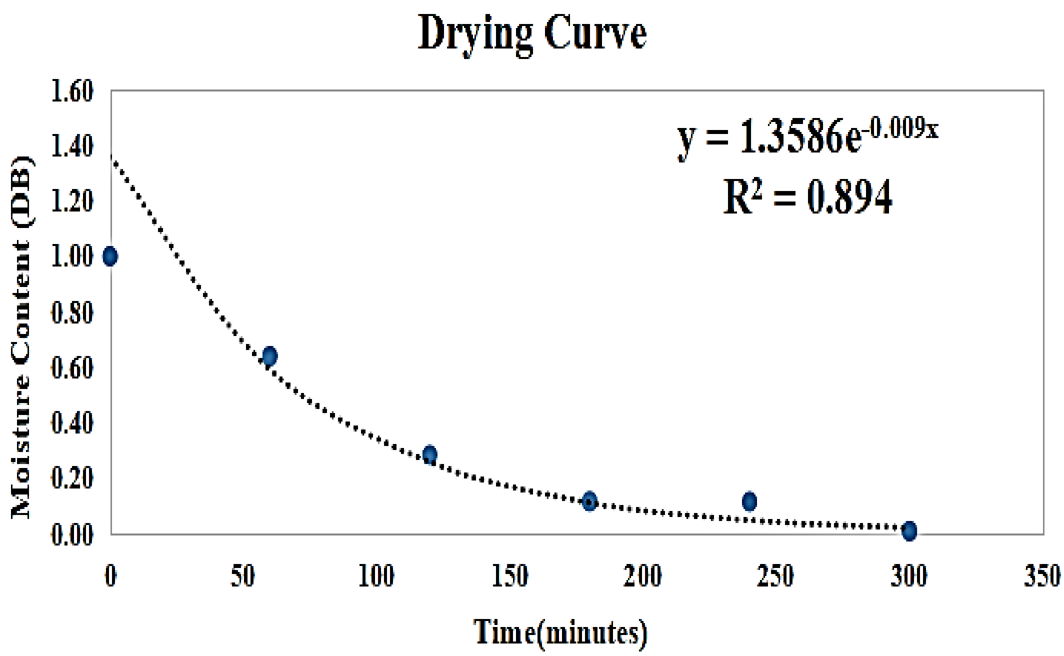


Fig. 4.1 Drying rate curve.

As shown in Figure X, the moisture content of moringa leaves decreased progressively with drying time at 45°C. The fitted exponential model (y = $1.3586e^{-0.009x}$, R^2 = 0.894) confirmed a good fit to the experimental data. Moisture loss was rapid in the initial period due to surface water evaporation, followed by a slower decline as internal moisture diffusion became limiting. This drying behavior is consistent with patterns reported in leafy vegetables and cereal-legume blends (Mishra *et al.*, 2020).

4.2 Sieve Analysis of Milled Flours

Sieve analysis was conducted to determine the particle size distribution of the milled flour used in weaning food formulation. The flour samples were passed through a stack of sieves with mesh sizes of 10 mm, 30 mm, 60 mm, 100 mm, and 150 mm. The retained fractions were weighed, and the percentage of particles finer than each sieve size was calculated. The results are presented in Table below.

Table 4.1 Calculation table for Sieve Analysis of Milled Flours

Sieve size (mm)	Mass (g) (wt. of each sieve mm)	Mass of each sieve + retained Flour (g)	Mass of flour retained (g)	% on each sieve (y/wt)	Cumulative % retained $\sum Rn$ (%)	% finer (100-Rn)
10	143.800	148.55	4.75	0.95	0.950	99.050
30	124.532	160.702	36.170	7.234	8.184	91.826
60	119.170	529.745	410.575	82.115	90.299	9.701
100	115.569	157.419	41.85	8.37	98.669	1.331
150	115.401	116.649	1.248	0.249	98.918	1.082

Sieve analysis showed 82.12% of the flour was retained on a 60 mm mesh, a size intentionally selected to ensure the smoothness and digestibility required for infant food. This specific particle fraction optimizes mixing behavior and safety for transitioning diets, with finer particles being crucial for reducing choking risks.. According to infant food texture guidelines, particles below 250 microns are considered safe and digestible (World Health Organization 2003). The findings from this analysis confirm that the flour used in this study meets those criteria, supporting its suitability for weaning food development**.**

4.2.1 Functional Properties

The formulations demonstrated desirable functional characteristics, with fine particle size confirmed by sieve analysis. Smooth texture ensured suitability for infant consumption, consistent with functional property ranges reported in complementary food formulations.

4.3 Uniformity Analysis of Formulated Weaning Food

To ensure that the formulated weaning food was uniformly blended, a mixing uniformity analysis was conducted using Excel-based calculations. The distribution of sample weights across different sieve fractions was evaluated to determine whether the ingredients were homogeneously mixed. Uniform mixing is critical in complementary food formulations, as it ensures consistent nutrient delivery and product quality. The results of the analysis confirmed that the blend achieved satisfactory homogeneity, comparable to standards reported in food mixing studies (Ranganna, 1986).

4.4 Formulation of the Weaning Food

The proportion of Different ingredients used for weaning food was formulated by using linear programming**.**

Table 4.2 Proportion of Maize, soyabean, Rice and Moringa leaf Powder

Parameters	Maize	Soyabean	Rice	Moringa Leaf Powder
Protein	0.06	0.32	0.08	0.065
Iron	0.000007	0.00008	0.00002	0.000007
Fiber	0.006	0.0398	0.016	0.0784
Vitamin C	0	0	0	0.00219
Calcium	0.0009	0.0002	0.00019	0.00397

The obtained proportions were converted to Kg/Kg from per 100 g product for sample production.

$0.06x_1 + 0.32x_2 + 0.08x_3 + 0.065\,x_4 \;\leq 0.15$

$0.000007x_1 + 0.00008x_2 + 0.00002x_3 + 0.000007\varkappa_4 \;\geq 0.000058$

$0.006x_1 + 0.0398x_2 + 0.016x_3 + 0.0784\varkappa_4 \leq 0.03$

$x_1 + x_2 + x_3 + 0.00219x_4 \;\geq 0.00008$

$0.0009\varkappa_1 + 0.0002x_2 + 0.00019x_3 + 0.00397\varkappa_4 \;\geq 0.003$

Minimise, $m\varkappa, +nx_2 + o\varkappa_3 + px_4$

$X_1X_2X_3X_4 > 0$, where, X_1 = Maize, X_2 = Soyabean, X_3 = Rice , X_4 = Moringa Powder

The linear programming model was applied to optimize the proportions of rice, soybean, maize, and moringa leaf powder in a weaning food formulation. The initial solution indicated that maize was not required to meet the defined nutrient constraints, as the combination of rice (0.6695), soybean (0.2939), and moringa (0.0365) was sufficient to satisfy energy, protein, and micronutrient targets. The maize coefficient was zero, suggesting that its inclusion was not necessary from a purely mathematical standpoint.

However, to improve the amino acid profile particularly lysine and methionine and enhance the functional properties of the formulation, a modified version was developed. In this version, the rice proportion was slightly reduced, and maize was incorporated. Maize is rich in methionine, complements the lysine content of soybean, and contributes to a more balanced amino acid profile essential for infant growth. Additionally, maize is a cost-effective, starch-rich ingredient that improves texture, making the weaning food neither too thin nor pasty, but suitable for infant feeding. The proportion of Different ingredients used for weaning food was formulated by using linear programming.

Table 4.3 Formulation of Maize, soyabean, Rice and Moringa leaf Powder

Materials	Formulation
Maize	16.80%
Soyabean	29.39%
Rice	50.21%
Moringa Leaf Powder	3.60%

The obtained proportions were converted to formulate ~1Kg product for sample production**.**

4.5 Recipe Preparation

The prepared weaning food formulation was then made ready using the proportion obtained. Formulation was taken for recipe preparation as it had the required nutrients balanced. The composition of the formulation and their per kg cost is calculated and is shown in the Appendix B.

4.6 Sensory Evaluation

Sensory scores indicated good acceptability among 2 samples. Panelists showed a statistically significant preference for the salted formulation, as confirmed by the McNemar test ($\chi^2 = 15.05$, $p < 0.05$). This highlights the role of moderate salt addition in improving palatability without compromising nutritional quality. These findings are consistent with previous reports on cereal–legume blends where salt enhanced preference. 24 panelists were selected based on formula used.(see appendix D)

4.6.1 Sensory Evaluation by McNemar Test

Sensory evaluation is a scientific discipline used to evoke, measure, analyze, and interpret reaction to those characteristics of food material as they are perceived by the senses of sight, smell, taste, touch, and hearing (sound). Sensory evaluation was conducted to assess whether the addition of salt influenced product preference among 24 semi trained panelists. The McNemar test was applied to paired nominal data, comparing preferences for the salted formulation versus the unsalted formulation. This test is appropriate for detecting significant shifts in preference when the same panelists evaluate both products.

