EFFECT OF INCORPORATION OF *MORINGA OLEIFERA* LEAF IN STICK NOODLES AND ITS STORAGE STABILITY

by

Asmita Bhandari

Department of Food Technology

Central Campus of Technology

Institute of Science and Technology

Tribhuvan University, Nepal

2022

Effect of Incorporation of *Moringa oleifera* Leaf in Stick Noodles and its Storage Stability

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

by

Asmita Bhandari

Department of Food Technology

Central Campus of Technology, Dharan

Institute of Science and Technology

Tribhuvan University, Nepal

December, 2022

Tribhuvan University

Institute of Science and Technology

Department of Food Technology

Central Campus of Technology, Dharan

Approval Letter

This ***dissertation*** entitled ***Effect of Incorporation of Moringa oleifera Leaf in Stick Noodles and its storage stability*** presented by **Asmita Bhandari** has been accepted as the partial fulfillment of the requirement for the **B. Tech. degree in Food Technology**

Dissertation Committee

1. **Head of the Department** ____________________

   (Mr. Navin Gautam, Asst. prof.)

2. **External Examiner** ____________________

   (Mr. Dinesh Subedi, Food Research Officer)

3. **Supervisor** ____________________

   (Mrs. Mahalaxmi Pradhananga, Asst. prof.)

4. **Internal Examiner** ____________________

   (Mr. Sabin Bahadur Khatri, Teaching Asst.)

December 29, 2022

Acknowledgements

It has been an immense honor to carry out research work under the supervision of respected Asst. Prof. Mahalaxmi Pradhananga to whom I would like to express my heartfelt gratitude for always providing constant guidance, enthusiastic support, frequent inspiration and valuable insights to coordinate the sources of information and proceed to the research work.

I am also grateful to Asst. Prof. Navin Gautam, Head of Department of Food Technology, for providing necessary facilities during the work. I would similarly like to thank the campus chief of Central Campus of Technology, Assoc Prof. Dr. Dil Kumar Limbu as well as all the lecturers of the campus for their continuous guidance towards academic excellence. I would like to thank my senior Mr. Saroj Katwal for helping me on writing this thesis.

I would like to acknowledge the laboratory and library staff for being so cooperative in times of need. I would also like to thank all my juniors, seniors and classmates for helping me directly and indirectly.

Finally, I owe my deepest gratitude to my parents Mr Abhi Narayan Bhandari and Mrs. Jaya Bhandari, my sister Abijita Bhandari for constant support and motivation.

Date of submission: December 29, 2022

(Asmita Bhandari)

Abstract

The aim of the work was to improve the nutritional value of the noodle product. Seven formulations were made using wheat flour and moringa leaf ratio 100:0, 96.25:3.75, 95:5, 92.5:7.5, 90:10, 88.75:11.25, 85:15 respectively coded as A, B, C, D, E, F and G. Nine point hedonic rating was used for sensory analysis and Genstat release 12.1 was used for statistical analysis. Moringa leaf were brought from Dharan and cabinet dried to make powder.

Analysis of wheat flour and moringa leaf powder showed that moringa leaf was superior in crude protein, crude fat, crude fiber, ash, minerals, antioxidant activity and chlorophyll content. Sample B which had 3.75 parts (w/w) moringa leaf powder was superior in terms of colour, texture and overall acceptance. Furthermore, control and superior sample were subjected to proximate analysis, chemical analysis, antioxidant activity, chlorophyll, phytate, tannin content, and cooking test. The moisture, crude fat, crude protein, crude fiber, ash, and carbohydrate of control and superior noodles were ranged from 10.76-8.83%, 0.43-0.51%,10-9.93%, 0.62-2%, 0.97-2.27% and 87.98-85.29% respectively. Result of mineral composition showed that calcium ranged from 3.67-6.07 mg/100g and iron 0.20-1.63 mg/100g. The antioxidant activity and chlorophyll content ranged from 23.94-26.88% and 0.46-0.82 mg/100g respectively. The phytate content ranged from 3.54-3.88 mg/100g and tannin 0.94-1.52 mg/100g. The cooking time varied from 8.33-7.17min, cooking loss 1.21-3.45%, water absorption capacity 121.63-170.07%. The shelf life study of superior noodles packaged in LDPE at room temperature showed that it was acceptable upto 3 months in terms of moisture content, TPC, yeast and mold.

Table of Contents

Approval Letter .... **iii**

Acknowledgements .... **iv**

Abstract .... **v**

List of Tables .... **xi**

List of Figures .... **xii**

List of Plates .... **xiii**

List of Abbreviations .... **xiv**

1. Introduction **1-4**

1.1 General Introduction 1

1.2 Statement of the problem 2

1.3 Objectives 3

1.3.1 General objectives 3

1.3.2 Specific objectives 3

1.4 Significance of the study 3

1.5 Limitations of the study 4

2. Literature Review **5-28**

2.1 Historical background 5

2.2 Classification of macaroni products 6

2.2.1 Extruded solid macaroni product 6

2.2.2 Noodles 7

2.2.3 Specialties 7

2.2.4 Extruded hollow macaroni product 7
2.3 Raw Materials for noodles making: 7
2.3.1 Wheat Flour 7
2.3.2 Salt (sodium chloride) 13
2.3.3 Water 13
2.4 Dough properties 14
2.4.1 Classification of dough according to temperature of water 14
2.4.2 Classification of dough according to moisture content 15
2.5 Technology of noodles making 15
2.5.1 Mixing and kneading 17
2.5.2 Sheeting 17
2.5.3 Cutting 17
2.5.4 Drying process of pasta products including noodles 18
2.6 Factor affecting quality of noodles 18
2.6.1 Based on raw materials 18
2.6.2 Based on salt used 18
2.6.3 Based on size 19
2.6.4 Based on processing 19
2.7 Moringa plant 19
2.7.1 Taxonomy of *Moringa oleifera* 20
2.7.2 *Moringa oleifera* in Nepal 20
2.7.3 Nutritive Value of *Moringa oleifera* plant 21

2.7.4 Consumption pattern of *Moringa oleifera* ... 21
2.7.5 Uses of Moringa: a multipurpose tree ... 22
2.7.6 Medicinal importance of *Moringa oleifera* ... 22
2.7.7 *Moringa oleifera* leaves ... 24
2.7.8 Composition of *Moringa oleifera* leaf ... 24
2.7.9 Nutritive properties of moringa leaves ... 25
2.7.10 Antinutritive properties of *Moringa oleifera* leaves ... 27
2.7.11 Suitability of moringa for noodles ... 28
3. Materials and methods ... 29-38
3.1 Materials ... 29
3.1.1 Collection of raw materials ... 29
3.1.2 Chemicals used ... 29
3.1.3 Equipment required ... 29
3.2 Method of Experiment ... 29
3.2.1 Methodology ... 29
3.2.2 Formulation of recipe ... 30
3.2.3 Preparation of moringa leaf powder ... 30
3.2.4 Preparation of noodles ... 31
3.3 Analytical Procedures ... 34
3.3.1 Determination of moisture content ... 34
3.3.2 Determination of crude fat ... 34
3.3.3 Determination of crude fiber ... 34

3.3.4 Determination of crude protein 34

3.3.5 Determination of ash content 34

3.3.6 Determination of carbohydrate 34

3.3.7 Determination of calcium content 34

3.3.8 Determination of iron content 35

3.3.9 Determination of Antioxidant Activity 35

3.3.10 Determination of chlorophyll 35

3.3.11 Determination of tannin 36

3.3.12 Determination of phytate 36

3.4 Microbiological analysis 36

3.5 Sensory analysis 37

3.6 Statistical analysis 37

3.87 Cooking Test of the product 37

3.7.1 Determination of Cooking Time 37

3.7.2 Determination of Cooking Loss 37

3.7.3 Determination of Water Absorption Capacity 38

4. Result and discussion 39-55

4.1 Proximate Analysis of raw materials 39

4.2 Chemical Analysis of wheat flour and moringa leaf powder 41

4.3 Antioxidants of wheat flour and moringa leaf powder 41

4.4 Anti-nutrients of wheat flour and moringa leaf powder 42

4.5 Sensory analysis of moringa incorporated noodles 42

4.5.1 Colour 43

4.5.2 Taste 44

4.5.3 Texture 45

4.5.4 Aroma 47

4.5.5 Overall acceptance 48

4.6 Comparison of superior noodles with control noodles 50

4.6.1 Overall comparison in terms of proximate components 50

4.6.2 In terms of minerals 51

4.6.3 In terms of antioxidants 52

4.6.4 In term of anti-nutrients 52

4.7 Shelf life study of moringa incorporated noodles 53

4.8 Cooking properties of control and superior noodles 54

4.9 Cost of the noodles incorporated with *Moringa* flour. 55

5. Conclusions and recommendations 56

5.1 Conclusions 56

5.2 Recommendations 56

6. Summary 57

References 58-66

Appendices 67-80

Color plates 81-82

List of Tables

Table No.	Title	Page No.
2.1	Composition of wheat flour	9
2.2	Genetic constitution of wheat	10
2.3	Analytical composition of wheat flour and its primary components	12
2.4	Mineral composition of wheat flour	12
2.5	Wheat flour grades	13
2.6	Classification of dough according to the temperature of water	15
2.7	Classification of dough according to moisture content	15
2.8	Energy value of different parts of moringa plant	21
2.9	Common medicinal uses of different parts of *Moringa oleifera*	23
2.10	Proximate composition of leaf	25
2.11	Antioxidant activity of different parts of *Moringa oleifera* plant	26
2.12	Chlorophyll content of *Moringa oleifera* leaves	27
2.13	Antinutritive value of *Moringa oleifera* leaves	27
3.1	Recipe formulation of noodles	30
4.1	Proximate composition of wheat and moringa leaf powder	39
4.2	Chemical analysis of wheat and moringa leaf powder	41
4.3	Antioxidants of wheat and moringa leaf powder	41
4.4	Anti-nutrients of wheat and moringa leaf powder	42
4.5	Proximate composition of superior and control noodles	50
4.6	Chemical analysis of superior and control noodles	51
4.7	Antioxidants of superior and control noodles	52
4.8	Anti-nutrients of superior and control noodles	52
4.9	Microbial load of superior and control noodles	54
4.10	Cooking properties of superior and control noodles	55

List of Figures

Figure No.	Title	Page No.
2.1	Structure of wheat grain	9
2.2	Technology of noodles making	16
3.1	Flowchart of moringa leaf powder preparation	31
3.2	Flowchart for moringa leaf powder incorporated noodles	33
4.1	Mean sensory scores for colour of noodles	43
4.2	Mean sensory scores for taste of noodles	44
4.3	Mean sensory scores for texture of noodles	45
4.4	Mean sensory scores for aroma of noodles	47
4.5	Mean sensory scores for overall acceptance of noodles	48
4.6	Moisture content of superior and control noodles upto 3 months	53

List of Plates

Color Plate No.	Title	Page no.
Color Plate 1	Raw material (moringa leaves)	81
Color Plate 2	Cabinet drying of moringa leaves	81
Color Plate 3	Sheeting of dough	81
Color Plate 4	Cutting of sheeted dough	81
Color Plate 5	Drying of stick noodles in closed room	82
Color Plate 6	Sample B (superior sample) after boiling	82

List of Abbreviations

Abbreviations	Full form
AA	Antioxidant activity
ANOVA	Analysis of Variance
AOAC	Association Of Analytical Communities
AR	Analytical reagent
DPPH	2,2-Diphenyl-1-picrylhydrazyl
IC_{50}	Half maximal inhibitory concentration
LDPE	Low-density polyethylene
TPC	Total plate count
WAC	Water absorption capacity

Part I

Introduction

1.1 General Introduction

Today’s lifestyle of individual is becoming more hectic, and people have very less time in preparing meals, this eventually affecting the rise in interest towards snacking patterns. Noodles are one of the oldest forms of processed food consumed. It is a staple food in many cultures and their global consumption is second only to bread. Noodles are made from unleavened dough which is stretched, extruded, or rolled flat and cut into one of a variety of shapes. It is frequently taken as a replacement for rice during the main meals or in between meals. While long, thin strips may be the most common, many varieties of noodles are cut into waves, helices, tubes, strings, shells, folded over, or cut into other shape (Ananthu and Singh, 2018). Noodles are widely consumed throughout the world due to convenience, ease of cooking, widely acceptable taste, flavour as well as affordable prices. Noodles are made from wheat flour, starch, water, salt and other ingredient that improve the texture of noodles. It is served in variety of forms that include raw, partially boiled, boiled, dried, steamed and fried. It is usually cooked in boiling water, sometimes with cooking oil or salt added (Nandkule *et al.*, 2015). Quality factor important for noodles are colour, flavour, texture and cooking quality, rehydration rates during final preparation and the presence or absence of rancid taste after extended storage (Pakhare *et al.*, 2016).

Green leafy vegetables occupy an important place among the food crops as these provide adequate amounts of many vitamins and minerals for humans. In nature, there are many underutilized greens of promising nutritive value, which can nourish the ever increasing human population (Joshi and Mathur, 2010). Moringa, “The Queen of Green”, is a medium-sized (about 10 meters high) tree belonging to the Moringaceae family. Moringa trees are commonly known by names such as ‘horse-radish’ tree or ‘drum stick tree’. It is called sitalchini in Nepali. They are available in the mid-hills and Terai of Nepal. Moringa is considered one of the world’s most useful trees, as almost every part of the tree can be used for food or has some other beneficial property. The roots, leaves, bark and pods are said to have medicinal properties. It is considered as one of the world’s most useful plant and thus all the plant parts is widely used in curing various ailments like antibiotic, anti-hypertensive, antispasmodic, antiulcer, anti-inflammatory, anti-asthmatic, hypocholesterolemic and hypoglycemic (Singh,Y. and Prasad,K. 2013).

Noodles products are popular throughout the world but it lacks different minerals and many other nutrients as it is a commodity primarily made of wheat flour and water. Nowadays, healthy and nutritious product requirement has been increasing. Therefore, research on the nutrition-rich but neglected crop is becoming visible to ensure global food security and to satisfy the nutritional need. Research indicated that moringa tree leaf powder has good nutritional value, but it is not yet customized and properly consumed (Zula *et al.*, 2021) . Therefore, a study was designed to utilize moringa leaves to develop value-added fortified noodles and to determine its nutrient composition.

1.2 Statement of the problem

Noodles are one of the oldest forms of processed food consumed. It is widely consumed throughout the world since it is convenient, easy to cook and of low cost with a relatively long shelf life. It is frequently taken as a replacement for rice during the main meals or in between meals. The consumption rate of noodles is increasing day by day, but the nutritional composition is limited with low fat, protein, minerals and fiber (Orisa and Ukpong, 2019).

Moringa oleifera (Drumstick tree) is one such tree having enormous nutritional and medicinal benefits. It is rich in macro and micro nutrients like protein, carbohydrate, calcium, phosphorus, potassium, iron, vitamins, beta carotene and other bioactive compounds which are important for normal functioning of the body and prevention of certain diseases. *Moringa oleifera* has tremendous therapeutic properties including anticancer, antiulcer, antimicrobial, antioxidant (Sahay *et al.*, 2017). Moringa tree grows well in a temperature range of 25°C to 35°C, but it also tolerates light frosts and temperatures up to 48° C. The mid-hills, foot-hills and terai region of Nepal is the most suited climate for its cultivation (Devkota and Bhusal, 2020). But use of moringa is narrowed to domestic level, leaves and pods are used as green vegetables. Scaling up of sales of moringa is limited to local markets only. Therefore, use of *Moringa oleifera's* leaf for incorporating in noodles can open a way for seeking potential aspects of other underutilized plants and also pave a new path for moringa noodles production. Use of moringa leaf might fulfill the amino acid profile of noodles and enrich other phytochemicals. It will provide the way of taking nutrition in tastier, easier and cheaper way.