The table below summarizes the preference patterns of panelists when comparing the salted product (Product A) with the unsalted product (Product B). Sensory evaluation was carried out with 24 semi-trained panelists, and each panelist evaluated both product formulations, allowing for a direct comparison of preferences. Results showed that a large number of panelists who did not favor the unsalted product later preferred the salted version, with 16 individuals switching their preference in this direction. On the other hand, only one panelist showed the opposite trend by moving from a preference for the salted product to the unsalted one. This clear difference in preference shifts highlights a strong overall liking for the salted formulation. The statistical significance of the results is mainly driven by this unequal pattern of preference change. The analysis emphasizes the responses of panelists who changed their preferences between the two samples, as these shifts provide important insight into differences in product acceptability. Overall, the findings indicate that the inclusion of salt played a key role in improving sensory appeal and increasing product acceptability among the panelists.

Table 4.4 Sample data for McNemar test

	Product A	
Product B	Preferrable	Not preferrable
Yes	3	1
No	16	4

The McNemar test statistic was calculated using the formula:

$$x^2 = \frac{(|b - c| - 1)^2}{b + c}$$

Where:

b = number of panelists who preferred Product B but not Product A

c= number of panelists who preferred Product A but not Product B

And so our calculated value becomes

$$x^2 = \frac{(|1 - 16| - 1)^2}{1 + 16}$$

$$= 15.059$$

The calculated chi-square value (15.059) exceeds the critical value of 3.84 at the 5% significance level, indicating a statistically significant difference in preference. Therefore, we reject the null hypothesis and conclude that panelists significantly preferred the salted formulation (Product A) over the unsalted version (Product B), as suggested by the frequency counts. This outcome demonstrates that salt addition enhanced sensory acceptability, particularly taste and overall preference, and supports its inclusion in the optimized weaning food formulation. Similar findings have been reported in complementary food studies, where moderate salt addition improved palatability and consumer acceptance (Samtiya *et al.*, 2020). Sensory evaluation results are consistent with literature emphasizing the role of seasoning in improving acceptability of nutrient-dense weaning foods.

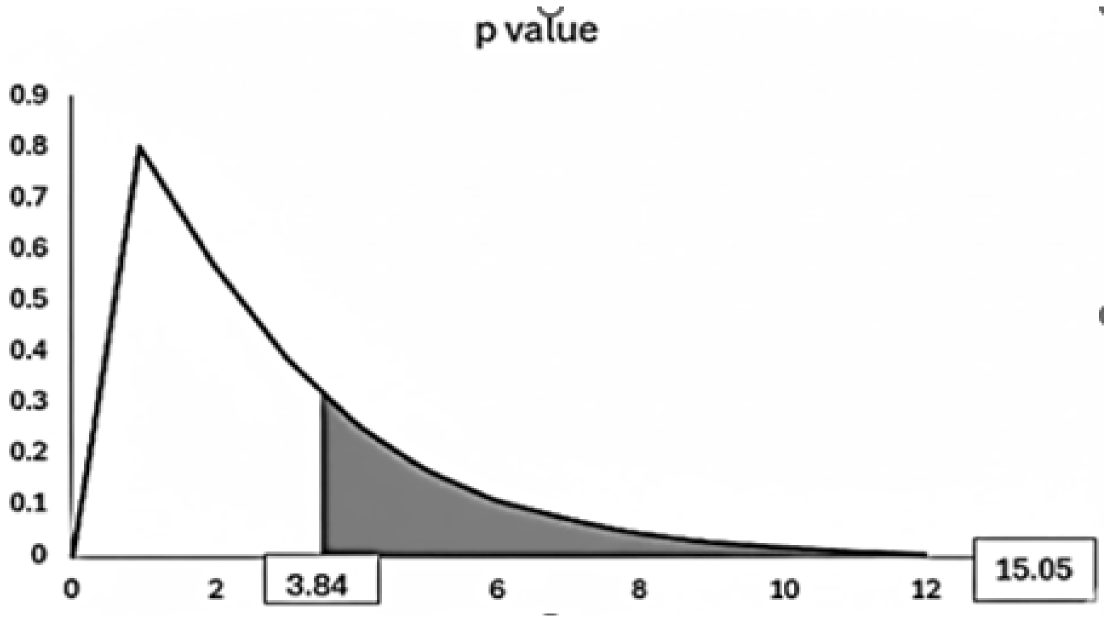


Fig. 4.2 Chi-square (p-value) distribution for sensory preference of Product A

4.7 Sample Size determination

Sample size for proximate analysis was calculated. Based on the variability in protein content and using a 95% confidence level with a 20% margin of error, the sample size for the Proximate and Ultimate analysis for the prepared weaning food is given below:

$$n = \frac{t^2 \times S^2}{e^2}$$

where, t= tabulated value, n= number of samples

s= standard deviation, e= marginal error

$$n = \frac{2.776^2 \times 0.209^2}{.2^2}$$

=8.437

The calculated sample size was determined to be statistically sufficient for conducting the proximate analysis, ensuring that the results obtained were both reliable and representative of the product under study. Selecting an adequate sample size is an important step in nutritional analysis, as it directly influences the accuracy and precision of the estimated nutritional parameters, such as moisture, protein, fat, ash, and carbohydrate content. By using an appropriate number of samples, the likelihood of random error was reduced, and potential sampling bias was minimized. This helped to ensure that the measured values genuinely reflected the nutritional characteristics of the formulated product rather than being influenced by chance variations.

The determination of sample size was carried out using Excel-based calculations, which allowed for a systematic, transparent, and easy-to-follow process. This approach not only simplifies the calculations but also made it possible to review, verify, and reproduce the sample size estimation if required. Such transparency is especially important in academic research, as it supports the credibility and reproducibility of the study. Furthermore, the methodology adopted was consistent with the recommendations provided by the Association of Official Analytical Chemists (AOAC), which are widely recognized and accepted as standard guidelines for food and nutritional analysis. Adhering to these established guidelines strengthens the scientific validity of the research and enhances confidence in the generated data. Overall, the carefully calculated sample size and standardized approach contributed significantly to the robustness and reliability of the proximate analysis results.

4.8 Physicochemical Composition of Weaning food

Table 4.5 Physical and chemical compositions of the prepared Weaning food

Parameters	Weaning Food
Moisture content (% wb)	7.400 ± 0.256
Crude fiber (% db)	1.539 ± 0.16
Crude protein (% db)	13.88 ± 0.14
Crude Carbohydate (%db)	57.50 ± 1.00
Total ash content (% db)	4.699 ± 0.37
Acid insoluble ash (% db)	0.092 ± 0.02
Crude fat content(% db)	7.59 ± 0.21
Iron Content (% db)	46.75 ± 0.35
Vitamin C content (% db)	150.731 ± 0.39
Calcium content (% db)	160.55 ± 0.48

The values are expressed in 95% confidence level.

4.8.1 Determination of Energy Value

One of the methods specified by FDA is employed. This uses the general factors of 4, 4, and 9 calories per gram of protein, total carbohydrate, and total fat, respectively, to calculate the calorie content of food (Bassey and Edem, 2013).

$$\text{Total energy} = (4\times CHO + 4\times Protein + 9\times Fat)$$

$$= (4\times 57.50 + 4\times 13.88 + 9\times 7.59)$$

$$= 353.83 \text{ kcal/100 g}$$

4.9 Interpretation and test of significance

4.9.1 Protein

Table 4.6 Interpretation of the result for Protein

One sample T

N	Mean	SD	SE Mean	95% CI	T
8	13.89	0.16	0.06	(14.01, 13.74)	-19.35

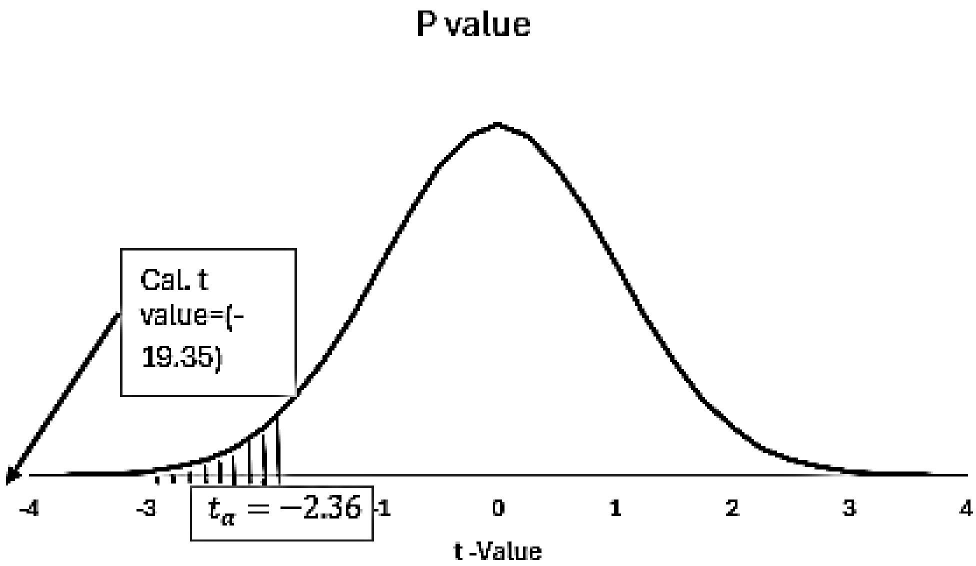


Fig. 4.3 Test of significance of protein.

The mean Protein content was 13.88%, compared to the Nepal government maximum standard of 15%. Under the 95% confidence level, (n= 8). the calculated t-value (–19.35) exceeded the tabulated value (2.3646), and the p-value was greater than 0.05. Thus, it does not reject null hypotheis, indicating that the observed Protein content lies within the standard. The result shows that the Protein content lies under Nepal government's requirements.

4.9.2 Fat

Table 4.7 Interpretation of the result for Fat

One sample T					
N	Mean	SD	SE Mean	95% CI	T Value
7	7.59	0.25	0.09	(7.80, 7.38)	-60.30

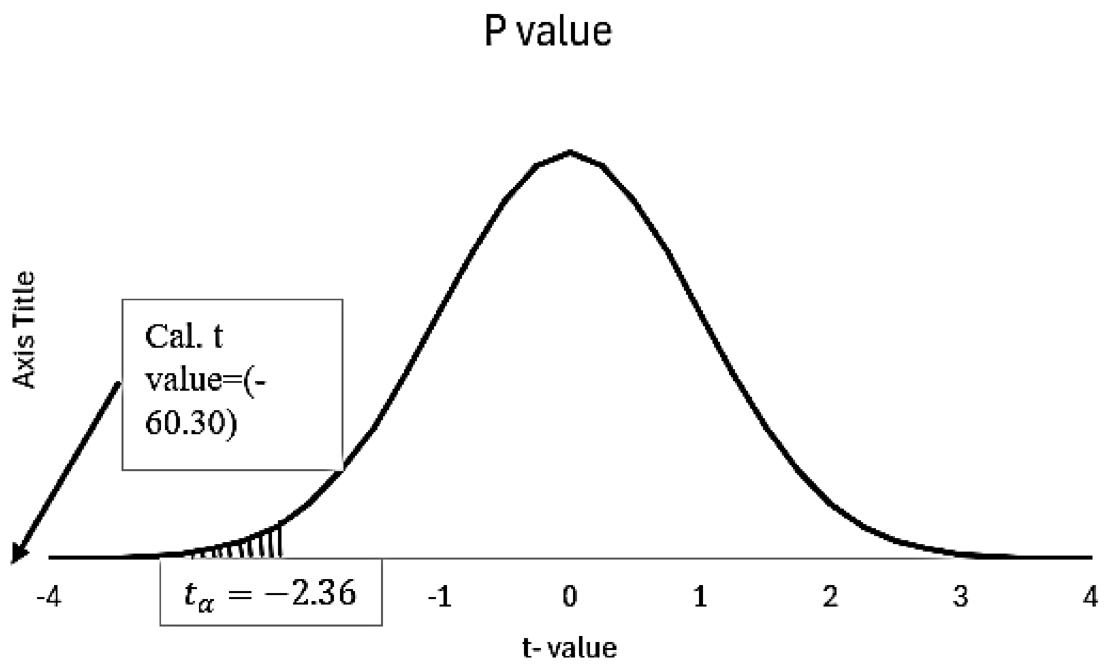


Fig. 4.4 Test of significance of fat.

The mean Fat content was 7.59 %, compared to the Nepal government maximum standard of 13%. Under the 95% confidence level, (n= 8), the calculated t-value (–60.30) exceeded the tabulated value (2.3646), and the p-value was greater than 0.05. Thus, it does not reject null hypotheis, indicating that the observed Fat content lies within the standard. The result shows that the Fat content lies under Nepal government's requirements.

4.9.3 Fiber

Table 4.8 Interpretation of the result for Fiber

One sample T					
N	Mean	SD	SE Mean	95% CI	T value
7	1.54	0.19	0.07	(1.70, 1.38)	- 21.35

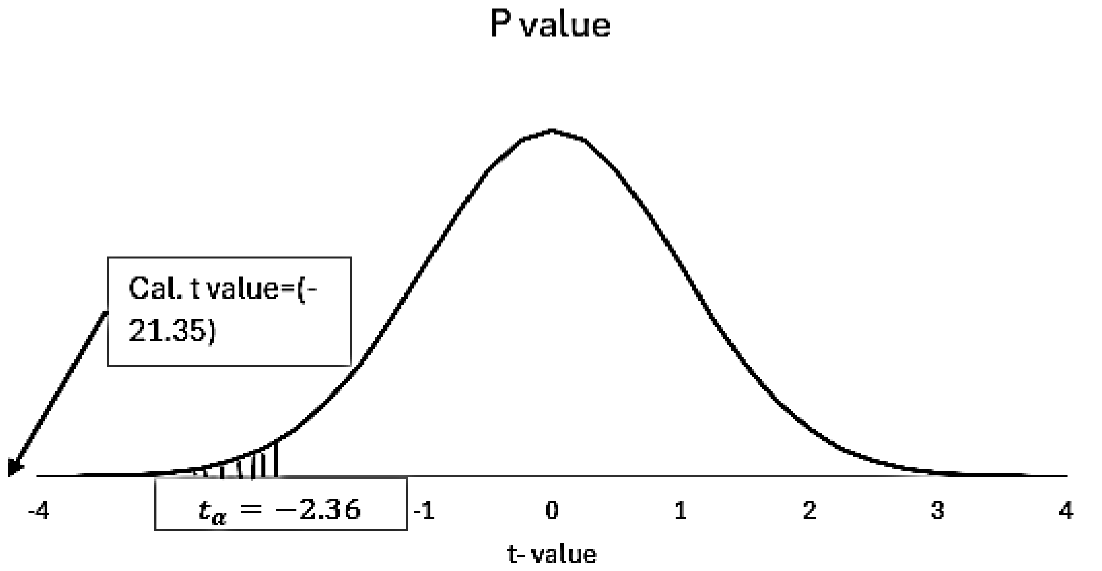


Fig. 4.5 Test of significance of fiber.

The mean fiber content was 1.53%, compared to the Nepal government maximum standard of 3%. Under the 95% confidence level, (n= 8). the calculated t-value (–21.34) exceeded the tabulated value (2.3646), and the p-value was greater than 0.05. Thus, the null hypothesis is not rejected, indicating that the observed fiber content lies within the standard. The result shows that the fiber content lies under Nepal government's requirements.

4.9.4 Iron

Table 4.9 Interpretation of the result for Iron

One sample T

N	Mean	SD	SE Mean	95% CI	T
7	6.75	0.42	0.15	(7.10,6.39)	6.31

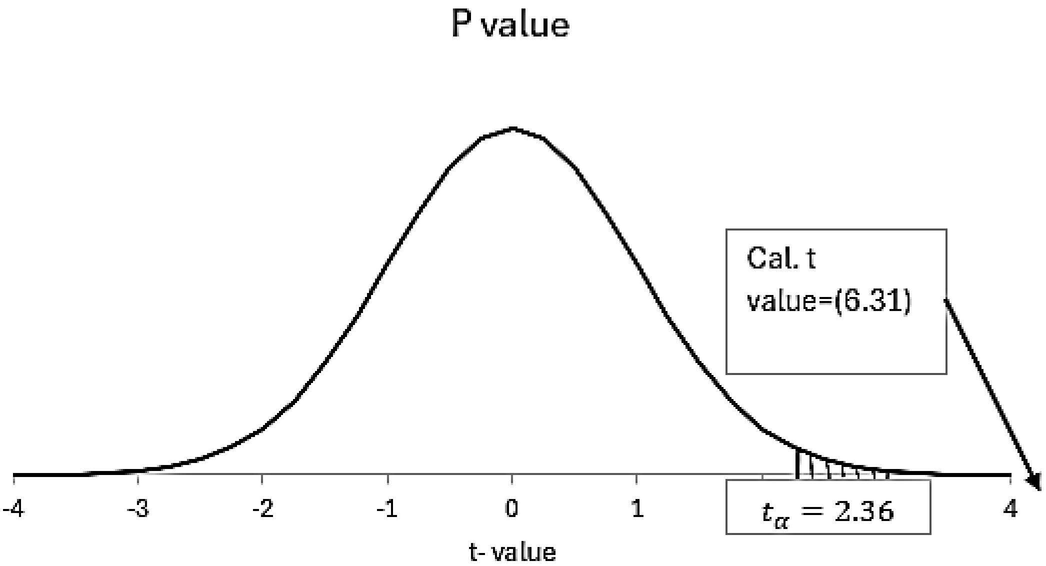


Fig. 4.6 Test of significance of iron.