1.3 Objectives

1.3.1 General objectives

The general objective of this research was to prepare stick noodles by incorporating moringa leaf powder and its quality evaluation.

1.3.2 Specific objectives

The specific objectives of the study were:

1. To analyse the chemical composition of wheat flour and moringa leaf powder.
2. To determine the effect of incorporation of moringa leaf powder on sensory quality of noodles.
3. To compare the nutritional composition of normal wheat noodles and moringa leaf powder incorporated noodles.
4. To study the effect of addition of moringa leaf powder on proximate composition, mineral content, antinutritional factor, antioxidant activity, chlorophyll content, cooking parameters and microbial activity of noodles.
5. To study the shelf life of control and superior noodles packaged in LDPE upto 3 months.

1.4 Significance of the study

Moringa oleifera leaves, roots, seeds and pods, are edible and provide essential nutrients for humans. In particular, *Moringa oleifera* leaves contain considerable amounts of phenolic compounds, proteins, dietary fiber , and minerals (e.g., calcium, potassium, iron, magnesium, manganese, and copper), while being low in fat and total available carbohydrates. For this reason, the food fortification with *Moringa oleifera* leaves could be healthy, e.g. protecting against oxidative stress for its high content in antioxidant compounds and contribute in reducing the minerals deficiency disorders that affect about one-third of the world's population and help in the mitigating the cancer and ulcer.as well. In addition, *Moringa oleifera* leaves have been used to restrain malnutrition in some areas of the world and are considered a valuable fortifying ingredient for staples such as bread, cookies, and dairy products (Simonato *et al.*, 2021).

While noodles products are popular throughout the world, noodles lack in different minerals and amino acids such as lysine, threonine and methionine because of its primary constituent just flour. This study will further reveal the suitability of using *Moringa oleifera* leaves in noodles preparation that will improve nutritional standard of noodles. It will also give idea to those industrialists who want to develop and bring new and healthy snacking products in the market.

1.5 Limitations of the study

1. One variety and one part (leaves) of *Moringa* was used.
2. Only calcium and iron content of the product was studied.

Part II

Literature review

2.1 Historical background (Noodles)

Noodles are one of the oldest forms of processed food consumed and it constitutes an important component of diets of communities living in South East Asia, for example, China, Japan, Indonesia, Malaysia, and Thailand. In recent years, noodles have also become popular and their consumption is increasing with each passing day in other parts of the world, for example developing economies like India and Pakistan. The developed and emerging economies like the USA, Mexico, Brazil, and European countries are promising markets for noodles. As per one global estimate, more than 1 billion meals containing noodles were served in the last year thus showing the rapid growing market (Hyeon *et al.*, 2015)

Consumers should not be confused between noodles and pasta, as these two terms are used interchangeable over the globe. However, these are two different products, as pasta is usually prepared from durum wheat and noodles are manufactured from common wheat. Pasta is one generic term that includes variety of products including macaroni, spaghetti, ravioli, lasagna, vermicelli, and egg macaroni. Most of the time, pasta and allied products are made up of durum wheat or semolina and water which are passed through a die at higher pressure (extrusion process) after mixing, while noodles are not extruded products. The serving method is also different for both products. Noodles may be served in variety of forms that may include raw, partially boiled, boiled, dried, steamed, and fried. In contrast, pasta is normally distributed in dried forms. Although, some types of noodles like dried noodles matches in some textural characteristics with pasta products but this is not the case with all of the noodles (Cole, 2007).

As mentioned earlier, noodles and allied products are dietary staples for communities living in South East Asia and spreading to whole globe with ~ 7 % annual growth. However, historical background suggests the art of noodles making belongs to Chinese communities. Later, the noodles gained immense popularity in closer vicinities like Japan, Malaysia, Indonesia, Thailand, Burma, and India (Fu, 2008).

One of the myth states that Marcopolo discovery was actually a rediscovery of a foodstuff that was once popular in Italy in Etruscan and Roman times. There is some evidence of an Etrusco-Roman noodles made from the same durum wheat as modern pasta called “lagane” (origin of the modern word for lasagna). However, this food, first mentioned in the first century AD was not boiled like pasta, it was cooked in an oven (Pokharel, 2010). By the 1300s dried pasta was very popular for its nutrition and long shelf life, making it ideal for long ship voyages. By that time different shapes of pasta have appeared and new technology made pasta easier to make (Pokharel, 2010). Lack of food and demand of quick serving food during 2nd world war led to the invention of “instant noodles”, which is a precooked noodles. During 1970’s a product was launched named as “instant ramen”, a product which is prepared in Japan during 1950 (Yu, 2003).

Different countries are trying to use different raw materials for the preparation of macaroni products including noodles. Suji or semolina or maida is generally used as primary raw material for the preparation of noodles. The use of different raw materials is gradually gaining prominence worldwide due to some economic and nutritional reasons. Defatted groundnut flour, tapioca flour and various other cereals and legumes, milk powder, casein, gluten, vegetable and spices may also be used as secondary ingredients to improve nutritional quality, flavour etc. (Hou, 2012)

2.2 Classification of macaroni products

According to Hummel (1996) macaroni products are classified into 3 categories:

2.2.1 Extruded solid macaroni product

2.2.1.1 Vermicelli

Vermicelli is a product with diameter 0.5-0.8 mm and may be short cut and scattered. It is popular in Italy and has a smallest diameter capellid Angeli (‘Angel’s hair’) (Hummel, 1996).

2.2.1.2 Spaghetti

It is most popular product with a diameter of 1.5-2.5 mm and length 220-250 mm most are straight and occasionally twisted (Hummel, 1996).

2.2.2 Noodles

Extruded noodles with a thickness of 0.8 mm of varying width may be narrow noodles 1.5 mm width or broad noodles of 12-25 mm width (Hummel, 1996).

2.2.3 Specialties

Screw shaped noodles, stars, melon seeds and shape made for soups (Hummel, 1996).

2.2.4 Extruded hollow macaroni product

2.2.4.1 Macaroni

Looks like hollow spaghetti, outer diameter 3-5 mm, and inner diameter should be selected to give a wall thickness of 1mm of length 120-500 mm (Hummel, 1996).

2.2.4.2 Elbows

Elbows are product with a characteristics curve of length 20-40 mm (Hummel, 1996).

2.2.4.3 Specialties

Specialties have thickness 2 mm, shaped in rings, wheels and letter of alphabets (Hummel, 1996).

2.2.4.4 Rolled and cut macaroni products

A large proportion of the world's production of noodles is cut by special cutting roller from sheet of dough specially prepared for this purpose (Hummel, 1996).

2.3 Raw Materials for noodles making:

2.3.1 Wheat Flour

Wheat, member of the Gramineae family, is among the oldest and most extensively grown of all crops. Its world production as a cereal crop is ranked second behind corn. Different species of wheat exist but the most widely used are *Triticum aestivum* (hexaploid), also called common wheat or bread wheat, and *Triticum turgidum* subsp. durum (tetraploid), also called durum wheat or macaroni wheat. It is estimated that there are between 12,000-30,000 varieties of wheat in existence. The wheat of commerce are divided into three groups and the botanical term *Triticum vulgare* is given to varieties milled to produce flour for the baker.

Flour milled from Durum wheat is used extensively for the manufacture of macaroni. The third of commercial wheat is club wheat (*Triticum compactum*). Flours milled from it are too soft for bread making (Atwell and Finnie, 2016).

Wheat is a crop of temperate regions but it is cultivated in the higher lands of the sub tropics and even the tropics; it is currently ahead of maize and second to rice as the main human food crop. All the wheat belongs to the genus *Triticum*, a member of the grass. Wheat is a major component of most diets of the world because of its agronomic adaptability, ease of storage, nutritional goodness, and the ability of its flour to produce a variety of palatable interesting and satisfying foods. Dough produced from wheat flour differs from those made from other cereals in their unique viscoelastic properties. This property is responsible for the universal use of wheat for a wide range of products. Among these are pan bread, noodles, cakes, biscuits/cookies, steamed bread doughnuts, croissants, bagels pizza, flat breads and chapatti. Each of these products is ideally produced from wheat selected to provide flour with the required characteristics (Khan and Shewry, 2009).

2.3.1.1 Structure of the wheat grain

The wheat kernel is a complex structure with many individual components. However, with respect to processing (i.e., milling), the wheat kernel is divided into three general anatomical regions. The outer protective layers of the kernel are collectively called the bran. The bran constitutes about 14% of the kernel by weight and is high in fiber and ash (mineral) content. The germ, the embryonic wheat plant, constitutes only 3% of the kernel. Most of the lipid and many of the essential nutrients in the kernel are concentrated in the germ. The remaining inner portion of the kernel is the starchy or storage endosperm. It provides the energy and protein for the developing wheat plant. It is characterized by its high starch and moderately high protein (i.e., gluten) content.

The endosperm is the major component of all kernels and is the primary constituent of flour. Finally, a single, highly specialized layer of endosperm cells forms a border between the starchy endosperm and the bran. This layer, called the aleurone, is biologically much more active than the starchy endosperm and has high enzymatic activity. Because of its composition, activity, and location, it can exert a variety of effects on the functionality and nutritional quality of flour. Due primarily to its location , the aleurone is removed during most flour milling operations and makes up a major part of the bran(Atwell and Finnie, 2016). The chemical composition of wheat flour is given in Table 2.1. The bran coating, the germ or embryo and the endosperm is shown in Fig. 2.1.

Table 2.1 Composition of wheat flour

Parameter	Wheat flour (%)
Moisture	9.1±0.3
Protein*	14.7±0.1
Fat*	1.93±0.13
Ash*	0.7±0.05
Crude fiber*	0.84±0.15
Carbohydrate*	72.73±0.04

[*represents values in dry basis, values following ± represents standard deviation]

Source: Nisar *et al.* (2020)

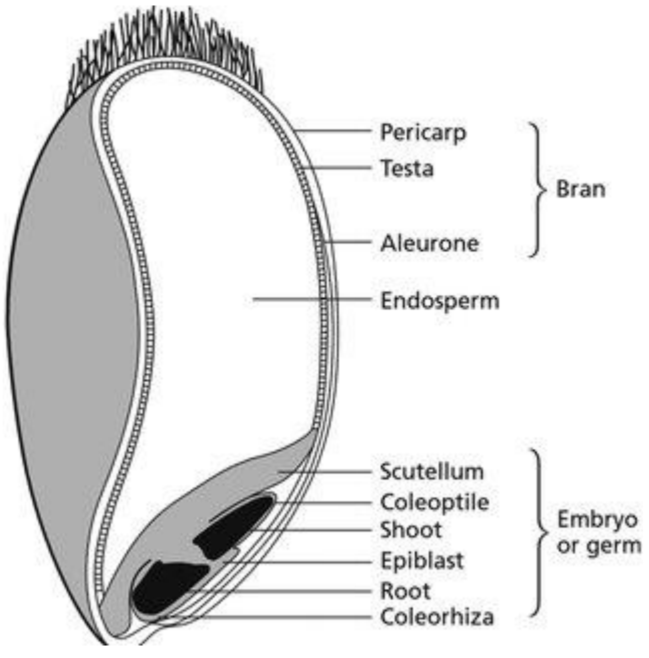

Fig. 2.1 Structure of Wheat grain

Source: Anon. (2005)

2.3.1.2 Wheat variety

There are about 16 cultivated species but the two important are bread wheat and durum wheat. Each of these species has thousands of cultivars and land races. Wheat species and their thousands of varieties can be grouped into three groups based on chromosome numbers. A widely used classification of cultivated wheat (*gahu*), and their probable wild ancestor and chromosome number (2n) is shown in Table 2.2.

Table 2.2 Genetic constitution of wheat

Wheat variety	Species	2n	Genomic constitution	Common name
Diploid Wheat	*Triticum monococcum* ssp.*aegilopoides* (*T. boeoticum*)	14	AA	Einkorn (wild)
	T. monococcum ssp. *monococcum* (T.*monococcum*)	14	AA	Einkorn (cultivated)
Tetraploid wheat	Triticum turgidum ssp. *dicoccoides* (*T.dicoccoides*)	28	AABB	Emmer (wild)
	T. turgidum ssp.*dicoccum* (*T.dicoccum*)	28	AABB	Emmer (cultivated)
	T. turgidum ssp. *durum* (T.*durum*)	28	AABB	Durum or Macaroni (cultivated)
	T. turgidum ssp.*turanicum* (*T*. turanicum)	28	AABB	Kamut (cultivated)
Hexaploid wheat	Triticum aestivum ssp.*spelta* (*T*. Spelta)	42	AABBDD	Spelt(cultivated)
	Triticum aestivum ssp. *aestivum* (*T. aestivum*)	42	AABBDD	Common or Bread (cultivated)

Source: Rossentrater and Evers (2017)

Durum wheat has its own characteristics, amber color, long, narrow pointed grain with a prominent dorsal ridge. Although it is very occasionally included in small proportion in bread and grits; it is mainly converted into semolina, which serves as the basic raw material in the manufacture of macaroni products.

It is generally believed that the ideal raw material for the noodles is semolina from durum wheat rather than milling products from other wheat types. As shown in Table 2.1, durum are tetraploids while common wheat (*T. aestivum* L.) are hexaploid. North American durum are mostly spring wheat's. Although winter durum also exists, they are not grown commercially. The durum wheat endosperm is high in carotenoid pigments, which give the pasta its yellow color. Because of the relationship between the yellow color and consumer acceptance, the level of pigmentation has been used as a selection tool of good quality durum. To produce first grade macaroni products, semolina must be milled exclusively from durum wheat. A good mill equipped for grinding durum wheat should produce about 65% semolina for the manufacture of the finest quality macaroni products rather fine semolina is to preferred, as it makes the running of modern equipment easier and requires less attention in the blending and mixing process (Delcour and Hoseney, 2010).

The wheat grain contains 2-3% germ, 13-17% bran and 80-85% mealy endosperm (all constituents converted to a dry matter basis). Whole wheat contains about 13% moisture content, 13.6% protein, 2.5% fat, 69.2% carbohydrate and some vitamins and minerals. Wheat is a good source of sulfur amino acids and tryptophan and poor source of lysine and threonine i.e. limiting amino acids. Under present condition, wheat can be rated as the third most important food grain crop of Nepal making 3.4 million tons as the area covered and the quantity of grain produced respectively (Atwell and Finnie, 2016) .

2.3.1.3 Classification of wheat

Kingdom	Plantae - plants
Subkingdom	Tracheobionta - vascular plants
Superdivision	Spermatophyte - seed plants
Division	Mangoliophyta - Flowering plants
Class	Liliopsida - Monocotyledons
Subclass	Commelinidae
Order	Cyperales
Family	Poaceae - Grass family
Genus	*Triticum* L. - wheat

Source: Kent-Jones and Amos (1967)

2.3.1.4 Chemical composition of wheat flour

The composition of wheat flour is shown in Table 2.3 and Table 2.4.

Table 2.3 Analytical composition of wheat flour and its Primary components

Parameter	Percentage
Moisture	14 (of flour)
Protein	7-15 (of flour)
Lipids	1 (of flour)

Source: Atwell and Finnie (2016)

Table 2.4 Mineral composition of wheat flour

Minerals	Wheat flour (mg/100g)
Ca	12.495
Mg	14.7
Fe	0.882
Zn	0.5145

Source:Dida *et al.* (2001)

2.3.1.6 Wheat flour grade

Flour from wheat grain can be classified into 3 groups on the basis of their moisture content, total ash, acid insoluble ash and gluten content. According to the Nepal Standard (2036), wheat flour can be graded as shown in Table 2.4.

Table 2.5 Wheat flour grades

Parameter	Grade A	Grade B	Grade C
Moisture content	13% max.	13% max.	13% max.
Total ash	1.0 % max.	0.7% max.	0.7% max.
Acid insoluble ash	0.05 % max.	0.05% max.	0.05% max.
Gluten	10% max.	8-10% max.	7-8% max.