The mean Iron content was 6.74 mg, compared to the Nepal government minimum standard of 5.8 mg. Under the 95% confidence level, (n= 8), the calculated t-value (6.31) exceeded the tabulated value (2.3646), and the p-value was smaller than 0.05. Thus, the null hypothesis is not accepted, indicating that the observed Iron content lies within the standard. The result shows that the Iron content lies under Nepal government's requirements.

4.9.5 Calcium

Table 4.10 Interpretation of the result for Calcium

One sample T					
N	Mean	SD	SE Mean	95% CI	T
7	160.55	0.56	0.20	(161.02, 160.09)	(-704.53)

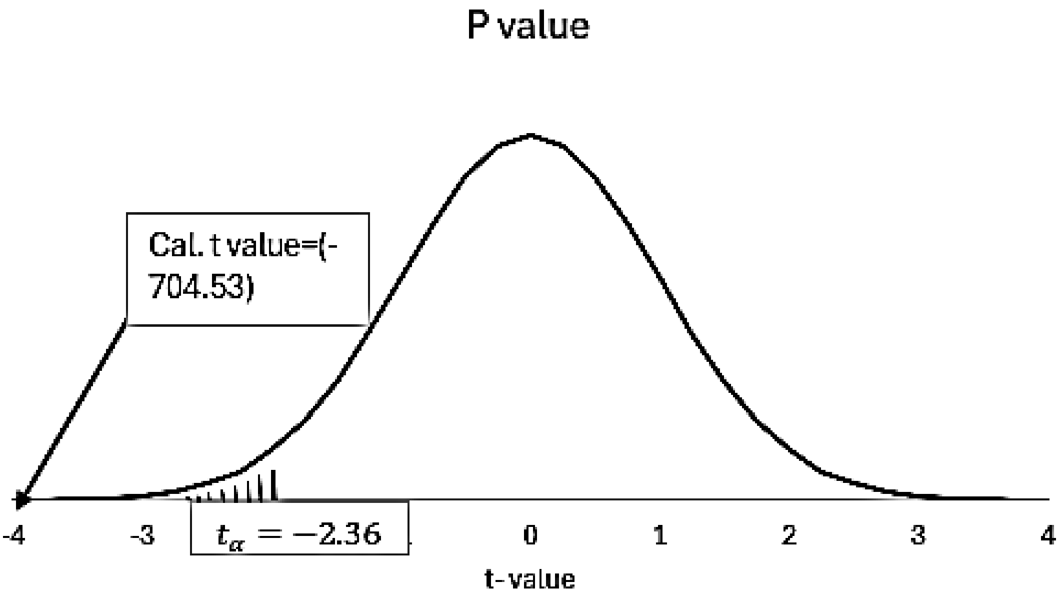


Fig. 4.7 Test of significance of Calcium.

The mean Calcium content was 160.55 mg, compared to the Nepal government minimum standard of 300 mg. Under the 95% confidence level, (n= 8), the calculated t-value (–704.53) exceeded the tabulated value (2.3646), and the p-value was greater than 0.05. Thus, the null hypothesis is not rejected, indicating that the observed Calcium content does not lie within the standard. The result shows that the Calcium content does not lie under Nepal government's requirements.

4.9.6 Moisture

Table 4.11 Interpretation of the result for Moisture

One sample T

N	Mean	SD	SE Mean	95% CI	T
7	7.400	0.305	0.1	(7.66, 7.15)	(-5.57)

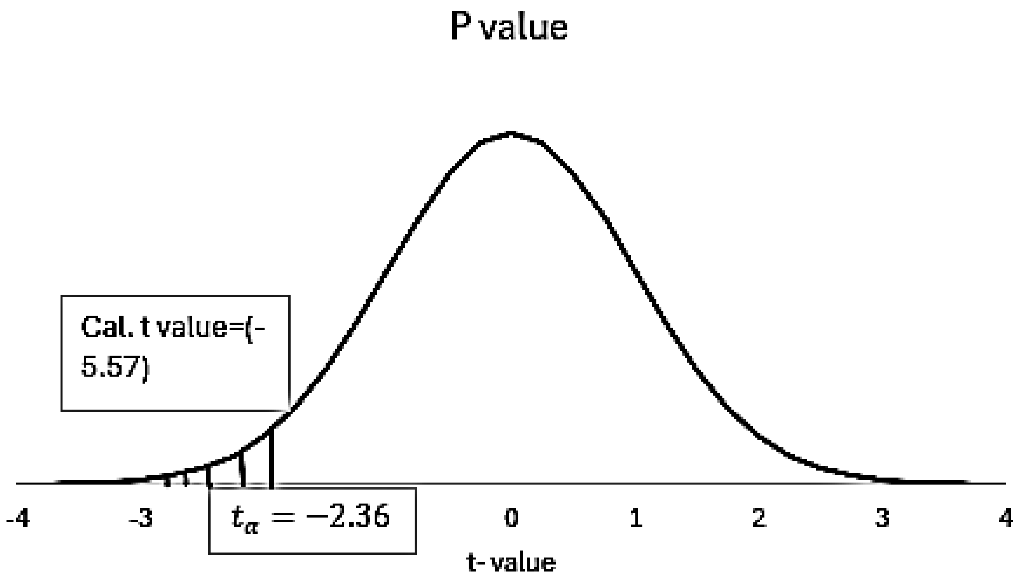


Fig. 4.8 Test of significance of Moisture.

The mean moisture content was 7.40 %, compared to the Nepal government maximum standard of 8 %. Under the 95% confidence level, (n= 8), the calculated t-value (–5.56) exceeded the tabulated value (2.3646), and the p-value was less than 0.05. Thus, the null hypothesis is not accepted, and indicating that the observed Moisture content lies within the standard. The result shows that the Moisture content lies under Nepal government's requirements.

4.9.7 Ash

Table 4. 12 Interpretation of the result for Ash

One sample T					
N	Mean	SD	SE Mean	95% CI	T
7	4.70	0.40	0.14	(5.03, 4.36)	(-30.52)

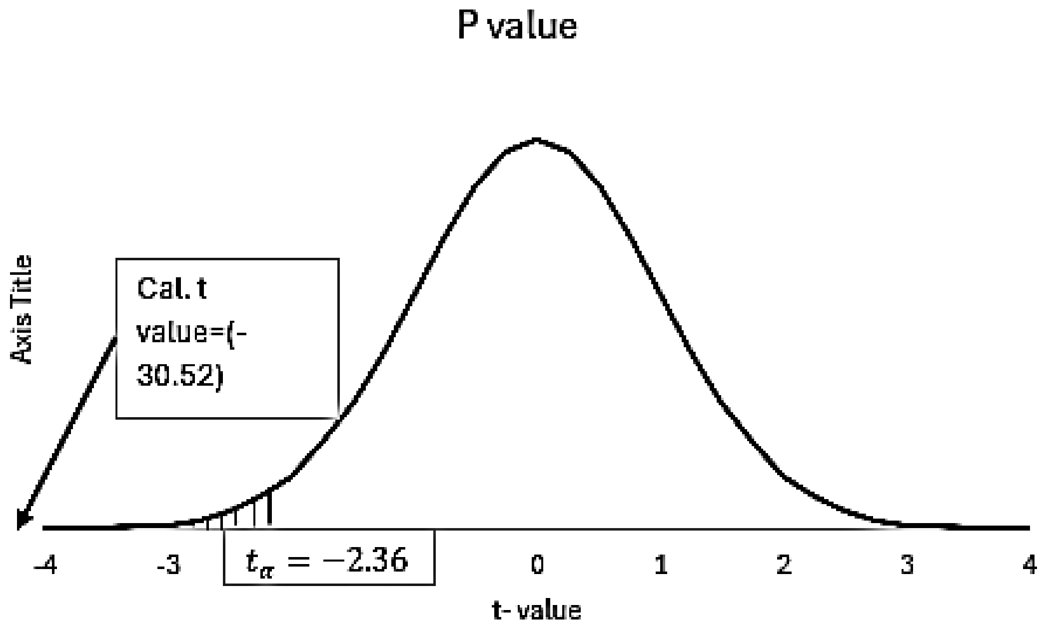


Fig. 4.9 Test of significance of Ash

The mean Ash content was 4.70 %, compared to the Nepal government maximum standard of 5%. Under the 95% confidence level, (n= 8), the calculated t-value (–30.52) exceeded the tabulated value (2.3646), and the p-value was greater than 0.05. Thus, it does not reject null hypotheis, indicating that the observed Ash content lies within the standard. The result shows that the Ash content lies under Nepal government's requirements.