Source: Pokharel (2010)

2.3.2 Salt (sodium chloride)

Sodium chloride addition is important to impact specific taste and addition of salt in noodles dough includes the tightening of gluten structure, improving the viscoelastic properties, and increasing the water permeability during cooking. It also helps in preventing cracking during drying, suppressing of lactic acid and alcoholic fermentation, and imparting astringency. It exerts its effects on gluten proteins by decreasing the solubility of gluten and results in compaction and exclusions of nonpolar lipids from the hydrophobic interior of the gluten. The concentration of salt can affect the rheological properties of the dough. The salt can be added from 0 to 2% but optimum flavor quality can only be achieved at 1.0% concentration. Overall, it can be concluded that the addition of salt in higher amounts (>2.0%) effect dough characteristics negatively thus causing deteriorations in dough properties (Karim and Sultan, 2014).

2.3.3 Water

Water is the ingredient most responsible for the biochemical and physical interaction that occurs in foods. Water is an essential ingredient necessary for gluten formation which provides viscoelastic properties to dough required for noodle processing. The gluten network formation based on water hydration is not as consistent in noodle dough as in bread dough. The water contents of noodles dough ranging from 28% to 35% allow formation of a continuous gluten matrix, rendering them less susceptible to gluten breakdown. During processing, water level can be used to control the dough strength and thereby, significantly influence machineability in products requiring molding and to assure proper texture of the final product. If water is added in less amounts than the recommended levels, the harder and stiffer dough will form that can withstand the pressure during subsequent pressure of sheeting and molding. The insufficient water levels also results in nonuniform white patches of flour on the surface of noodles. In contrast to lower levels, amount of water added in higher amounts than the recommended results in dough of low viscosity and higher stickiness. The sticky dough creates problems during subsequent operations like sheeting and cutting. Moreover, the noodles strips stretches more thus enhancing the cooking losses (Karim and Sultan, 2014).

2.4 Dough properties

Sufficient dough strength is required in noodles flour so that noodles will retain its integrity (correct dimension) during the various stages of processing. Excessive strength should be avoided as this will lead to sheeting and cutting problem. According to the Moss (1967), generally flour with maximum extensograph resistance over 300 units are acceptable. Below this figure, the eating quality is adversely affected. Apart from raw materials used, the quality of rolled noodles depends to a considerable extent on the careful manufacture of the sheet of dough. The coming from the kneader after having been kneaded only the shortest possible time should be rolled as quickly as possible. Long exposure to the air will bleach the dough (Pokharel, 2010).

2.4.1 Classification of dough according to temperature of water

Water used in the manufacture of noodles should be clear without taste, odor. It should be reasonably free from microbes and contain only a small proportion of salts. Water temperature affects the temperature of dough and macaroni dough can be classified on the basis of temperature of water used in dough making. On the basis of temperature of water used for making the dough, the dough can be classified as shown in Table 2.5.

Table 2.6 Classification of dough according to the temperature of water

Types of dough	Temperature of water (^{o} C)
Hot dough	75-85
Warm dough	55-65
Cold dough	<30

Source:Pokharel (2010)

2.4.2 Classification of dough according to moisture content

Hard dough possesses hard and short type of gluten and this gives short types of macaroni products. Gluten of medium dough is hard and long type and is usually used for long type of macaroni products. Soft dough also possesses hard and long type of gluten and is usually used for long types of macaroni products. Soft dough is easy for sheeting and rolling whereas hard dough is easy to press. The classification of dough according to moisture content is shown in Table 2.6

Table 2.7 Classification of dough according to moisture content

Types of dough	Moisture content (%)
Hard dough	28-29
Medium dough	29.1-31
Soft dough	31-32.5

Source: Pokharel (2010)

2.5 Technology of noodles making

Noodles are the types of pasta that is generally made from wheat flour rather than semolina or farina and water. In addition, other ingredients as salt, egg, color, composite flour along with wheat flour, Bengal gram flour etc. (Shelke, 1990).

The US standard of identity of noodles state that noodles must be made from wheat dough containing eggs. Dried noodles must contain less than 13% moisture content and more than 5.5% egg solid. Wet noodles are cooked in boiling water before they sold. They contain about 52% moisture content and thus they have relatively short shelf life. Dry noodles are not precooked. Steamed and dried noodles are precooked with low pressure steam, shaped and then dried to about 10% moisture content (Pokharel, 2010). The manufacturing process of noodles consists of mixing of wheat flour with water, with or without addition of color, kneading to form dough of desired moisture content, sheeting, cutting then drying and packing. Addition of vegetables and fruits to pasta can contributes to natural attractive look, new tastes and sense of complete meal (Rekha *et al*., 2013). The general flow sheet for making noodles is shown in Fig. 2.2.

Wheat Flour

Salt (2 parts), water, (30-40 parts) and $NaCO_3$ →

↓

Mixing and kneading

(15-20 min)

↓

Rolling

(7-8 times)

↓

Cutting

(as per desired size of final product)

↓

Drying

(3 stage drying)

↓

Packaging in PE

Fig 2.2 Technology of noodles making

Source: Shelke (1990)

2.5.1 Mixing and kneading

In mixing, water is added to wheat flour or maida and kneaded for about 15-20 min. The mixed product is then dumped into a kneader where the dough is compacted. At the end of operation, the chunks of dough are fed into a machine called 'dough break' (Bhandari, 1992).

2.5.2 Sheeting

After mixing, prepared slab of dough are fed back and forth through a roller, which are moved closer and closer gradually to reduce thickness of the dough sheet. The dough sheet is folded double on several passes to laminate the sheet. The dough sheet is rolled 7-10 successive passes through the reduction roll. After reducing the desire thickness the dough sheet is wound in spindle for latter feeding to cutter where it is passed through a pair of cutting rolls. The function of sheeting is to develop the gluten and the preparation of the uniform sheet of dough (Sangroula, 2019). Because of noodle dough is always sheeted in the same direction, the gluten fibrils are aligned in the same direction of sheeting. That alignment gives the noodles more strength in their long rather than their short direction (Karki, 1998).

Two important factors in noodles dough sheeting are the sheeting speed and the sheeting ratio. The sheeting speed is the speed of the rolls or how fast the dough passes through the rolls. The sheeting ratio is the thickness of the dough after sheeting divided by the thickness of dough before sheeting. Both of these variables must be controlled to obtain good noodles. Generally, the sheet thickness varies from 2-3 mm (Hoseney, 1986).

2.5.3 Cutting

A noodle cutting is performed by a pair of slotted rolls aligned so that they run point to point, there by producing a noodle with square cross section. The gap between the cutting rollers is maintained according to final thickness desired. The grooves on the rolls are made in different sizes so as to produce noodles of varying widths. The walls are fitted on a small frame and may be changed easily, making it possible to use the same equipment for the production of noodles of different widths (Hummel, 1996).

2.5.4 Drying process of pasta products including noodles

The objective of drying is to lower moisture content of the product from about 31% to 12-13% so that the macaroni products will be hard, retain its shape and can be stored without spoilage (Poudyal, 1988). Drying is generally carried out in continuous belt tunnels using multiple stages for careful control of the drying process. The importance of drying can't be over emphasized and more pasta (macaroni, vermicelli, spaghetti, noodles) is spoilt by being dried too quickly than other causes. In Italy, drying in the open air being carried out but obviously this is possible where suitable climatic conditions exist. Too rapid drying results in curling, cracking and splitting of the finished products. It is impossible to dry too slowly with the introduction of trouble from souring or from mold growth. Some authorities advocate an initial quick drying followed by a slow drying to the final moisture content (Kent-Jones and Amos, 1967).

In local manufacturing practice of raw noodles (Thukpa) in Nepal, noodles are kept for about 48 h in closed room with little air circulation and then dried in sun for about 6 h (Pokharel, 2010).

2.6 Factor affecting quality of noodles

2.6.1 Based on raw materials

Noodles can be made can be made from wheat flour or mixture of hard wheat with buckwheat flour. The noodles are typically light brown or gray in color with a unique taste and flavor. Based on the kind of wheat used there are two major noodles types available the Chinese type and Japanese type. Chinese type noodles are generally made from hard wheat flour, characterized by a bright creamy white or bright yellow color and a firm texture. Japanese noodles are typically made from soft wheat flour of medium protein and are characterized by a creamy white color and a soft and elastic texture (Hau, 2001).

2.6.2 Based on salt used

Based on the absence or presence of alkaline salt in the formula, noodles can be classified as whited salted or yellow alkaline noodles. Alkali give noodles their characteristic yellowness. White salted noodles comprise Chinese raw noodles or dry noodles. Japanese noodles and Korean white salted noodles (Hau, 2001).

2.6.3 Based on size

According to the width of noodle strands, Japanese noodles are classified into four noodle types. Since the smaller size noodles usually soften faster in hot water than the larger size.

2.6.4 Based on processing

The simplest way to classify noodles is based on processing. They are classified as Fresh noodles, Dried noodles, Boiled noodles, Steamed noodles and Instant noodles (Hau, 2001).

2.7 Moringa plant

Moringa oleifera is a small perennial tree native of sub-Himalayan regions of North west India, but now is indigenous to many regions in Africa and also found around the globe. It is commonly known as horseradish tree, drumstick tree, Moringa tree. Moringa tree belongs to family *Moringaceae* that consists of 14 known species of which M. oleifera is the most widely known species (Anwar *et al.*, 2007). The history of Moringa dates back to 150 B.C. Historical proofs reveal that ancient kings and queens used Moringa leaves and fruit in their diet to maintain mental alertness and healthy skin (Dhakar *et al.*, 2020). The tree ranges in height from 5-12 m with an open umbrella-shaped crown (Ghazali and Abdulkarim, 2011). Moringa is a highly valued plant, with impressive range of medicinal uses with high nutritional value. Moringa is said to provide 7 times more vitamin C than oranges, 10 times more vitamin A than carrots, 17 times more calcium than milk, 9 times more protein than yoghurt, 15 times more potassium than bananas and 25 times more iron than spinach (Rockwood *et al.*, 2013).

2.7.1 Taxonomy of *Moringa oleifera*

Kingdom:	Plantae
Subkingdom:	Tracheobionta
Superdivision:	Spermatophyta
Division:	Magnoliophyta
Class:	Magnoliopsida
Subclass:	Dilleniidae
Order:	Capparales
Family:	Moringaceae
Genus:	*Moringa*
Species:	*oleifera* Lam.

Source: Mallenakuppe *et al.* (2015)

2.7.2 *Moringa oleifera* in Nepal

Moringa tree is called *sitalchini*, *sajiwaan* in Nepali. It is native to Nepal, Pakistan and India. It primarily grows in the mid-hills, the siwalik and the terai of Nepal. Moringa goes by the Sanskrit name *Shigru*, and has been used as traditional medicine in Ayurveda in Nepal and India for over many years. Even though it seems that cultivation of *Moringa oleifera* is in 'rudimentary stage of evolution'. However in recent years, a handful of entrepreneurs are getting involved in its plantation. Extensive cultivation of *Moringa oleifera* is done in Kunathari, Surkhet in Bheri zone of mid-western Nepal. Products like power and tea are made from moringa leaf and also few exports are also made of the Nepalese production. It is seen as an 'economical herb' of great potential (Singh, 2017).

Moringa is a great supplement to provide essential amino acids, micronutrients, and protein to the typically nutrient-lacking rural Nepalese diet. Also Nepal's central cereal crops are struggling with decreasing rainfall brought up by climate change, *Moringa* could be a drought resistant alterantive as it does not require much irrigation (Nepal FAO, 2007).

2.7.3 Nutritive Value of *Moringa oleifera* plant

Moringa oleifera is a plant with high value rich in nutrients and each part is consumable so energy given from different plant parts is given in Table 2.7.

Table 2.8 Energy value of different parts of moringa plant

Part	Energy (cal/100 g)
Fresh leaf	92
Dry leaf	329
Leaf powder	205
Flower	384
Pods	26

Source: Dhakar *et al.* (2020)

2.7.4 Consumption pattern of *Moringa oleifera*

The leaves of *Moringa oleifera* are collected, cooked and eaten like other vegetables. It is utilized in fortifying sauces, juices, spices, milk, bread, and most importantly, instant noodles. Many commercial products like Zija soft drink, tea, and neutroceuticals are available all over the globe. Leaves have been used successfully in its dried state or powdered form to make delicious meals and porridge diets for pregnant expectant mothers, nursing mothers, infants and young children, as well as adults of all age groups. In Africa, nursing mothers have been shown statistically to produce far more milk when they add (Mahmood *et al.*, 2010). *Moringa oleifera* leaves to their daily diets and malnourished children have made significant weight gains when nursing mothers and caregivers add them to their diets as well. For pregnant and breast feeding-nursing women, the leaves can do much to preserve the mothers' health and pass on strength to the fetus or nursed child. 100 g portion of the leaves could provide a woman with over one-third of her daily requirement of calcium and gives her important quantities of iron, protein, copper, sulphur, B – vitamin (Alakali *et al.*, 2015). It has also been consumed by incorporated in biscuits, tea, porridges and other food products.

2.7.5 Uses of Moringa: a multipurpose tree

Moringa is grown for its nutritious pods, edible leaves and flowers and can be utilized as food, medicine, cosmetic oil or forage for livestock (Padayachee and Baijnath, 2020). The many uses of *Moringa oleifera* include: alley cropping (biomass production), animal forage (leaves and treated seed-cake), biogas (from leaves), domestic cleaning agent (crushed leaves), blue dye (wood), fencing (living trees), fertilizer (seed-cake), foliar nutrient (juice expressed from the leaves), green manure (from leaves), gum (from tree trunks), honey- and sugar cane juice-clarifier (powdered seeds), honey (flower nectar), medicine (all plant parts), ornamental plantings, bio-pesticide (soil incorporation of leaves to prevent seedling damping off), pulp (wood), rope (bark), tannin for tanning hides (bark and gum), water purification (powdered seeds) (Mutiara *et al.*, 2012). *Moringa oleifera* seed oil (yield 30-40% by weight), also known as Ben oil, is a sweet non-sticking, non-drying oil that resists rancidity. It has been used in salads, for fine machine lubrication, and in the manufacture of perfume and hair care products (Tsaknis *et al.*, 1999).

2.7.6 Medicinal importance of *Moringa oleifera*

A number of medicinal properties have been ascribed to various parts of this highly esteemed tree as shown in Table 2.8. Almost all the parts of this plant : root, bark, gum, leaf, fruit (pods), flowers, seed and seed oil have been used for various ailments in the indigenous medicine of South Asia.

Table 2.9 Common medicinal uses of different parts of *Moringa oleifera*

Plant Part	Medicinal uses
Root	Antilithic, rubefacient, vesicant, carminative, antifertility, anti-inflammatory, stimulant in paralytic afflictions; act as a cardiac/circulatory tonic, used as a laxative, abortifacient, treating rheumatism, inflammations, articular pains, lower back or kidney pain and constipation.
Leaves	Purgative, applied as poultice to sores, rubbed on the temples for headaches, used for piles, fevers, sore throat, bronchitis, eye and ear infections, scurvy and catarrh; leaf juice is believed to control glucose levels, applied to reduce glandular swelling
Stem bark	Rubefacient, vesicant and used to cure eye diseases and for the treatment of delirious patients, prevent formation of tuberculous glands of the neck, to destroy tumors and heal ulcers.
Gum	Used for dental caries, and is astringent and rubefacient; Gum, mixed with sesame oil, is used to relieve headaches, fevers, intestinal complaints, dysentery and asthma.
Flower	High medicinal value as a stimulant, aphrodisiac, abortifacient, cholagogue; used to cure inflammations, muscle diseases, hysteria and tumors.
Seed	Seed extract exerts its protective effect by decreasing liver lipid peroxides, antihypertensive compounds thiocarbamate and isothiocyanate.

Source: Anwar *et al.* (2007)

2.7.7 *Moringa oleifera* leaves

The leaves of the Moringa oleifera tree are very nutritious. They can be consumed fresh, cooked or dried. Since dried Moringa leaves retain their nutrient content, it is possible to convert them into leaf powder. When there is an abundance of leaves, this leaf powder can be made and stored easily. Moringa Leaf Powder is an excellent nutritional supplement and can be added to any dish. Moringa leaves can be harvested at any time once trees are established. Once leaves are harvested, they should be stripped off the stems. Leaves are then rinsed in clean water or a very weak bleach solution (1:100) to remove dirt and germs. Moringa Leaf Powder can be added to any food or beverage and it will increase the vitamin, mineral and protein content. Moringa Leaf Powder has the greatest impact on those who are more vulnerable: malnourished children, pregnant or lactating women, children at weaning age, HIV/AIDS patients, and the elderly (Doerr and Cameron, 2005).

2.7.8 Composition of *Moringa oleifera* leaf

Energy value of leaf of *Moringa oleifera* plant and their proximate composition is given in Table 2.9.

Table 2.10 Proximate composition of leaf

Parameter	Dried leaf
Moisture %	7.96
Crude protein (%, db)	22.14
Crude fat (%, db)	7.19
Crude fiber (%, db)	10.44
Ash content (%, db)	9.12
Iron (mg/100g db)	47.13
Calcium (mg/100g db)	1255.31
Potassium (mg/100g db)	2044.50
Carbohydrate (%, db)	51.11
Energy (Kcal/100g)	357.71

Source: Hasaballa *et al.* (2017)

2.7.9 Nutritive properties of moringa leaves

As sources of nutrients and vitamins, leaves of moringa ranks among the best of perennial vegetables. Numerous researchers says that moringa leaf as an exceptional source for proteins as *M. oleifera* leaves contains 20-30% of dry weight of protein. In addition to that leaves contain unsaturated fatty acids involving linoleic acids that are very unusual in plant sources. Almost all kinds of vitamins, such as vitamin A, vitamin B including folic acid, pyridoxine and nicotinic acid, vitamin C, vitamin D and vitamin E are abundant in M. oleifera leaves (Qi *et al.*, 2016). Moringa is an excellent non-animal source of protein as it contains all of the amino acids in good proportion, even arginine (1325 mg/100 g dry leaf) and histidine (613 mg/100 g dry leaf) that are especially important for infants who are unable to make enough protein for their growth (Dhakar *et al.*, 2020).

(Arise *et al.*, 2014) reported higher protein content of 25%, fat content of about 1.5%, fibers and ash content around 7.5% and 6% respectively. Variations in protein and fat is found, protein as low as 19% and fat was higher, about 8.80%, as reported by (Hasaballa *et al.*, 2017); fiber and ash content were about 6.75% and 8% respectively.

According to (Hasaballa *et al.*, 2017), calcium was reported as 1255.31mg/100 g and iron 47.13 mg/100 g. Moreover, (Yameogo *et al.*, 2011) reported contradicting results as calcium was much higher than that reported by data i.e. 2098.10 mg/100 g while lower iron content of only 28.3 mg/100 g compared to (Hasaballa *et al.*, 2017). The antioxidant activity is shown in Table 2.10. The chlorophyll content of *Moringa oleifera* leaves is shown in Table 2.11.

Table 2.11 Antioxidant activity of different parts of *Moringa oleifera* plant

	Summer			**Winter**		
Part	Recovery (%)	DPPH (EC_{50}) (μg/mL)	Phenolics (mg/100g db)	Recovery (%)	DPPH (EC50) (μg/mL)	Phenolics (mg/100g db)
Leaf	51.95	387^{c}	200^{a}	81.72	200^{c}	181.3^{a}
Stem	60.86	1116^{b}	71.9^{b}	77.50	316^{b}	134.4^{b}
Stalk	30.25	1874^{a}	68.8^{b}	85.38	624^{a}	93.8^{c}

Source :Shih *et al.* (2011)

Table 2.12 Chlorophyll content of *Moringa oleifera* leaves

Extraction solvent	**Total phenolic (g GAE/100 g DM)**		**Flavonoids (g CE/100 g DM)**		**Chlorophyll (mg/g)**	
	45 days	60 days	45 days	60 days	45 days	60 days
Methanol	4.02 ± 0.21l	4.57 ± 0.20m	1.12 ± 0.14f	1.13 ± 0.06f	0.265 ± 0.001c	0.263 ± 0.002c
Ethanol	3.64 ± 0.15k	3.97 ± 0.17l	1.82 ± 0.08h	1.82 ± 0.07h	0.275 ± 0.002d	0.273 ± 0.00d
Aqueous	3.67 ± 0.00k	2.16 ± 0.31i	0.92 ± 0.04e	1.04 ± 0.07f	0.084 ± 0.008a	0.089 ± 0.002a

Source: Nobossé *et al.* (2018)

2.7.10 Antinutritive properties of *Moringa oleifera* leaves

Although moringa leaf is a good source of nutrition, there are some antinutrients present in it. The antinutrients present in *Moringa oleifera* leaves is shown in Table 2.12

Table 2.13 Antinutritive value of *Moringa oleifera* leaves.

Antinutrients	***Moringa oleifera* leaves**
Phytate (mg/100g)	10.58 ± 0.01
Tannin (mg/100g)	8.19 ± 0.01
Oxalate (mg/100g)	334.33 ± 0.67
Alkaloid (%)	1.72 ± 0.01
HCN (mg/100g)	3998.30 ± 0.49

Source: Auwal *et al.* (2019)

2.7.11 Suitability of moringa for noodles

Moringa oleifera is referred as miracle plant or tree of life as the name is based particularly on its uses regarding to medicine and nutrition. All parts of *Moringa oleifera* tree are edible and has exceptionally high nutritional value. Mainly, the leaves are an outstanding source of calcium, protein, potassium, iron and fiber. The content of amino acids such as methionine and cystine is also high. Carbohydrates, fats and phosphorous content are low making this one of the finest plant food (Dhakar *et al.*, 2020).

Though noodles are popular, it holds a notion of ‘low fiber food’ as they are generally prepared from refined wheat flour, which by its nature lacks fiber (Ganga *et al.*, 2019). Noodles also lack in macro and micro nutrients like protein, calcium, phosphorus, potassium, iron, vitamins, beta carotene and other bioactive compounds which are important for normal functioning of the body and prevention of certain diseases. In order to enrich the nutrition of noodles and improve its health function, *Moringa oleifera* can be used as a potential ingredient in noodles manufacturing market.

Part III

Materials and methods

3.1 Materials

3.1.1 Collection of raw materials

The ingredients used for the research work are: Wheat flour, Moringa leaves powder and salt. Wheat flour was bought from local market of Dharan manufactured by Vikash flour Mill, Banke, Nepal. Moringa leaves were collected from Sunsari district, Dharan, Nepal. Salt was brought from local market of Dharan manufactured by Salt Trading Corporation Limited, Kathmandu, Nepal. Moringa leaves powder was prepared in the laboratory of Central Campus of Technology, Dharan, Nepal.

3.1.2 Chemicals used

All the chemicals used for analytical purpose were obtained from laboratory of Central Campus of Technology, Dharan, Nepal which is shown in Appendix B.

3.1.3 Equipment required

The equipment's used in the experiment were obtained from laboratory of Central Campus of Technology, Dharan, Nepal which is shown in Appendix C.

3.2 Method of Experiment

3.2.1 Methodology

Fresh *Moringa oleifera* leaves were collected from Sunsari district, Dharan, Nepal. Leaves were destalked and foreign particles were removed. It was then kept in 1% brine solution for (10-15 min). Then it was rinsed thoroughly. Later leaves were cabinet dried at about 50°C for about 6 h and then powdered. It was stored in air-tight bottle. Wheat flour was substituted with leaf powder to prepare a recipe for moringa noodles. Seven formulations were made using wheat flour and leaf ratio 100:0, 96.25:3.75, 95:5, 92.5:7.5, 90:10, 88.75:11.25, 85:15 respectively for sample A, B, C, D, E, F and G. Salt and water was added to the formulated ratio to make dough followed by sheeting, cutting, drying and packaging.

3.2.2 Formulation of recipe

The recipe formulation of moringa noodles by varying proportion of moringa leaf powder with wheat flour is given in Table 3.1. The recipe for amount of leaf powder to be used was finalized after trials for threshold determination in pilot scale.

Table 3.1 Recipe formulation of noodles

Ingredients	A	B	C	D	E	F	G
Wheat Flour*	100	96.25	95	92.5	90	88.75	85
Moringa leaf*	0	3.75	5	7.5	10	11.25	15
Salt*	2	2	2	2	2	2	2
Water, ml	31.52	39.024	38.56	37.64	36.72	36.26	34.86

[* represents all ingredients are in gram. Noodles were made as per the recipe and coded A, B, C, D, E, F and G for each *Moringa* noodles made. The noodles made were of soft dough type.]

3.2.3 Preparation of moringa leaf powder

For the preparation of moringa leaf powder the method suggested by (Hasaballa *et al.*, 2017) was followed and it was dried at 50 °C in oven for 6 h instead of alternative method to dry at 45°C in cabinet dryer to a constant weight. It was then pulverized to make powder and kept in air tight plastic bags to prevent moisture absorption by dried ingredients. Destalking and removal of foreign particles was done manually. Procedure for leaf preparation is shown in Fig. 3.1.

Moringa leaf

↓

De-stalking and removal of foreign materials

↓

Dipping into brine solution (1%) for (10-15 min)

↓

Drying (50^{o}C for 6 h)

↓

Pulverizing (595 µ) and sieving

↓

Leaf powder

Fig 3.1: Flow chart of moringa leaf powder preparation

3.2.4 Preparation of moringa leaf powder incorporated noodles

The standard formula for this study consists of 100 parts of composite flour, 30-40 parts moisture content in final dough, 1 parts sodium carbonate and 2 parts salt. The amount of water to be added is calculated by using following formula:

Amount of water required to dose (Gw) = Gm (Wd- Wf) / (100- Wd)

Where, Gw = amount of water required for dosing

Gm = dosing of the flour in kg

Wd = moisture content of dough

Wf =moisture content of flour

The prepared dough was mixed thoroughly for about 10-15 min. Then the dough was left for 45 min to stiff. The dough was transferred to the noodles making machine. The dough mixture was pressed in the roller of the noodles machine. The gap between the rollers was set 3.8 mm. The mixed dough was passed through the roller at low speed. The sheet was folded in half and passed between the roller gaps setting of 5.68 mm. The cycle was repeated for 6 times. The dough sheet was then gradually reduced in thickness without folding by decreasing the roller gap till 4 mm. the sheet was then passed through the cutter rolls to slit into strands. Noodles strip were hanged on bamboo sticks in a close room at room temperature for about 24 h which acts as sweating period. The noodles were sun dried by hanging them on the sticks to the safe moisture level. The final noodles were weight and packed on polyethylene bag (Shelke, 1990). It was carried out in Central Campus of Technology. Seven different formulations of noodles were made following similar processing and preparation technique varying the amount of wheat flour and leaf powder. The procedure followed for noodle making is shown in Fig 3.2.

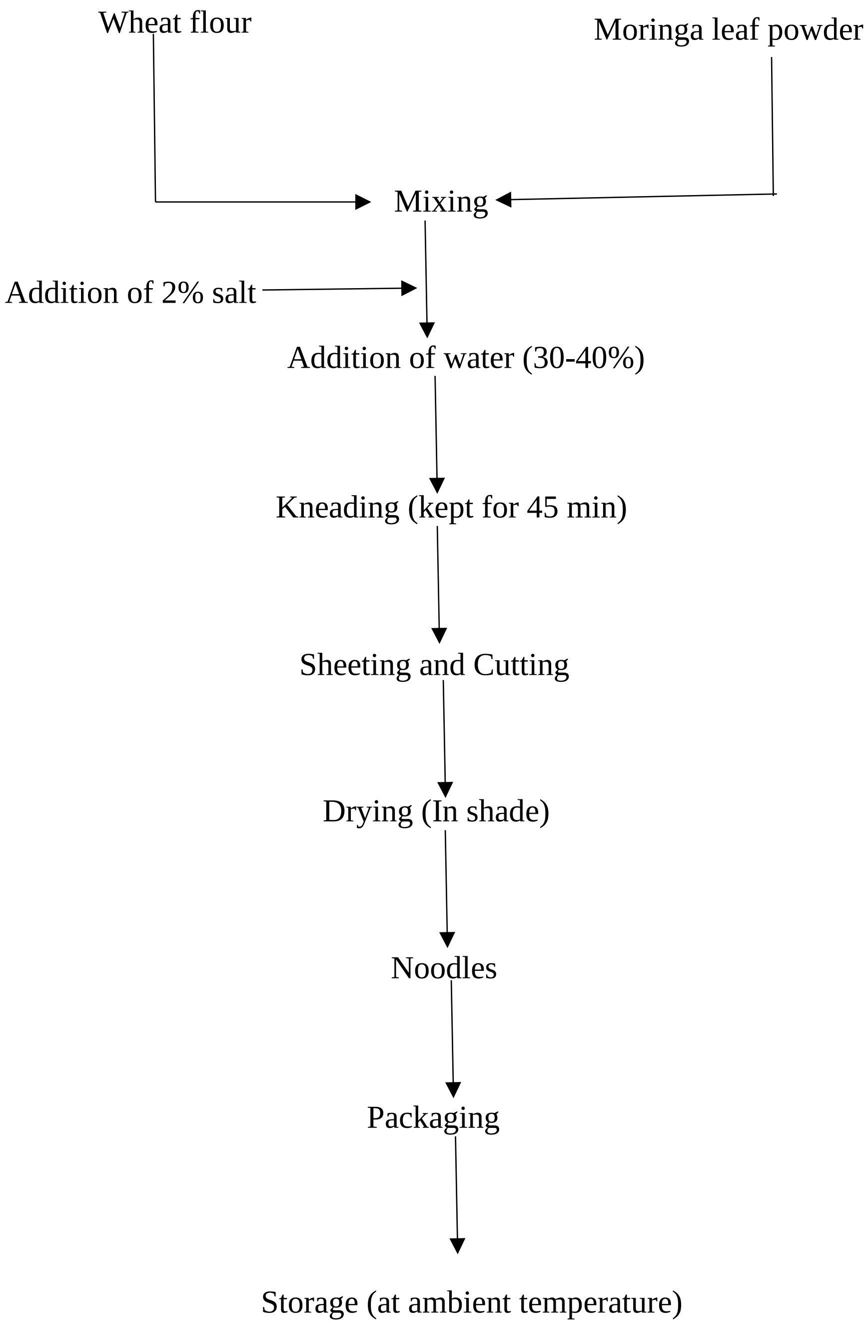

Fig. 3.2 Flowchart of moringa leaf powder incorporated

3.3 Analytical Procedures

3.3.1 Determination of moisture content

Moisture content of the sample was determined by weight loss during heating in a thermostatically controlled oven at 105 °C by hot air oven method as described in (Rangana, 1986).

3.3.2 Determination of crude fat

The crude fat content of the sample was determined by solvent extraction method as described by (Rangana, 1986).

3.3.3 Determination of crude fiber

The crude fiber content of raw materials and noodles was determined as described by (AOAC, 2005).

3.3.4 Determination of crude protein

The crude protein content of raw materials and noodles samples was determined as described in (AOAC, 2005).

3.3.5 Determination of ash content

Ash content of the noodles samples and raw materials is determined as described in (AOAC, 2005).

3.3.6 Determination of carbohydrate

Carbohydrate content was determined by difference method.(AOAC, 2005).

3.3.7 Determination of calcium content

Calcium content was determined following method described by (KC and Rai, 2007) titrimetrically from the prepared ash solution.