4.9.8 Acid Insoluble Ash

Table 4.13 Interpretation of the result for Acid Insoluble Ash

One sample T

N	Mean	SD	SE Mean	95% CI	T
7	0.091	0.007	0.022	(0.03, -0.01)	(-46.24)

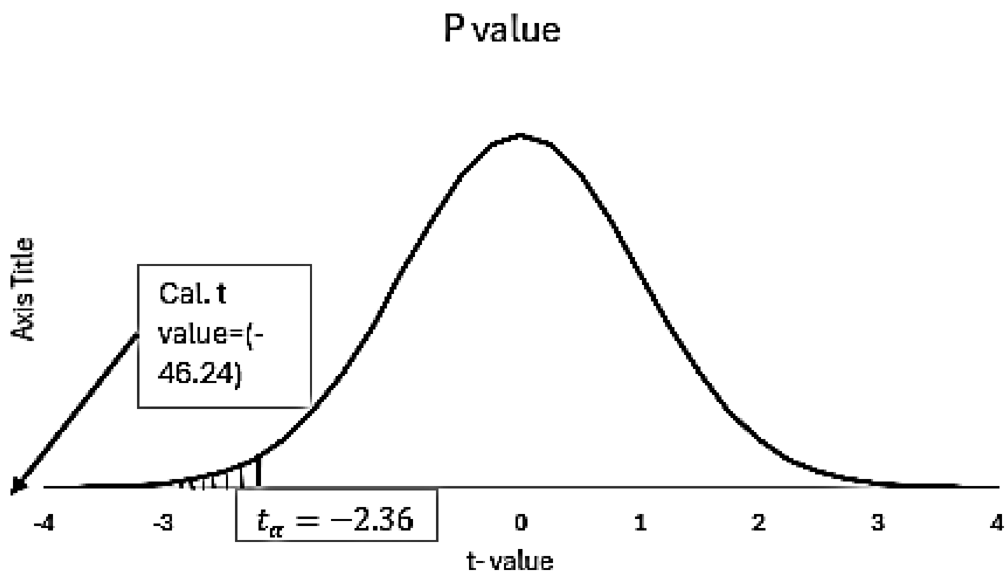


Fig. 4.10 Test of significance of Acid Insoluble Ash

The mean Acid Insoluble Ash content was 0.09 %, compared to the Nepal government maximum standard of 0.1%. Under the 95% confidence level, (n= 8), the calculated t-value (–0.008) exceeded the tabulated value (2.3646), and the p-value was greater than 0.05. Thus, it does not reject null hypotheis, indicating that the observed Acid Insoluble Ash content lies within the standard. The result shows that the Ash content lies under Nepal government's requirements.

4.9.9 Vitamin C

Table 4.14 Interpretation of the result for Vitamin C

One sample T					
N	Mean	SD	SE Mean	95% CI	T
7	150.73	0.16	0.46	(151.11, 150.35)	9.03

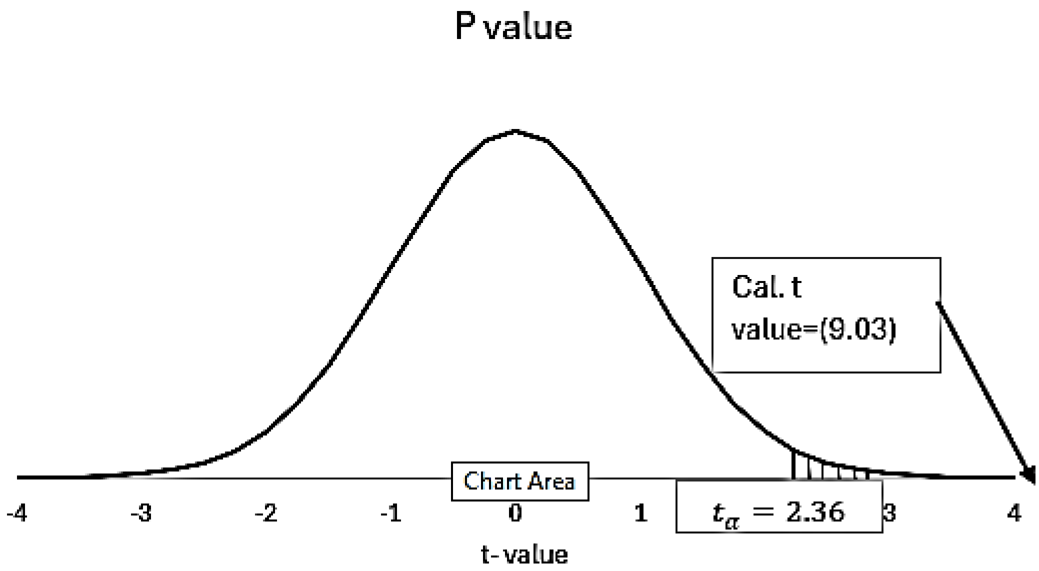


Fig. 4.11 Test of significance of Vitamin C

The mean Vitamin C content was 150.73 mg, compared to the Nepal government minimum standard of 80 mg. Under the 95% confidence level, (n= 8), the calculated t-value (9.03) exceeded the tabulated value (2.3646), and the p-value was greater than 0.05. Thus, it does not reject null hypotheis, indicating that the observed Vitamin C content lies within the standard. The result shows that the Vitamin C content lies under Nepal government's requirements.

4.9.10 Carbohydrate

Table 4.15 Interpretation of the result for Carbohydrate

One sample T					
N	Mean	SD	SE Mean	95% CI	T
7	57.49	1.21	0.43	(58.50, 56.48)	3.50

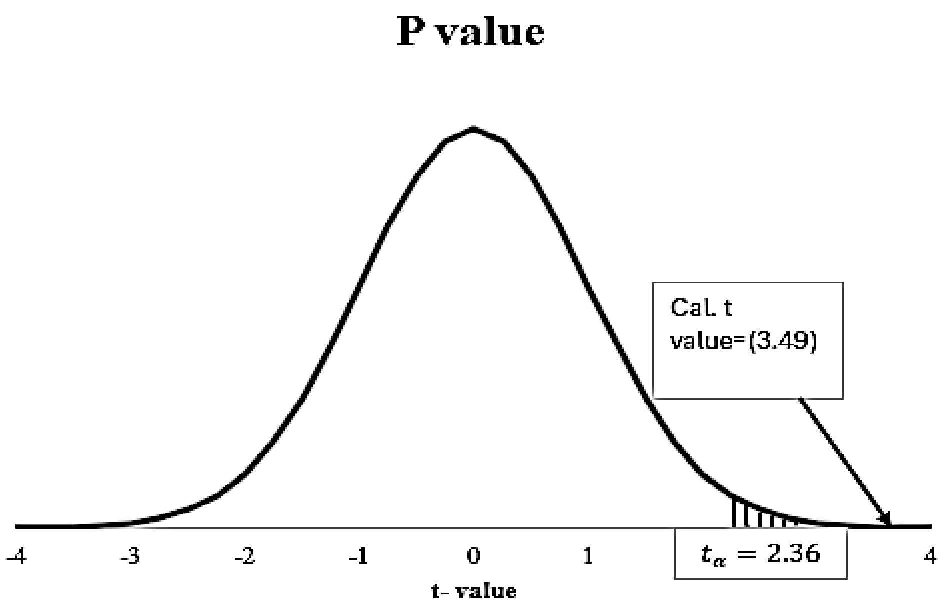


Fig. 4.12 Test of significance of Carbohydrate.