3.3.8 Determination of iron content

Iron content was determined from the ash solution prepared colorimetrically at absorption of 480 nm, setting absorbance '0' for the blank. Iron was determined colorimetrically as described by (KC and Rai, 2007).

3.3.9 Determination of Antioxidant Activity

Antioxidant activity of the extracts of samples and products were determined by method described by , (Hawa *et al.*, 2018) with slight variation. Different concentration of samples were made with 80% methanol. 1 ml of prepared extract was mixed with 2 ml of 0.1 mM DPPH solution and left in dark for 30 min and absorbance was measured at 517 nm. Blank samples were prepared with methanol and DPPH.

% inhibition was expressed in percentage using the equation:

$$\%\ \text{Inhibition} = \frac{(A_b - A_s)}{A_b} \times 100$$

Where, A_b is the absorbance of control, A_s is the absorbance of test sample. The 50% inhibitory concentration (IC_{50}) was expressed as the quantity of extracts to react with a half of DPPH.

3.3.10 Determination of chlorophyll

Total chlorophyll content in *Moringa* sample is determined as per (KC and Rai, 2007).

Chl a, mg/g tissue = $12.7(A_{663}) - 2.69(A_{645}) \text{ x } \frac{V}{1000 \text{ x } W}$

Chl b, mg/g tissue = $22.9(A_{663}) - 4.68\ (A_{645}) \text{ x } \frac{V}{1000 \text{ x } W}$

Total chlorophyll, mg/g tissue = Chl a + Chl b (calculated above)

Where A= absorbance at specific wavelengths

V = final volume of chlorophyll extract

W = fresh weight of tissue extracted

3.3.11 Determination of tannin

Colorimetric estimation of tannins is based on the measurement of the blue color formed by the reduction of Folin-Ciocalteu reagent by tannin-like compounds in alkaline condition.

The sample weighing 0.5 g was boiled for 30 min with 40 ml of water. Then it was cooled and was transferred to a 50 ml volumetric flask and diluted to mark. It was then shaked well and filtered. 0 to 1 ml aliquots of the standard tannic acid solution were taken in test tube and 7.5 ml water was added to each. Then, 0.5 ml Folin-Ciocalteu reagent and 1 ml Na_2CO_3 solution was added and volume was made to 10 ml. After then, color was measured after 30 min at 760 nm against experimental blank adjusted to 0 absorbency (Ranganna, 1986).

3.3.12 Determination of phytate

The sample weighing 0.2 g was placed in a 250 ml conical flask. It was soaked in 100 ml of 20% concentrated HCl for 3 h, the sample was then filtered. 50 ml of the filtrate was placed in a 250 ml beaker and 100 ml distilled water was added to the sample. Then, 10 ml of 0.3% ammonium thiocyanate solution was added as indicator and titrated with standard iron (III) chloride solution which contained 0.00195 g iron per 1 ml (Emmanuel and Deborah, 2018).

$$\%\ \text{Phytic acid} = \frac{\text{Titer value} \times 0.00195 \times 1.19 \times 100}{2}$$

Source: Emmanuel and Deborah (2018)

3.4 Microbiological analysis

Total Plate Count (TPC) was determined by pour plate technique on Plate Count Agar (PCA) medium (incubated at 37℃/48 h). The plate count agar (PCA) was again used with chloramphenicol addition for yeast and mold count after incubation at 25℃ for 5 days. Visible colonies were counted using a colony meter (AOAC, 2005).

3.5 Sensory analysis

Sensory analysis was evaluated by ten semitrained panelists in closed room and sensory parameters analyzed were colour, aroma, taste, texture and overall acceptability using Hedonic rating scale (Rangana, 1986). Samples were served after boiling. Sensory score card is given in Appendix A.

3.6 Statistical method

The triplicate data of each experimental analysis were analyzed by one- way analysis of variance (ANOVA) and this was carried out by using software GenStat Release 12.1 (Copyright 2009, VSN International Ltd.).Means were separated using Tuckey's HSD post hoc.test ($P<0.05$).

3.7 Cooking Test of the product

Physical analysis was performed to analyze cooking time , cooking loss and water absorption of the noodles.

3.7.1 Determination of Cooking Time

In this method 5 g sample in 30 ml water was taken in each petriplate and was cooked and the suitable cooking time was determined by inspection of filling. To determine cooking time noodles thread being cooked was cut with spoon and exposed part was observed. It was cooked till there was no uncooked specks on the cut-exposed part (Bhandari, 1992).

3.7.2 Determination of Cooking Loss

Cooking loss was determined by measuring the amount of solid substance lost to cooking water. 2 g Sample was taken with the addition of water (50 ml) in a previously weighed cleaned and dried petriplate and cooked for 10 min. After cooking, noodles were removed from petriplate and residual losses was obtained by evaporation at first on water bath and finally on hot air oven (Bhandari, 1992).

Cooking loss (%) of the product is given by the formula: $= (y/x) \times 100$

Where, y = Weight of the remaining residue in petriplate after drying.

x= Weight of the sample taken.

3.7.3 Determination of Water Absorption Capacity

First dry weight of the noodles was taken and then cooked in boiled water for 10 min. After cooking, water was drained and the noodle was weighed. Water absorption capacity (W.A.C.) is expressed in percentage using formula given below (Bhandari, 1992).

% W.A.C = (Final weight - Initial weight) / (Initial weight) x 100

Part IV

Result and discussion

Preparation and quality evaluation of moringa leaf incorporated stick noodles was carried out with wheat : leaf ratio of 100:0, 96.25:3.75, 95:5, 92.5:7.5, 90:10, 88.75:11.25, and 85:15 and coded as control, A, B, C, D, E, F and G respectively.

Leaves from a common variety of *Moringa oleifera* from Sunsari District was taken and dried. They were powdered and analysis of proximate components, minerals, antinutrients content and antioxidant activity were done. Then noodles were prepared according to the formulation. Sensory analysis was carried out to know the preference among recipes and only superior and control noodles samples were analyzed.

4.1 Proximate Analysis of raw materials

Table 4.1 shows the mean values of the triplicate data for proximate composition of wheat flour and moringa leaf powder

Table 4.1 Proximate composition of wheat flour and moringa leaf powder

Parameters	Wheat flour (%)	Moringa leaf powder (%)
Moisture	11.65±0.02	6.28±0.18
Crude fat*	1.45±0.13	2.83±0.27
Crude protein*	10.23±0.09	28.01±0.20
Crude fiber*	0.64±0.11	10.42±0.13
Carbohydrate*	87.15±0.14	47.54±0.08
Ash content*	0.53±0.20	11.20±0.3

[*represents values in dry basis, values following ± represents standard deviation]

The moisture content of wheat flour was 11.65%. The commercial wheat flour had moisture content less than 14% according to (Ahmed and Islam, 2018). The moisture content of flour was affected due to the tempering and milling conditions of flour. The moisture content of moringa flour was found to be 6.28% whereas the moisture content of moringa leaf powder was 7.43% as reported by (Rajput *et al.*, 2017). The lower moisture content of the leaves powder made it shelf stable and the leaves could be stored for a considerable length of time (up-to 1 year) at room temperature when packed properly (Riaz and Wahab, 2021).

The fat contents was found to 2.83% in moringa flour however fat in wheat was 1.45% which was slightly lower. Fat content of the moringa leaf powder varied greatly from that reported by (Hasaballa *et al.*, 2017), which is 7.19%. But fat content in leaves could be as low as the obtained data. This was supported by the data from the work of (Dhakar *et al.*, 2020).

The protein content was wheat flour and moringa flour were 10.28% and 28.01% respectively. The obtained result (28.01%) for leaf was slightly higher than that reported by (Hasaballa *et al.*, 2017) which was 22.14% at moisture 7.96%. But researches had shown the variation in protein content from 20% to 35% of dry weight (Yang *et al.*, 2018).

Moringa leaves were excellent sources of dietary fibers as obtained data indicates. The crude fiber in the moringa flour was far greater than the crude fiber in the wheat flour. The values of crude fiber in moringa flour and wheat flour were 10.42% and 0.64%. The data obtained for leaves was found similar to (Hasaballa *et al.*, 2017).

Leaves were rich source of minerals as indicated by the ash content. The ash content of moringa flour was significantly higher as compared to wheat flour. The values of ash content in moringa flour and wheat flour were 11.20% and 0.53%. (Hasaballa *et al.*, 2017) also reports that leaf (9.12%) was rich in mineral content It might be due to the high minerals content in moringa leaf (Sahay *et al.*, 2017).

And the carbohydrate content of wheat flour was found to be 87.15% whereas the carbohydrate content of moringa flour was found to be 47.54%. The carbohydrate content of moringa leaves was 51.11% as reported by (Hasaballa *et al.*, 2017).

4.2 Chemical Analysis of wheat flour and moringa leaf powder

Table 4.2 shows the calcium and iron content of wheat flour and moringa leaf powder. The calcium content of moringa flour was similar to the data obtained by (Hasaballa *et al.*, 2017) but iron content of leaf was lower than his (47.13 mg/100g). (Yameogo *et al.*, 2011) reported that iron content in leaf is 28.3 mg/100g. This suggested that the iron content varied greatly according to place of raw materials. Iron content in leaf was nearer with the data reported by (Solana *et al.*, 2015).

Table :4.2 Chemical analysis of wheat and moringa leaf powder

Parameter(db)	Wheat flour	Moringa leaf powder
Calcium (mg/100g)	30.80±3.20	1310±0.2
Iron (mg/100g)	3.33±0.28	18.56±0.2

[Values are the means of triplicates, values following ± represents standard deviation]

4.3 Antioxidants of wheat flour and moringa leaf powder

The antioxidants and chlorophyll content of wheat flour and moringa leaf powder is shown in Table 4.3. The antioxidant activity of moringa leaf powder was slightly low as compared to (Hasaballa *et al.*, 2017). (Jahan *et al.*, 2015) stated that antioxidant activity of moringa leaves differ with the stage of maturity. Free radical scavenging activity in moringa leaves was positively correlated to chlorophyll (Nobossé *et al.*, 2018). According to (Niroula *et al.*, 2019), the chlorophyll content of wheat flour was 16.82±0.39 mg/100g.

Table :4.3 Antioxidants of wheat flour and moringa leaf powder

Antioxidants(db)	Wheat flour	Moringa leaf powder
AA (IC50%)	26.6±0.3	30±0.1
Chlorophyll(mg/100g)	12±0.21	21.76±0.03

[Values are the means of triplicates, values following ± represents standard deviation]

4.4 Anti-nutrients of wheat flour and moringa leaf powder

The phytate content of wheat flour and moringa flour 3.19 mg/100g and 13 mg/100g which showed that the phytate content of moringa flour was higher as compared to wheat flour. Similarly, the tannin content of moringa flour was also greater than the wheat flour. The values of tannin content of moringa flour and wheat flour were 5.68 mg/100g and 0.68 mg/100g. According to (Auwal *et al.*, 2019), the phytate content of moringa leaves was 10.58 mg/100g and the tannin content was 8.19 mg/100g. Phytate and tannin content of wheat flour and moringa leaf powder is shown in Table 4.4.

Table: 4.4 Anti-nutrients of wheat flour and moringa leaf powder

Parameters(db)	**Wheat flour**	**Moringa leaf powder**
Phytate (mg/100g)	3.19±0.04	13±0.2
Tannin (mg/100g)	0.68±0.2	5.68±0.6

[Values are the means of triplicates, values following ± represents standard deviation]

4.5 Sensory analysis of moringa incorporated noodles

Statistical analysis of sensory score was obtained from 10 semi-trained panelist using 9-points hedonic rating (9 =extremely like, 1=dislike extreme) for *Moringa oleifera* leaves incorporated noodles formulations. Sensory analysis was performed with aid of different panelist evaluating colour, taste ,texture, aroma and overall acceptability of moringa incorporated noodles.

4.5.1 Colour

The mean sensory scores of colour were found to be 7.5, 8.5, 6.3, 5.5, 4.1, 3.4, 3.1 for the noodles formulation A, B, C, D, E, F and G. The obtained mean values of treatments are presented in Fig. 4.1.

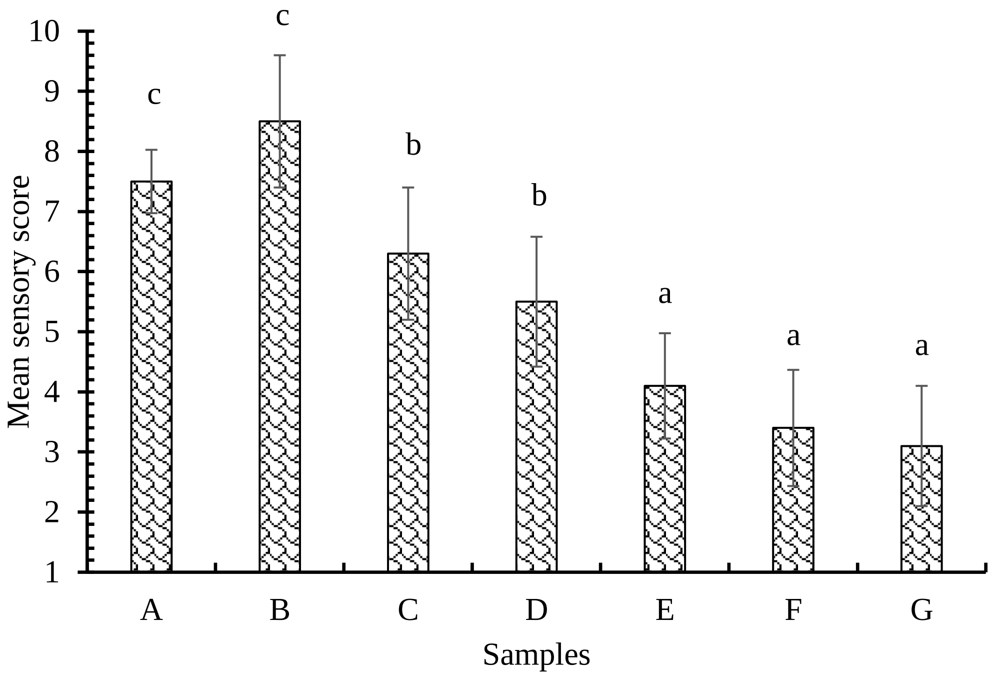

Fig.4.1 Mean sensory scores for colour of noodles

[A, B, C, D, E, F and G denotes formulation of 0, 3.75, 5, 7.5, 10, 11.25 and 15 parts (w/w) of moringa powder. Vertical error bars represent ± standard deviations of scores given by 10 panelist. Values on top of the bars bearing similar superscript are not significantly different ($p>0.05$) at 5% level of significance.]

The statistical analysis shows that there is significant difference ($p<0.05$) among the prepared samples in terms of colour. But no significant difference was seen in sample A and B. In terms of highest mean score, sample B was superior. Sample C and D also showed no significant difference whereas sample E, F and G were least preferred by the panelists.

As reported by (Karim, O. *et al* 2015), Moringa leaf powder had deep green colour due to high chlorophyll content, and this green colour of moringa leaf powder changed the colour of noodles. The highest mean score of sample B might be due to the unique and appealing colour of noodles with 3.75 parts (w/w) moringa leaf incorporation. Sample A was also liked by the panelists due to the panelists being habituated to plain noodles. The colour of noodles with high moringa leaves powder presented an unusual colour. The natural green colour of leaves was due to mixture of chlorophyll which was directly related to magnesium. During drying, the magnesium molecules were changed to pyropheophytin and pheophytin (Ali *et al.*, 2014). Peculiarity of color for panelist played significant role for lower score to formulated noodles with high concentration of moringa leaves compared to that of control noodles. All moringa-supplemented samples were noticeably green, even at 1% incorporation. Moringa leaf powder used in wheat breads also significantly changed the color of the product at the same supplementation level (Sengev *et al.*, 2012).