The mean Carbohydrate content was 57.49 g, compared to the Nepal government standard maximum standard of 56%. Under the 95% confidence level, (n= 8), the calculated t-value (3.49) exceeded the tabulated value (2.3646), and the p-value was less than 0.05. Thus, it does not reject Alternative hypotheis, indicating that the observed Carbohydrate content does not lie within the standard.

4.10 Proximate Composition

The proximate analysis of the formulations revealed protein content of 13.881%, CHO content 57.49%fat 7.59%, crude fiber 1.539%, and total ash 4.699 %, with moisture maintained at 7.400%. These values confirm that the blend of maize, rice, soybean, and moringa leaf powder provides a balanced macronutrient profile suitable for infant feeding. Compared to traditional cereal-based weaning foods, the inclusion of soybean and moringa significantly improved protein and mineral density, aligning with findings reported by Mishra *et al.* (2020). The presence of acid-insoluble ash (0.0918) indicates minimal contamination and good processing hygiene. Overall, physicochemical composition supports the product's suitability for weaning, aligning with WHO/WFP standards and comparable to values.

4.10.1 Micronutrient Content

Micronutrient analysis showed appreciable levels of iron (4.613 mg/100 g), calcium (160 mg mg/100 g), and vitamin C (150.731 mg/100 g). These values meet or exceed WHO recommendations for complementary foods, demonstrating that incorporation of moringa leaf powder enhanced the micronutrient profile. Similar improvements in lysine and calcium balance have been reported in blended flour studies using brewers' spent grain by Nembang (2023), supporting the potential of local crop fortification. However, while the overall composition appears nutritionally promising, one limitation was observed in calcium content. The measured value of 160 mg/100 g falls below the minimum requirement of 300 mg/100 g recommended for complementary foods. This shortfall suggests that calcium remains a limiting nutrient in formulation. The deficiency highlights the need for further fortification or incorporation of calcium-rich ingredients to meet the recommended dietary allowance. Similar challenges in achieving adequate calcium levels have been reported in cereal-legume blends, where fortification strategies are often necessary to ensure nutritional adequacy (Mishra *et al.*, 2020). Nutrient values change with origin, the calcium contribution of this ingredient here is insufficient.

4.11 Cost evaluation of the prepared weaning food

Table 4.16 Details of cost evaluation of the prepared weaning food (see appendix G)

S.N.	Particulars	Quantity	Cost
1.	Maize	168 g	17
2.	Soyabean	293.5 g	49
3.	Rice	502 g	60
4.	Moringa Leaf Powder	36.5	56
5.	Packaging	30 g	25
6.	Fuel and Electricity		200
7.	Labour charge		200
8.	Overhead cost (multiply by .07)		42.49
9.	Total Cost		649.49

4.12 Shelf-life estimation of the prepared flour

To evaluate the shelf life of moringa leaf powder based on vitamin C degradation, samples were packaged in glass jars and LDPE plastic pouches, then stored at 45 °C. Vitamin C content was measured at 2-day intervals over 14 days, and the degradation was modeled using first-order kinetics, where the natural logarithm of vitamin C concentration was plotted against time.

The degradation followed the first-order kinetic equation:

$$-\frac{dA}{dt} = kt$$

$$\ln A_0 - \ln A = Kt$$

$$t_s = \frac{\ln\left(\frac{A_0}{A_e}\right)}{k}$$

Where:

A= vitamin C concentration at time t

A_0 = initial concentration at time t=0

A_e = Quality of the moringa leaf, that decereases to a minimum acceptable level

k = degradation rate constant

t = time in days

t_s= time at the end of shelf life

For LDPE packaging, the regression equation derived from the plot was:

ln A =(-0.0134t+5.0047) and R^2=0.9805

This indicates a strong linear fit and a faster degradation rate. Using the equation, shelf life was calculated as the time when vitamin C drops below 50% of its initial value:

K=0.0134

So, $t_s = \frac{\ln\left(\frac{150.731}{15}\right)}{0.0134}$

=172.20 days (5 months 22 days)

The figure shows a steep decline in vitamin C content, confirming that LDPE packaging offers limited protection under elevated temperature.

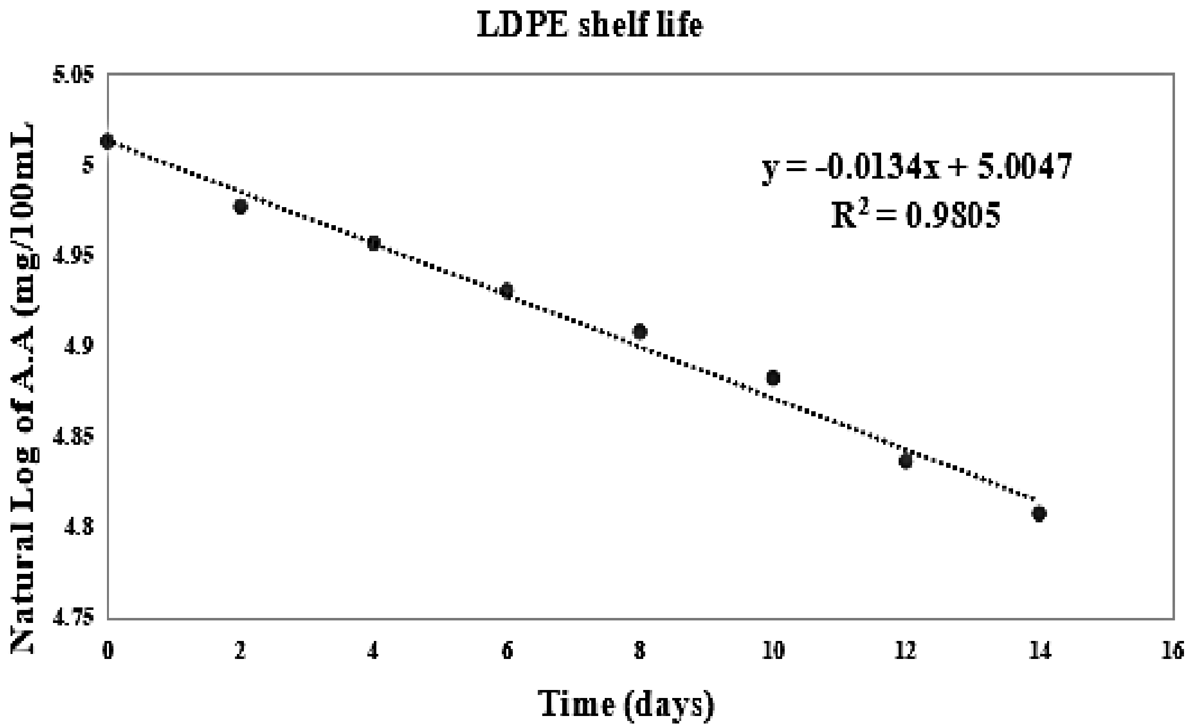


Fig. 4. 13 LDPE Shelf Life

Glass Packaging:

The regression equation for glass was:

ln A =(-0.0082t+5.0025) and R^2=0.9741

This slower degradation rate yielded a longer shelf life:

K=0.0082

So, $t_s = \frac{\ln\left(\frac{150.731}{15}\right)}{0.0082}$

= 281.40 days (9 months 11 days)

The corresponding figure shows a gentler slope, indicating better retention of vitamin C over time.