4.5.2 Taste

The mean sensory scores of taste were found to be 8.1, 7.9, 7.5, 6.7, 5.1, 4.4, 4.5 for the noodles formulation A, B, C, D, E, F and G. The obtained mean values of treatments are presented in Fig. 4.2.

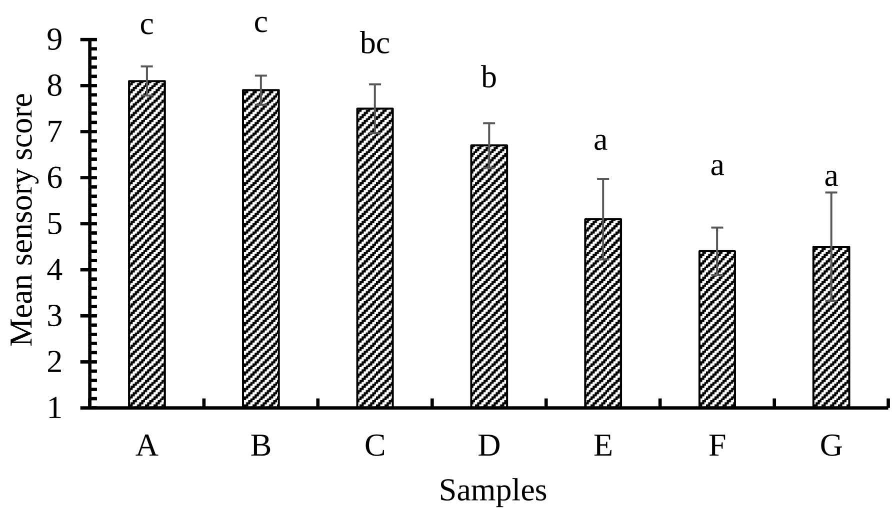

Fig.4.2 Mean sensory scores for taste of noodles

[A, B, C, D, E, F and G denotes formulation of 0, 3.75, 5, 7.5, 10, 11.25 and 15 parts (w/w) of moringa powder. Vertical error bars represent ± standard deviations of scores given by 10 panelist. Values on top of the bars bearing similar superscript are not significantly different ($p>0.05$) at 5% level of significance.]

The mean sensory score for taste was found to be significantly different ($p<0.05$) among the samples. From the sensory analysis it was found that sample A was superior in terms of highest mean score. No significant difference ($p>0.05$) was seen among sample A, B and C. This might be because panelists liked the unique taste of less concentration moringa leaf incorporated in noodles. But as the % of moringa powder increased, it contributed to grassy/bitter taste. Sample E, F and G were not preferred by the panelists. The bitter taste of moringa was the work of glucosinolates and polyphenol contents. As well as presence of saponins in moringa leaf might have contributed to bitter taste in noodles with higher leaves percentage in them as per (Indriasari *et al.*, 2016). Slight sensation of grassy taste was observed in all the formulated noodles, similar to the findings of (Sengev *et al.*, 2012) who found grassy taste by incorporating leaf powder as low as 1%.

4.5.3 Texture

The mean sensory scores of texture were found to be 7.8, 8.1, 7, 6.5, 6.2, 5.5, 5.4 for the noodles formulation A, B, C, D, E, F and G. These obtained mean values of treatments are presented in Fig. 4.3.

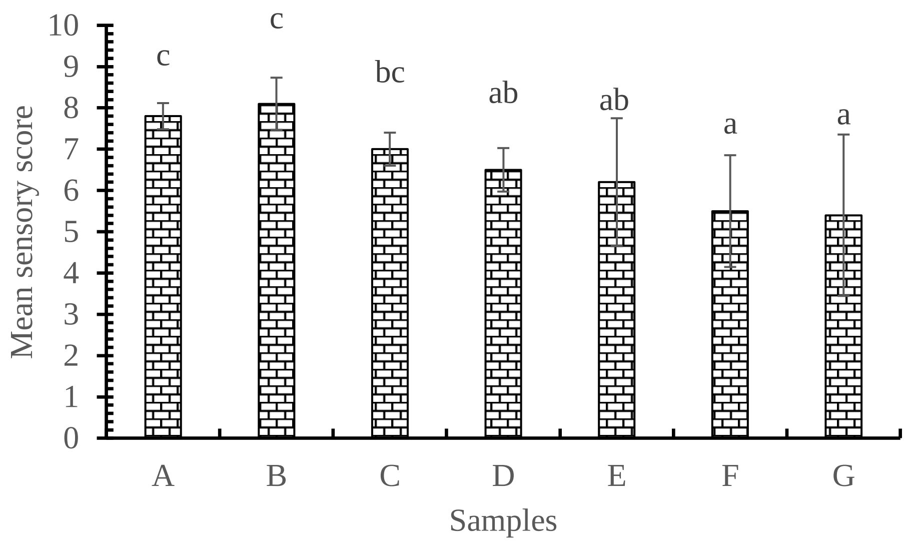

Fig.4.3 Mean sensory scores for texture of noodles

[A, B, C, D, E, F and G denotes formulation of 0, 3.75, 5, 7.5, 10, 11.25 and 15 parts (w/w) of moringa powder. Vertical error bars represent ± standard deviations of scores given by 10 panelist. Values on top of the bars bearing similar superscript are not significantly different ($p>0.05$) at 5% level of significance.]

Statistical analysis showed that, significant difference ($p<0.05$) was found in terms of texture among the various formulations. But sample A and B showed no significant difference ($p>0.05$). Sample B was superior in terms of highest mean score among all the samples. No significant difference was seen in sample D and E whereas sample F and G had coarse and gritty texture and was not quite preferred by the panelists.

Texture of samples decreased with increase in concentration of moringa powder due to high content of crude fiber and less network development due to less gluten. The gritty and coarse texture of high concentration of moringa powder incorporated noodles resulted in decrease in gumminess, springiness and strength of noodles. As the addition of moringa flour increased dough was less elastic, less sticky, and less extensible. The high ash content and less gluten development deteriorated the textural properties of moringa noodles compared to the wheat noodles (Kang *et al.*, 2017). Therefore, due to the poor network formation tougher texture and cracks were seen in noodles and texture of the noodles may have decreased as reported by (Jing *et al.*, 2018). Earlier, studies have also reported that with the addition of bran, high protein, dietary fibre, calcium and iron diluted the gluten which resulted in the development of hard dough having less gumminess and springiness with hard nature (Dachana *et al.*, 2010). The firm texture and no cracks of sample A which might be due to adequate amount of gluten development as no moringa was incorporated in it.

4.5.4 Aroma

The mean sensory scores of aroma were found to be 7.8, 7.6, 7.1, 6.45, 5.4, 5.1, 4.8 for the noodles formulation A, B, C, D, E, F and G. The obtained mean values of treatments are presented in Fig. 4.4.

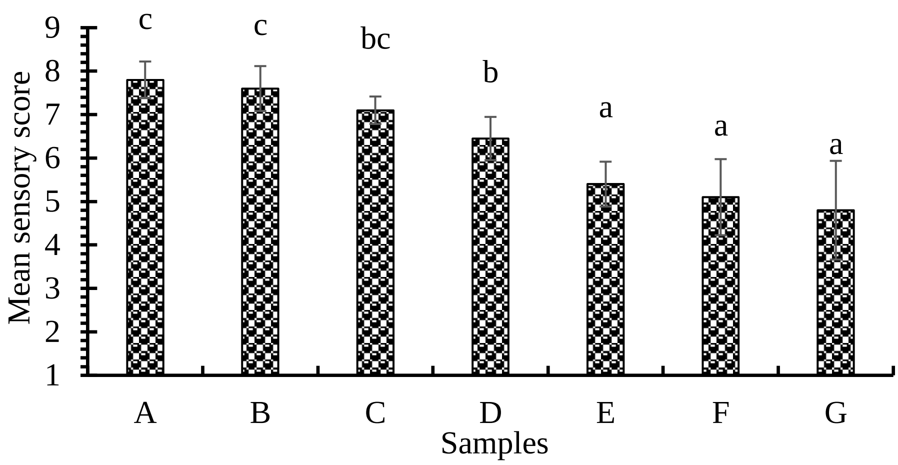

Fig.4.4 Mean sensory scores for aroma of noodles

[A, B, C, D, E, F and G denotes formulation of 0, 3.75, 5, 7.5, 10, 11.25 and 15 parts (w/w) of moringa powder. Vertical error bars represent ± standard deviations of scores given by 10 panelist. Values on top of the bars bearing similar superscript are not significantly different ($p>0.05$) at 5% level of significance.]

Statistical analysis showed that substitution of wheat flour with moringa flour had significant($p<0.05$) effects on samples of sticky noodles in terms of aroma. From the sensory analysis it was found that Sample A was superior in terms of highest mean score No significant difference ($p>0.05$) was seen in sample A and B. No significant variation in terms of aroma can be concluded among sample C and D as well. Sample E, F and G were least preferred.

The unique herbal aroma of moringa leaves made the moringa noodles quite preferred when less concentration of moringa leaf powder was incorporated. The lowest mean score of sample E, F and G might be due to the grassy or earthy smell due to higher percentage of leaf powder. The unfavorability, could be a consequence of the respondents' unfamiliarity with moringa or a genuine dislike (Ntila *et al.*, 2019). As the percentage of the moringa flour increased aroma in stick noodles was undesired due to the lipoxidase enzymes and essential oils present in moringa leaves. Lipoxidase enzymes and oils had volatile properties, producing a distinctive aroma that was less preferred (Nurjanah *et al.*, 2021).

4.5.5 Overall acceptance

The mean sensory scores of overall acceptance were found to be 7.75, 8.1, 7, 6.05, 5.1, 4.4, 4.2 for the noodles formulation A, B, C, D, E, F and G. The obtained mean values of treatments are presented in Fig. 4.5.

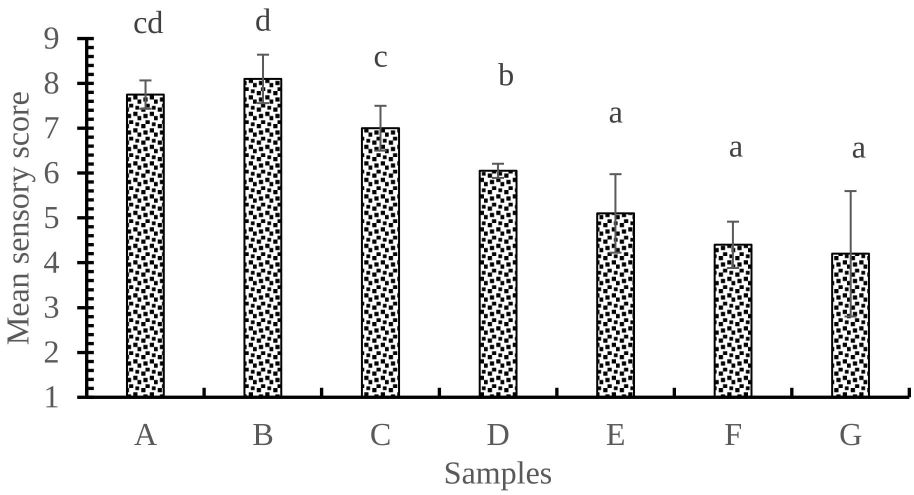

Fig.4.5 Mean sensory scores for overall acceptance of noodles

[A, B, C, D, E, F and G denotes formulation of 0, 3.75, 5, 7.5, 10, 11.25 and 15 parts (w/w) of moringa powder. Vertical error bars represent ± standard deviations of scores given by 10 panelist. Values on top of the bars bearing similar superscript are not significantly different ($p>0.05$) at 5% level of significance.]

Statistical analysis showed that substitution of wheat flour with moringa flour had significant($p<0.05$) effects on samples of sticky noodles in terms of overall acceptance. But the sample A was not significantly different from sample B and sample C. Sample B was considered the superior in terms of highest mean score. Sample E, F and G was not quite preferred by the panelists.

Although high concentration moringa powder incorporated noodles got lower ranks on terms of overall acceptability, the acceptance of noodles can be further increased if consumers are made aware of the beneficial health attributes and nutritional information of the moringa noodles (Gopalakrishnan *et al.*, 2016). As the amount of the moringa leaf increased bitterness also increased which was significantly noticed when amount of moringa flour was reached 15 parts (w/w). The reason of bitterness was increase in amount of polyphenol contents. The results obtained from sensory analysis was matched with (Ganga *et al.*, 2019). Overall acceptability of moringa flour incorporated noodles seemed to increase upto 3.75 parts and then decreases gradually this may be due to high polyphenols contents, decreased gluten development, unpalatable colour, grassy and bitter flavour, gritty and coarse texture due to high concentration of leaf powder.

4.6 Comparison of superior noodles with control noodles

4.6.1 Overall comparison in terms of proximate components

The results shown on Table 4.5 showed the variation between the control noodles and formulated noodles. According to the sensory panelists, sample B was preferred than all the other formulated noodles in terms of colour, texture and overall acceptability. Sample A was the control noodles. The results here show that, though protein content in moringa leaf powder was high, there was no significant difference at level of significance ($p>0.05$). Significant difference was seen on others parameters like crude fat, crude fiber, carbohydrate and ash content.

Table 4.5 Proximate composition of superior and control noodles

Parameters	Superior noodles	Control noodles
Moisture	$8.83^{a}\pm0.05$	$10.76^{b}\pm0.09$
Crude fat *	$0.51^{a}\pm0.03$	$0.43^{b}\pm0.06$
Crude protein *	$9.93^{a}\pm0.05$	$10^{a}\pm0.15$
Fiber *	$2^{a}\pm0.03$	$0.62^{b}\pm0.04$
Carbohydrate *	$85.29^{a}\pm0.24$	$87.98^{b}\pm0.08$
Ash content *	$2.27^{a}\pm0.29$	$0.97^{b}\pm0.02$

[*represents values in dry basis, values following ± represents standard deviation and alphabetical superscripts represents that there is significant difference ($p<0.05$) among the samples]

The moisture content of sample B and control noodles varied from 8.83% to 10.76%. This was due to the low water absorptivity and low moisture content of moringa leaf powder, Moisture content of formulated noodles were found to be low as compared to control noodles (Sengev *et al.*, 2012). The results were in line with result obtained by (Zula *et al.*, 2021).

The crude fat of noodles varied from 0.51% to 0.43%. Since moringa had good nutritional profile as reported by (Islam *et al.*, 2021), noodles made with a higher concentration of moringa leaf powder could have higher fat content. Many studies had reported increase of about 20%-22% of protein content in food products through moringa leaf powder incorporation. The protein content contributed in elasticity, strength and extensibility of noodles. But no significant difference could be seen in protein content at 5% level of significance despite the fact that moringa leaves had high protein content.

One of the major reasons to prepare the moringa incorporated noodles was to improve the fiber content compared to that of normal noodles. Since, leaves were great source of fiber as stated by (Hasaballa *et al.*, 2017). The objective seemed to be achieved as significant increase ($p<0.05$) in fiber content in noodles could be seen.

The ash content of noodles varied from 2.27% to 0.97%. The higher ash content in the noodles made from the blend of higher concentration of moringa leaf powder might be due to moringa leaf being known by its higher mineral content as reported in (Islam *et al.*, 2021). The carbohydrate of noodles was varied from 85.29% to 87.15%. Carbohydrate was determined by difference method. Significant difference was seen in the carbohydrate content. The reduction in the carbohydrate content in the superior noodles might be due to the low carbohydrate content of the moringa leaves powder.

4.6.2 In terms of minerals

The results shown in Table 4.6 showed the calcium and iron content. The results indicated moringa leaf powder supplemented noodles were richer in mineral profile than control with significant increase in iron and calcium. The significant increase in iron and calcium content could be due to presence of higher iron and calcium content in the moringa leaf powder. (Zhang *et al.*, 2017) had also reported improvement of mineral, in noodles supplemented by moringa.