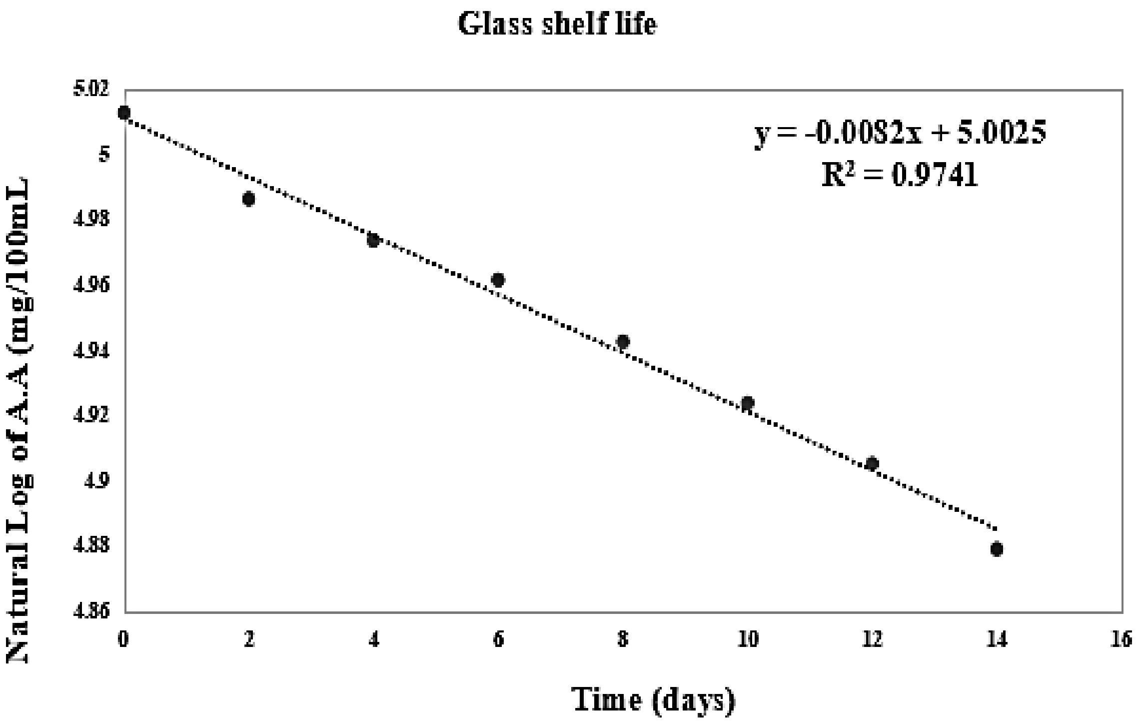


Fig. 4.14 Glass Shelf Life.

Part V

1. Conclusions and recommendations

5.1 Conclusion

From the above results and discussions, it can be concluded that:

1. Proximate analysis revealed that the formulated weaning food contained adequate levels of protein (13.88%), fat (7.59%), CHO (57.50%), fiber (1.54%), and total ash (4.70%), with moisture content maintained below 8%, which is favorable for shelf stability. The inclusion of soybeans significantly improved protein quality, while moringa leaf powder enhanced micronutrient density, particularly iron and vitamin C. The iron (6.45 mg/100 g) and vitamin C (150.73mg/100 g) contents were within or close to recommended ranges for complementary foods, indicating the product's potential to address common micronutrient deficiencies among infants.
2. Drying kinetics of moringa leaves at 45 °C showed a smooth exponential moisture loss pattern, confirming that low-temperature drying effectively reduced moisture while preserving heat-sensitive nutrients. Functional properties such as fine particle size ensured smooth texture, making the product suitable for infant consumption. Sensory evaluation indicated good acceptability of the formulated weaning food in terms of taste, texture, aroma, and overall preference, supporting its cultural and practical suitability.
3. Calcium content (160.56 mg/100 g) was lower than recommended standards, indicating that calcium remains a limiting nutrient in the formulation. Despite this limitation, the overall findings demonstrate that nutrient-rich, affordable, and acceptable weaning foods can be developed using local resources and simple processing techniques. This formulation has strong potential to support improved complementary feeding practices and contribute to reducing infant malnutrition in Nepal.

4. The weaning food formulation was successfully optimized using linear programming to meet defined nutritional constraints for protein, iron, fiber, vitamin C, and calcium. The initial model showed that maize was not mathematically required, as a blend of rice (0.0695), soybean (0.299), and moringa leaf powder (0.0365) satisfied all nutrient targets. However, to improve the amino acid profile—particularly lysine and methionine—and enhance functional properties, maize was reintroduced in the final formulation. The adjusted blend (Maize 16.80%, Soybean 29.39%, Rice 50.21%, Moringa 3.60%) provided a nutritionally balanced composition suitable for infant growth, while also supporting practical sample production at the 1 kg scale.
5. The shelf life of moringa leaf powder was significantly longer in glass packaging (281.40 days) compared to LDPE (172.20 days). This confirms that glass packaging is more effective in preserving vitamin C under accelerated storage conditions.
6. The unsalted formulation is considered more suitable for infants despite having lower sensory score as it complies with infant nutrition guidelines that recommend avoiding the use of added salt during complementary feeding.

5.2 Recommendations

1. Based on the findings of this study, the following recommendations are proposed:
2. Calcium enhancement
   Future formulations should incorporate calcium-rich ingredients such as sesame seeds, small fish powder, milk powder, or eggshell calcium to meet recommended calcium requirements for infants.
3. Fortification strategies
   Nutrient fortification, particularly with calcium, zinc, and vitamin A, should be explored to further improve the nutritional adequacy of the weaning food.
4. Microbiological analysis
   Comprehensive microbiological testing should be conducted to ensure product safety and confirm suitability for infant consumption during storage.
5. Extended shelf-life studies
   Shelf-life evaluation should be expanded under different storage conditions and packaging materials to determine commercial feasibility and long-term stability.
6. Processing optimization
   Further optimization of germination, roasting, and drying parameters may enhance nutrient bioavailability and reduce residual anti-nutritional factors.
7. Policy and nutrition programs
   The developed weaning food formulation can be considered for inclusion in national nutrition programs and community-based interventions aimed at combating child malnutrition in Nepal.
8. Scale-up and commercialization
   Collaboration with local food processors and cooperatives is recommended to scale up production and make the product accessible to low-income households.
9. Instead of using added salt, the inclusion of naturally sweet vegetables and Milk Powders as well as certain processes such as germination or roasting can be done to improve acceptability while preparing baby food.

PART VI

2. Summary

This study focused on developing a nutrient-dense, locally sourced weaning food for infants in Nepal using maize, rice, soybean, and moringa leaf powder. Appropriate processing techniques like soaking, roasting, drying, grinding, and blending were applied, and linear programming was used to optimize the formulation for balanced nutrition, cost-effectiveness, and local applicability.

Proximate analysis showed that the weaning food contained adequate protein (14.65%), fat (7.80%), CHO (57.50%), fiber (1.70%), and ash (5.03%), with moisture below 8%, supporting good shelf stability. Soybean improved protein quality, while moringa leaf powder enhanced micronutrient content, particularly iron (5.85 mg/100 g) and vitamin C (150.73 mg/100 g). These levels were within or close to recommended values for complementary foods, suggesting potential to address common infant nutrient deficiencies.

Functional properties, such as fine particle size ensure smooth texture. Drying kinetics of moringa leaves at 45 °C indicated effective moisture reduction while preserving heat-sensitive nutrients. Sensory evaluation demonstrated high acceptability in taste, texture, aroma, and overall preference. However, calcium content (161 mg/100 g) was below recommended levels, indicating the need for calcium-rich ingredients in future formulations.

The study highlights that locally available ingredients, combined with simple processing techniques and optimization, can produce affordable, acceptable, and nutrient-rich weaning foods. Recommendations include calcium fortification, microbiological testing, extended shelf-life studies, community feeding trials, processing optimization, and potential scale-up for commercial production. The developed formulation has strong potential to improve complementary feeding practices and contribute to reducing infant malnutrition in Nepal.

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Appendices

Appendix-A

1. Sensory evaluation card

Mc Nemer Test

Weaning Food

Name……………………….
Date……………………….…

Tester Number………….
Code……………………………

Please rinse your mouth with water before starting.

Please test the sample present on the table. You may test as much as you would like, but you must consume at least half the sample provided. If you have any questions, ask the server now.

Circle the sample you prefer

(You must make a choice)

yes **no**

Thank you for your participation**.**

Any comments……………………………………………………………………

Appendix-B

1. **Sensory evaluation using Mc Nemer test**

		Product A	
Product B		preferrable	not preferrable
	Yes	3	1
	No	16	4

((1-16)-1)^2/(1+16)

15.059 chi inv value

Appendix-C

C1. Estimation and Significance test by constraints:

C1.1 <u>Protein content=15%</u>

Final product protein content = 13.881

Standard deviation=0.16

$$t = \frac{\bar{x} - \mu_0}{S/\sqrt{n}}$$

$$t = \frac{13.881 - 15}{0.16/\sqrt{8}}$$

= -19.35

Hence, the tabulated value (-19.35) indicates that the null hypothesis is not rejected.

C1.2 <u>Fiber content= 3 %</u>

Final product fiber content = 1.53

Standard deviation=0.19

$$t = \frac{\bar{x} - \mu_0}{S/\sqrt{n}}$$

$$t = \frac{1.53 - 3}{0.19/\sqrt{8}}$$

= -21.34

Hence, the tabulated value (-21.34) indicates that the null hypothesis is not rejected.

C1.3 <u>Iron content = 5.8 mg</u>

Final product Iron content = 6.75 mg

Standard deviation=0.42

$$t = \frac{\bar{x} - \mu_0}{S/\sqrt{n}}$$

$$t = \frac{6.75 - 5.8}{0.42/\sqrt{8}}$$

= 6.31

Hence, the tabulated value (6.31) indicates that the null hypothesis is not accepted.