Table: 4.6 Chemical analysis of superior and control noodles

Parameters(db)	Superior noodles	Control noodles
Calcium (mg/100g)	$6.07^{a}\pm0.2$	$3.67^{b}\pm0.28$
Iron (mg/100g)	$1.63^{a}\pm0.2$	$0.20^{b}\pm0.05$

[Values following ± represents the standard deviation and alphabetical superscripts represents that there is significant difference ($p<0.05$) among the samples]

4.6.3 In terms of antioxidants

The results shown in Table 4.7 showed the antioxidant activity and chlorophyll content. The antioxidant activity increased as the moringa was added to the noodles. Significant difference ($p<0.05$) was seen between superior and control noodles. (Winawati *et al.*, 2021) stated that one of the most prominent content of moringa plants is antioxidants especially on the part of the leaves that contain the highest antioxidants and chlorophyll.

Table 4.7 Antioxidant of superior and control noodles

Antioxidants(db)	Superior noodles	Control noodles
AA(IC50%)	$26.88^{a}\pm0.1$	$23.94^{b}\pm0.3$
Chlorophyll(mg/100g)	$0.82^{a}\pm0.19$	$0.46^{b}\pm0.06$

[Values following ± represents the standard deviation and alphabetical superscripts represents that there is significant difference ($p<0.05$) among the samples]

4.6.4 In term of anti-nutrients

The results shown in Table 4.8 showed the phytate and tannin content. The study showed that phytate and tannin content were high in superior noodles as compared to control noodles. Significant difference was seen in phytate content but the difference between tannin content was not statistically significant ($p>0.05$). This shows that antinutritional contents of noodles increased as moringa leaf was incorporated in noodles. The higher phytate and tannin content of noodles made with the blend of moringa leaf powder could be due to the moringa leaf being known by its antinutritional content as reported by (Ghasi *et al.*, 2000).

Table 4.8 Anti-nutrients of superior and control noodles

Parameters(db)	Superior noodles	Control noodles
Phytate (mg/100g)	$3.88^{a}\pm0.1$	$3.54^{b}\pm0.12$
Tannin (mg/100g)	$1.52^{a}\pm0.3$	$0.94^{a}\pm0.2$

[Values following ± represents the standard deviation and alphabetical superscripts represents that there is significant difference ($p<0.05$) among the samples]

4.7 Shelf life study of moringa incorporated noodles

Moringa incorporated noodles were packed using low density polyethylene of 50 μm thickness and was stored in room temperature. The noodles become more susceptible to microbial spoilage if the moisture content is high (Karim and Sultan, 2014). The moisture content, total plate count, yeast and mold were studied from the date of manufacture till 3 months in the interval of 15 days. Figure 4.6 shows moisture content of superior and control noodles upto 3 months.

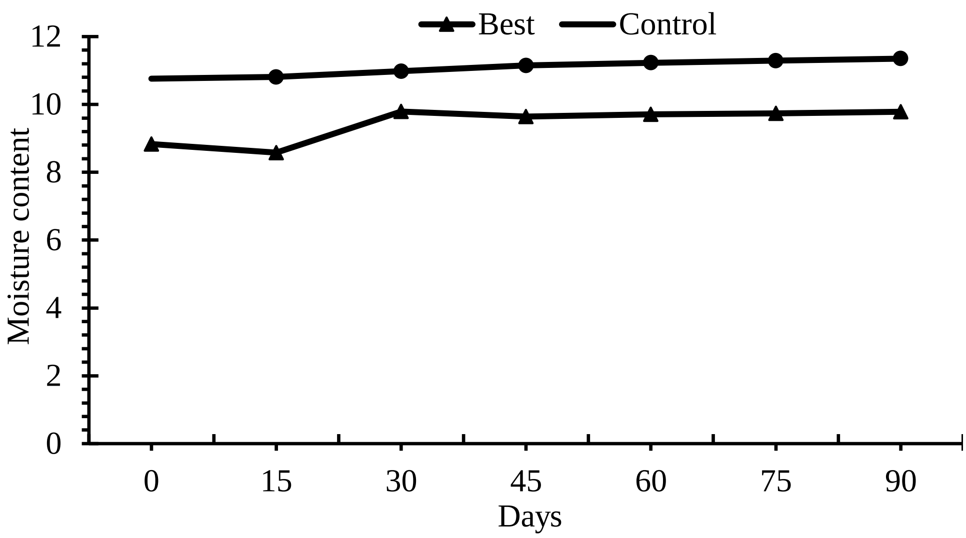

Fig 4.6: Moisture content of superior and control noodles upto 3 months.

According to Nepal Government (1970), the moisture content of noodles should be less than 12.5%. The table showed that both the products were within the limits. The moisture content of *Moringa* incorporated noodles and control noodles were 8.83% and 10.76% respectively at the beginning. The moisture content of superior sample reached 8.58%, 9.79%, 9.64%, 9.71%, 9.74% and 9.78%within 15, 30, 45, 60, 75 and 90 days. The superior sample had slight increase of moisture after 15 days. Whereas the moisture content of control sample within 15, 30, 45, 60, 75, 90 days were 10.81%, 10.98%, 11.15%, 11.23%, 11.29% and 11.35% respectively. Due to low water absorptivity and the lower moisture content of the leaves powder, *Moringa* incorporated noodles was shelf stable. It could be stored upto 3 months at room temperature when packed properly.

Table 4.9. Microbial load of superior and control noodles

	Storage Days						
Samples	**0**	**15**	**30**	**45**	**60**	**75**	**90**
Superior							
TPC (log cfu/g)	3.562	4.439	4.581	5.751	5.788	6.691	6.766
Yeast and Mold (log cfu/g)	3.415	4.581	5.322	5.474	5.682	6.567	6.661
Control							
TPC (log cfu/g)	3.827	4.770	4.987	5.791	5.957	6.812	6.954
Yeast and Mold (log cfu/g)	3.771	4.812	4.498	5.769	5.909	6.745	6.875

The microorganisms influenced the quality of food. The Table 4.9 showed the microbial load.100% wheat flour noodles had higher total plate count as compared to noodles made with the blend of moringa leaf powder The study showed that the total plate count of noodles was significantly decreased as moringa leaf powder concentration increased. The total plate count for cereal-and legume-based products exceeding 10^6 cfu/g was considered microbiologically unsafe (Olaoye and Beatrice, 2011). The lower total plate count in noodles made with the blend of higher concentration of moringa leaf powder might be due to the antimicrobial activity of moringa leaf as reported in (Amabye and Gebrehiwot, 2015).

Similarly, the study revealed that noodles made with the blend of moringa leaf powder had lower yeast and mold count as compared to 100% of wheat flour noodles. Therefore, like total plate count, yeast and mold count was decreased as moringa concentration increased. The lower yeast and mold count for noodles made with the blend of higher concentration of moringa leaf powder might be due to antimicrobial activity of moringa as reported in (Nepolean *et al.*, 2009).

4.8 Cooking properties of control and superior noodles

The cooking properties: cooking time, cooking loss and water absorption capacity is given in the Table 4.10. According to (Pokharel, 2010), the cooking time of wheat flour noodles prepared from wheat-buckwheat-malt composite flour was found to be 8 min. According to Sangroula (2019), the cooking time of noodle prepared from cassava-wheat composite flour was found to be 6±0.3 min. The cooking time of superior noodles was found to be less than that of wheat-buckwheat-malt noodles but more than that of cassava-wheat composite flour.

The cooking loss of the moringa noodles was more than that of the wheat flour noodles. An increase in the cooking loss with noodles containing moringa powder may have been due to the increase in fiber content, which interrupted the protein and starch matrix. These results were in the agreement with (Maribel *et al.*, 2009) who reported that partial or complete substitution of wheat with fiber material could result in negative changes to pasta quality, including increased cooking loss.

Table 4.10 Cooking properties of superior and control noodles

Cooking properties	Superior noodles	Control noodles
Cooking time (min)	$7.17^{a}\pm0.26$	$8.33^{b}\pm0.15$
Cooking loss (%)	$3.45^{a}\pm0.11$	$1.21^{b}\pm0.11$
Water Absorption Capacity (%)	$170.07^{a}\pm0.01$	$121.63^{b}\pm0.01$

[Values are the mean of triplicate data and values following ± represents the standard deviation]

Lee and Jung (2003) mentioned that the degree of water absorption in noodles during cooking was mainly affected by starch gelatinization as well as protein hydration related to particle size of starch**.** The addition of moringa flour enhanced the interaction between starch granules and protein matrix resulting in better quality noodles Moringa noodles had higher fiber content than wheat noodles, which also resulted in higher water absorption due to strong water binding ability of fibers. The results for water absorption agree with that of (Dachana *et al.*, 2010) who reported a significant increase in the water absorption capacity of wheat moringa flour (59.2-66.7%).

4.9 Cost of the noodles incorporated with *Moringa* flour.

The total cost associated with the superior product was calculated and cost of the moringa incorporated noodles per 100 gram was NRs.9.83 including overhead cost and profit of 10% (Calculation is given in the appendix G)

PART V

Conclusions and recommendations

Based on research, following conclusion can be drawn:

5.1 Conclusions

From the above analysis, following conclusion can be drawn

1. Noodles containing 3.75 parts (w/w) moringa leaf powder found to be superior in terms of colour, texture and overall acceptability in sensory quality.
2. Moringa powder was high in crude fat, crude protein, fiber, minerals, iron, calcium, chlorophyll and antioxidant activity as compared to wheat flour due to which the nutritional quality of the stick noodles of moringa incorporated noodles was also enhanced.
3. The superior sample was found to be rich in terms of proximate composition, mineral content, chlorophyll content and antioxidant activity except protein content from control sample.
4. Cooking loss was higher in moringa incorporated noodles than in control noodles.
5. The moisture and microbiological analysis of products showed that moringa leaf powder incorporated stick noodles was accepted upto 3 months at room temperature.

5.2 Recommendations

1. Entrepreneurs can utilize the moringa leaf powder upto 3.75 parts (w/w) to produce noodles with rich nutrient content.
2. Different treatments could be done to retain the phytochemicals of leaf before producing the noodles.
3. Acid Value and Peroxide value of sticky noodles can be analysed for shelf life analysis.
4. Other parts of *Moringa oleifera* plant such as root, stem bark, gum, flower, seed can also be used to prepare different products.

Summary

Noodles are popular staple food in several countries of the world. Even though the nutritional composition is limited, it's consumption has been increasing. Therefore, there is a need to complement wheat flour with other raw materials like *Moringa oleifera* leaves for enriching noodles with good nutritional value. *Moringa oleifera* leaves is considered to have a number of nutrients, such as protein, minerals, vitamins, calcium, iron and other mineral content.

Design expert (Response surface methodology) was used to formulate the recipe of noodles. Seven different formulations; A, B, C, D, E, F and G, were made with 0, 3.75, 5, 7.5, 10, 11.25 and 15 parts of leaves. Colour, texture, taste, aroma, and overall acceptability were the basis of sensory analysis. Genstat was used to evaluate sensory analysis (two way ANOVA no blocking). Proximate analysis, iron and calcium content, antioxidant activity, chlorophyll content, phytate and tannin content were observed of moringa leaf and wheat flour and as well as of superior and control sample . The moisture content, TPC, Yeast and mold were evaluated from the date of manufacture upto 3 months. Cooking test: cooking time, cooking loss, water absorption capacity were examined.

Sample B was superior in terms of colour, texture and overall acceptability. Moisture, ash, crude protein, crude fat, crude fiber, carbohydrate for control noodles were found to be 10.76%, 0.97%, 10%, 0.43%, 0.62% and 87.98% and for superior noodles were 8.83%, 2.27%, 9.93%, 0.51%, 2%, 85.29% respectively. Iron content were 0.20 mg/100g and 1.63 mg/100g for control and superior noodles while calcium content were 3.67 mg/100g and 6.07 mg/100g. Antioxidant Activity in IC_{50} was 23.94% and 26.88% for control and superior sample respectively. The chlorophyll content for control and superior noodles were 0.46 and 0.82 mg/g respectively. The phytate and tannin of control noodles were 3.54mg/g and 0.94 mg/g whereas of superior were 3.88 mg/g and 1.52 mg/g respectively. The cooking time varied from 8.33-7.17 min, cooking loss 1.21-3.45% and water absorption capacity 121.63-170.07% for control and superior samples respectively. Moisture content remained below 12.5% and microbial counts were within accepted limits upto 3 months.

It was observed that noodles samples with more than 3.75 parts (w/w) concentration of moringa leaf powder, had contributed low sensory scores. High level of chlorophyll and antinutritional factor of the leaves might have overshadowed the normal colour and taste of the noodles.

References

Ahmed, M. W. and Islam, M. N. (2018). Moisture sorption characteristics of selected commercial flours (wheat, rice and corn) of Bangladesh. *Am. J. Food Sci Technol.* **6** (6), 274-279. [doi:10.12691/ajfst-6-6-7].

Alakali, J. S., Kucha, C. T. and Rabiu, I. A. (2015). Effect of drying temperature on the nutritional quality of Moringa oleifera leaves. *Afr. J. Food Sci.* **9** (7), 395-399. [doi:10.5897/AJFS2014.1145].

Ali, M. A., Yusof, Y. A., Chin, N. L., Ibrahim, M. N. and Basra, S. M. A. (2014). Drying kinetics and colour analysis of Moringa oleifera leaves. *Agric Agricultural Sci. Procedia*. **2**, 394-400. [doi:10.1016/j.aaspro.2014.11.055].

Amabye, T. G. and Gebrehiwot, K. (2015). Chemical compositions and nutritional value of Moringa oleifera available in the market of Mekelle. **3** (5), 187-190.

Ananthu, S. and Singh, J. K. (2018). Development and Quality Evaluation of Noodles Prepared From Wheat Flour Supplemented with Tamarind Kernel Powder. *Int. J. Sci. Res. Sci. Technol.* **4** (7), 285.

Anon. (2005). Struture of wheat grain Retrieved from http://www.goenfoods.com/wheat-grain-structure/. [Accessed 2022 December 20].

Anwar, F., Latif, S., Ashraf, M. and Gilani, A. H. (2007). *Moringa oleifera*: A food plant with multiple medicinal uses. *Phytotherapy Res.* **21**, 17-25. [doi:10.1002/ptr.2023].

AOAC. (2005). "Official Methods of Analysis of the Association of Official Analytical Chemists" (18th ed.). Association of Official Analytical Chemisits. Arlington, Virginia, USA.

Arise, A. K., Arise, R. O., Sansui, M. O., Esan, O. T. and Oyeyinka, S. A. (2014). Effect of *Moringa oleifera* flower fortification on the nutritional quality and sensory properties of weaning food *Croatian J. Food Sci. Technol.* **6** (2), 65-71.

Atwell, W. and Finnie, S. (2016). "Wheat flour". Elsevier. USA. [ISBN 0-128-12366-4].

Auwal, M. M., Yelwa, J. M., Abubakar, I., Umar, J. B., Anchau, H. G. and Tanimu, F. B. (2019). The Levels of Antinutritional Factors in Moringa Oleifera and Vernomia Amygdalina Leaves Found in Some Part of Plateau State, Nigeria. *Oriental J. Physical Sci.*, 10. [doi:10.13005/OJPS04.02.06].

Bhandari, U. (1992). Preparation of Noodles from composite flour and study on their nutritive value. B.Tech, Dissertation. Tribhuban Univ., Nepal.

Cole, M. (2007). Prediction and measurement of pasta quality. *Int. J. Food Sci. Technol.* **26** (2), 133-151. [doi:10.1111/j.1365-2621.1991.tb01149.x].

Dachana, K. B., Jyotsna, R., Indrani, D. and Jamuna, P. (2010). Effect of dried moringa leaves on rehological, microbiolpical, nutritional, textural and organoleptic characteristics of cookies. *J. Food Qual.* **33**, 660-667. [doi:10.1111/j.1745-4557.2010.00346.x].