C.1.4 <u>Calcium content = 300 mg</u>

Final product calcium content =160.55

Standard deviation=0.56

$$t = \frac{\bar{x} - \mu_0}{S/\sqrt{n}}$$

$$t = \frac{160.55 - 300}{0.56/\sqrt{8}}$$

= -704.53

Hence, the tabulated value (-704.53) indicates that the null hypothesis is not rejected

C.1.5 <u>Moisture content=8%</u>

Final product moisture content = 7.40

Standard deviation=0.31

$$t = \frac{\bar{x} - \mu_0}{S/\sqrt{n}}$$

$$t = \frac{7.40 - 8}{0.31/\sqrt{8}}$$

= -5.56

Hence, the tabulated value (-5.56) indicates that the null hypothesis is not accepted.

C.1.6 <u>Ash content =5</u>

Final product ash content = 4.66

Standard deviation=0.40

$$t = \frac{\bar{x} - \mu_0}{S/\sqrt{n}}$$

$$t = \frac{4.66 - 5}{0.40/\sqrt{8}}$$

= -30.52

Hence, the tabulated value (-30.52) indicates that the null hypothesis is not rejected.

C.1.7 <u>Acid Insoluble Ash content = 0.1%</u>

Final product Acid Insoluble Ash content = 0.09

Standard deviation=0.022

$$t = \frac{\bar{x} - \mu_0}{S/\sqrt{n}}$$

$$t = \frac{0.09 - 0.1}{0.022/\sqrt{8}}$$

= -46.24

Hence, the tabulated value (-46.24) indicates that the null hypothesis is not rejected.

C.1.8 <u>Fat content = 13</u>

Final product fat content = 7.59

Standard deviation=0.25

$$t = \frac{\bar{x} - \mu_0}{S/\sqrt{n}}$$

$$t = \frac{7.59 - 5}{0.25/\sqrt{8}}$$

= -60.31

Hence, the tabulated value (-60.31) indicates that the null hypothesis is not rejected.

C.1.9 <u>Vitamin C content = 150</u>

Final product Vitamin C content = 150.73

Standard deviation = 0.45

$$t = \frac{\bar{x} - \mu_0}{S/\sqrt{n}}$$

$$t = \frac{150.73 - 150}{0.45/\sqrt{8}}$$

= 9.03

Hence, the tabulated value (9.03) indicates that the null hypothesis is not rejected.

Appendix-D

Determination of Sample size for sensory analysis

Z- value for 95% confidence level = 1.96

Population Proportion($\widehat{P}$)= 0.5

Margin of error (Σ) = 0.05

N=sample size

Then, n = $\frac{z^2\hat{p}(1-\hat{P})}{\Sigma^2}$

So, n = = $\frac{1.96^2 * 0.5(1-0.5)}{0.05^2}$

= 24.01 people

Appendix- E

Shelf life estimation using Vitamin C.

	ldpe		glass	
Time(days)	A.A(mg/100ml	Ln(A)	A.A(mg/100ml	Ln(A)
0	150.3	5.012633297	150.3	5.012633297
2	145	4.976733742	146.38	4.98620598
4	142.1	4.956531035	144.54	4.973556286
6	138.4	4.930148043	142.78	4.961304984
8	135.3	4.907494535	140.1	4.942356453
10	131.9	4.88204406	137.49	4.923551187
12	126	4.836281907	134.95	4.904904339
14	122.4	4.80729437	131.47	4.878778689

Appendix- F

WHO Nutrient Guidelines for Supplementary Foods (MAM, 6–59 Months)

Category	Nutrient	Unit	Minimum	Maximum
Macronutrients	Protein	g	20	43
	Fat	G	25	65
Minerals	Sodium (Na)	mg	-	500
	Calcium (Ca)	Mg	1000	1400
	Iron (Fe)	mg	18	30
Water-Soluble Vitamins	Vitamin C (Ascorbate)	mg	>150	-
Nutrient Ratios	Ca/p	-	1	1.5
	Vitamin C/Fe	-	3	16

Source: (World Health Organization, 2012).

Appendix G

Cost evaluation

	Rice	Soyabean	Maize	Moringa		package
cost/kg	120	170	100	1500		840
wt. used in g	0.5	0.29	0.168	0.037		0.03
Actual Cost	60	49.3	16.8	55.5	181.6	25.2

Appendix

Photo gallery

Fig. 8.1: Determination of Iron by colorimeter.

Fig. 8.2: Calcium Content determination by volumetric method.

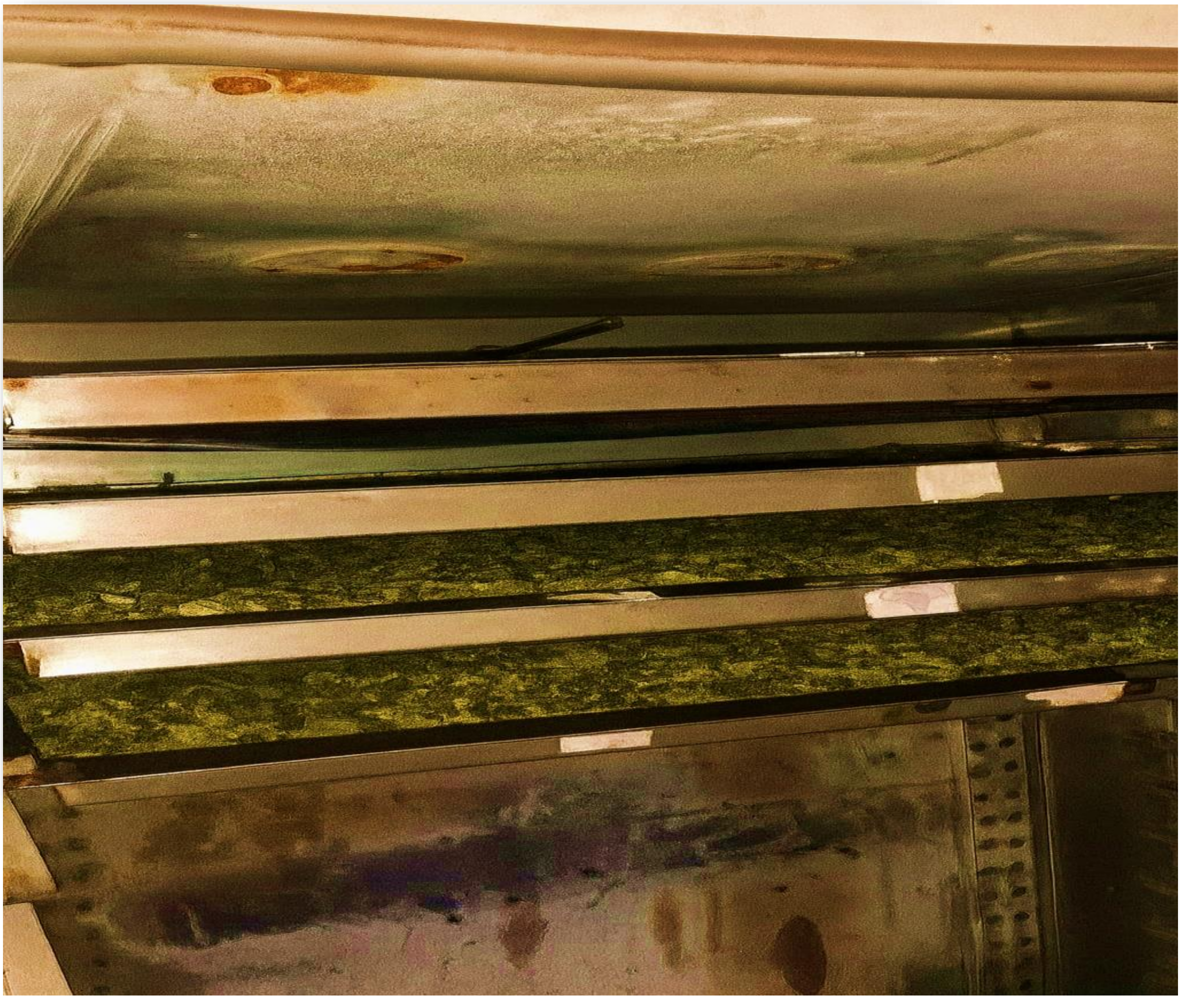

Fig. 8.3: Drying of Moringa leaves.

Fig. 8.4: Determination of Crude Fiber.

Fig. 8.5: Sieving of the prepared flour.