Delcour, J. A. and Hoseney, R. C. (2010). "Principle Of Cereals Science and Technology" (3rd ed.). Vol. 222. AACC International. St. Paul,. USA. [ISBN 978-1-891-12763-2].

Devkota, S. and Bhusal, K. K. (2020). Moringa oleifera: A miracle multipurpose tree for agroforestry and climate change mitigation from the Himalayas – A review. *Cogent Food Agric.*, 3. [doi:10.1080/23311932.2020.1805951].

Dhakar, R. C., Maurya, S. D., Pooniya, B. K., Bairwa, N., Gupta, M. and Sanwarmal. (2020). *Moringa*: The herbal gold to combat malnutrition. *Chronicles Young Scientist*. **2** (3), 119-125.

Dida, I., Grozdan, K. and Angel, A. (2001). Mineral composition of Bulgarian wheat bread. *Eur. Food Res. Technol.*, 245. [doi:10.1007/s002170100331].

Doerr, B. and Cameron, L. (2005). Moringa leaf powder. *ECHO Technical Note*.

Emmanuel, E. and Deborah, S. (2018). Phytochemical and anti-nutritional studies on some commonly consumed fruits in lokoja, kogi state of Nigeria. *Gen. Med. Open*. **2** (3), 1-5. [doi:10.15761/GMO.1000135].

Fu, B. X. (2008). Asian noodles: History, classification, raw materials, and processing. *Food Res. Int.* **41** (9), 888-902. [doi: 10.1016/j.foodres.2007.11.007].

Ganga, M. U., Karthiayani, A., Vasanthi, G. and Baskaran, D. (2019). Study on Development of Fiber-enriched Noodles using Moringa Leaves (Moringa olifera). *Asian J. Dairy Food Res.* **38** (2), 145-149. [doi: 10.18805/ajdfr].

Ghasi, S., Nwobodo, E. and Ofili, J. O. (2000). Hypocholesterolemic effects of crude extract of leaf of Moringa oleifera Lam in high-fat diet fed Wistar rats. *J. ethnoPharmacol.* **69** (1), 21-25. [doi:10.1016/s0378-8741(99)00106-3].

Ghazali, H. M. and Abdulkarim, S. M. (2011). Moringa (Moringa oleifera) seed oil: Composition, nutritional aspects and health attributes. *In:* "Nuts and Seeds in Health and Disease Prevention".). pp. 787-794. London. Academic Press

Gopalakrishnan, L., Doriya, K. and Kumar, D. S. (2016). Moringa oleifera: A review on nutritive importance and its medicinal application. *Food Sci. human wellness*. **5** (2), 49-56. [doi:10.1016/j.fshw.2016.04.001].

Government, N. (1970). "Nepalese food standards". Department of food technology and quality control (Ministry of food and agriculture), Nepal p. 32. [Accessed 10 October, 2022].

Hasaballa, M. A., Elsohaimy, S. A., Shaltout, O. E. and Zeitoun, M. A. M. (2017). Chemical Composition and Bioactive Compounds of Leaves, Flowers and Seeds of Moringa Plant. *J. Adv. Agric. Res.* **22** (4), 662-674.

Hau, G. (2001). Oriental noodles. *J. Adv. Food Nutr.*, 77. [doi:10.1016/S1043-4526(01)43004-X].

Hawa, A., Satheesh, N. and Kumela, D. (2018). Nutritional and anti-nutritional evaluation of cookies prepared from okara, red teff and wheat flours. *Int. Food Res. J.* **25** (5), 2042-2050.

Hoseney, R. C. (1986). "Principle of Cereals Science and Technology". American Association of Cereal Chemist.Inc.St.Paul,. USA. [ISBN 978-0-913-250792].

Hou, G. G. (2012). "Asian Noodles Science, Technology and Processing" (2nd ed.). Vol. 468. A John Wiley & Sons, Inc. Hoboken. New Jersey. [ISBN 978-0-470-17922-2].

Hummel, C. (1996). "Macroni Product" (2nd ed.). Food Trade PLace Limited. London.

Hyeon, J. K., Jeong, J. K., Byung, J. J., Jong, H. K., Sang, H. Y. and Suyong, L. (2015). Utilization of brown rice flour as a functional ingredient in instant fried noodles. *J. Korean Soc. Appl. Biol. Chem.* **58** (5), 637-642. [doi:10.1007/s13765-015-0086-y].

Indriasari, Y., Kumalaningsih, W. and Kumalaningsih, S. (2016). Effect of blanching on saponins and nutritional content of moringa leaves extract. *J. Food Res.* **5** (3), 55-60. [doi:10.5539/jfr.v5n3p55].

Islam, Z., Islam, S. M., Hossen, F., Mahtab-ul-Islam, K., Hasan, M. R. and Karim, R. (2021). Moringa oleifera is a prominent source of nutrients with potential health benefits. *Int. J. Food Sci.* **2021**. [doi:10.1155/2021/6627265].

Jahan, M. S., Zawawi, D. D. and Abdulkadir, A. R. (2015). Effect of chlorophyll content and maturity on total phenolic, total flavonoid contents and antioxidant activity of Moringa oleifera leaf (Miracle tree). *J. Chem. Pharm. Res*. **7** (5), 1147-1152.

Jing, Q., Yingguo, L., Yuanhui, W., Jie, C. and Panfeng, H. (2018). Formula and quality study of multigrain noodles. *Grain Oil Sci. Technol.* **1** (4), 157-162. [doi:10.3724/SP.J.1447.GOST.2018.18051].

Joshi, P. and Mathur, B. (2010). Preparation of value added products from the leaf powders of dehydrated less utilized green leafy vegetables. *J. horticulture forestry*. **2** (9), 223-228.

Kang, J., Lee, J., Choi, M., Jin, Y., Chang, D., Chang, Y. H., Kim, M., Jeong, Y. and Lee, Y. (2017). Physicochemical and textural properties of noodles prepared from different potato varieties. *Preventive Nutr. Food Sci.* **22** (3), 246. [doi: 10.3746/pnf.2017.22.3.246].

Karim, R. and Sultan, M. T. (2014). "Yellow Alkaline Noodles: Processing Technology and Quality Improvement". Springer. Malaysia. [ISBN 978-3-319-12864-1].

Karki, D. (1998). Optimization of drying of noodles prepared locally. B.Tech Dissertation. Tribhuvan Univ., Nepal.

KC, J. B. and Rai, B. K. (2007). "Basic Food Analysis Handboook" (1st ed.). Prompt Printers Pvt. Ltd. Kathmandu, Nepal.

Kent-Jones, D. W. and Amos, A. J. (1967). "Modern Cereal Chemistry" (6th ed.). Food Trade Press,. London.

Khan, K. and Shewry, R. P. (2009). "Wheat Chemistry and Technology" (4th ed.). AACC International, Inc. St.Paul. USA. [ISBN 978-1-891-12755-7].

Lee, Y. T. and Jung, J. Y. (2003). Quality characteristics of barley ${\beta} $-glucan enriched noodles. *Korean J. Food Sci. Technol.* **35** (3), 405-409.

Mahmood, K. T., Mugal, T. and Haq, I. U. l. (2010). Moringa oleifera: a natural gift-A review. *J. Pharm. Sci. Res.* **2** (11), 775.

Mallenakuppe, R., Homabalegowda, H., Gouri, M. D., Basavaraju, P. S. and Chandrashekharaiah, U. B. (2015). History, Taxonomy and Propagation of Moringa oleifera-A Review. *SSR Inst. Int. J. Life Sci.* . **3** (3.28), 3.15. [doi:10.21276/SSR-IIJLS.2019.5.3.7].

Maribel, O. M., Sonia, S. A., Edith, A. A., Isabel, G., Bello, P. and Luis, A. (2009). Unripe banana flour as an ingredient to increase the undigestible carbohydrates of pasta. *Food Chem.* **113** (1), 121-126. [doi:10.1016/j.foodchem.2008.07.035].

Mutiara, K. T., Estiasih, T. and Sriwahyuni, E. (2012). Nutrient content of kelor (Moringa oleifera Lamk) leaves powder under different blanching methods. *Food and Public Health*. **2** (6), 296-300.

Nandkule, V. D., Masih, D., Sonkar, C. and Patil, D. D. (2015). Development and quality evaluation of jackfruit seed and soy flour noodles. *Int. J. Sci. Eng. Technol.* **3** (3), 802-806. [doi:10.2348/ijset06150802].

Nepal FAO. (2007). Food and agricultural markets in Nepal. Nepal Food and Agricultural Organization of the United Nations. Retrieved from http://www.un.org.np/node/10514.

Nepolean, P., Anitha, J. and Emilin, R. R. (2009). Isolation, analysis and identification of phytochemicals of antimicrobial activity of Moringa oleifera Lam. *Current biotica*. **3** (1), 33-37.

Niroula, A., Khatri, S., Timilsina, R., Khadka, D., Khadka, A. and Ojha, P. (2019). Profile of chlorophylls and carotenoids of wheat (Triticum aestivum L.) and barley (Hordeum vulgare L.) microgreens. *J Food Sci Technol.* [doi: 10.1007/s13197-019-03768-9].

Nisar, N., Mustafa, F., Tahir, A., Qadri, R., Yang, Y., Khan, M. I. and Wang, F. (2020). Proximate composition, functional properties and quantitative analysis of benzoyl peroxide and benzoic acid in wheat flour samples: effect on wheat flour quality. *National Library Med.*, 1175. [doi:10.7717/peerj.8788].

Nobossé, P., Fombang, E. N. and Mbofung, C. M. F. (2018). Effects of age and extraction solvent on phytochemical content and antioxidant activity of fresh Moringa oleifera L. leaves. *Food Sci. Nutr.* **6** (8), 2188-2198. [doi:10.1002/fsn3.783].

Ntila, S., Ndhlala, A. R., Siwela, M., Kolanisi, U. and Abdelgadir, H. (2019). Acceptability of a moringa-added complementary soft porridge to caregivers in Hammanskraal, Gauteng province and Lebowakgomo, Limpopo province, South Africa. *S. Afr. J. Clinical Nutr.* **32** (3), 27-33.

Nurjanah, N., Hidayati, L., Kiranawati, T. M., Fatimah, N. and Susanto, H. (2021). The characteristics and organoleptic qualities of Moringa oleifera jelly candy post kelor leave puree supplementation. *AIP Conference Proceedings*. **2353**, 030097.

Olaoye, O. A. and Beatrice, I. O. A. O. (2011). Composite flours and breads: potential of local crops in developing countries. *In:* "Flour and breads and their fortification in health and disease prevention".). pp. 183-192. Elsevier.

Orisa, C. A. and Ukpong, S. U. (2019). Proximate and mineral compositions of noodles made from Triticum durum, Digitaria exilis, Vigna unguiculata flour and Moringa oleifera powder. *J. Food Sci. Eng.* **9** (7), 276-286. [doi:10.17265/2159-5828/2019.07.003].

Padayachee, B. and Baijnath, H. (2020). An updated comprehensive review of the medicinal, phytochemical and pharmacological properties of Moringa oleifera. *S. Afr. J. Bot*. **129**, 304-316. [doi:10.1016/j.sajb.2019.08.021].

Pakhare, K. N., Dagadkhair, A. C., Udachan, I. S. and Andhale, R. A. (2016). Studies on preparation and quality of nutritious noodles by incorporation of defatted rice bran and soy flour. *J. Food Process. Technol.* **7** (10).

Pokharel, B. (2010). Preparation of Noodles from composite flour and its quality evaluation. B.Tech Dissertation. Tribhuvan Univ, Nepal.

Qi, N., Feng, X., Wamg, X., Xu, Y. and Lin, L. (2016). Simultaneous analysis of eight vitamin E isomers in *Moringa oleifera* Lam. leaves by ultra performance convergence chromatography. *Food Chem.* **207**, 157-161. [doi:10.1016/j.foodchem.2016.03.089].

Rajput, H., Prasad, S. G. M., Srivastav, P., Singh, N., Suraj, L. and Chandra, R. (2017). Chemical and phytochemical properties of fresh and dried Moringa oliferiea (PKM-1) leaf powder. *Chem. Sci. Rev. Lett*. **6**, 1004-1009.

Rangana, S. (1986). "Handbook of Analysis and Quality Control for Fruit and Vegetable Products" (Second ed.). Tata McGraw-Hill Education, 1986. [ISBN 978-0-074-51851-9].

Ranganna, S. (1986). "Handbook of Analysis and Quality Control for Fruit and Vegetable Products". Tata McGraw-Hill Education. New Delhi. [ISBN 0074518518].

Riaz, A. and Wahab, S. (2021). Efficacy of Moringa leaves powder as a supplement in whole wheat flour biscuit. *Sarhad J. Agric.* **37**, 573-585. [doi:10.17582/journal.sja/2021/37.2.573.585].

Rockwood, J. L., Anderson, B. G. and Casamatta, D. A. (2013). Potential uses of *Moringa oleifera* and an examination of antibiotic efficacy conferred by M. *oleifera* seed and leaf extracts using crude extraction techniques available to under-served indigenous populations. *Int. J. Phytotherapy Res.* **3** (2), 61-71.

Rossentrater, K. and Evers, A. D. (2017). "Kent's Technology Of Cereals" (5th ed.). Vol. 926. Woodhead Publishing. USA. [ISBN 978-1-85573-660-3].

Sahay, S., Yadav, U. and Srinivasamurthy, S. (2017). Potential of Moringa oleifera as a functional food ingredient: A review. **8** (9.06), 4-90.

Sengev, I. A., Abu, J. O. and Gernah, D. I. (2012). Effect of M. *oleifera* leaf powder supplementation on the quality characteristics of wheat bread. *Intercontinental J. Food Sci. Nutr.* **1** (1), 1-5. [doi:10.4236/fns.2013.43036].

Shelke, K. (1990). Chinese wet noodle formulation: A response surface methodology study. *Cereal Chem*. **67**, 338-342.

Shih, M. C., Chang, C. M., Kang, S. M. and Tsai, M. L. (2011). Effect of Different Parts (Leaf, Stem and Stalk) and Seasons (Summer and Winter) on the Chemical Compositions and Antioxidant Activity of Moringa oleifera. *Int. J. Mol. Sci.*, 6080. [doi:10.3390/ijms12096077].

Simonato, B., Tolve, R., Rainero, G., Rizzi, C., Sega, D., Rocchetti, G., Lucini, L. and Giuberti, G. (2021). Technological, nutritional, and sensory properties of durum wheat fresh pasta fortified with Moringa oleifera L. leaf powder. *J. Sci. Food Agric.* **101** (5), 1920-1925. [doi:10.1002/jsfa.10807].

Singh, R. M. (2017). The tree of life: Moringa Oleifera. Online Khabar. Retrieved from https://english.onlinekhabar.com/the-tree-of-life-moringa-oleifera.html.

Solana, M. A. V., Garcia, V. Y. M., Valencia, A. T., Arenas, G. G., Pacheo, J. S., Romero, J. A. and Campos, E. S. (2015). Nutritional Content and Elemental and Phytochemical Analyses of *Moringa oleifera* Grown in Mexico. *J. Chem.*, 1-9. [doi:10.1155/2015/860381].

Tsaknis, J., Lalas, S., Gergis, V., Dourtoglou, V. and Spiliotis, V. (1999). Characterization of Moringa oleifera variety Mbololo seed oil of Kenya. **47** (11), 4495-4499.

Winawati, H. S., Susantinah, W. N. and Sri, R. M. J. H. (2021). Marketing Mix Analysis on Consumer Buying Interests of Moringa Leaf Noodle Products in Malang City. *Russian J. Agric. Socio-Economic Sci.* [doi:10.18551/rjoas.2021-07.20].

Yameogo, C. W., Bengaly, M. D., Savadogo, A., Nikiema, P. A. and Traore, S. A. (2011). Determination of chemical composition and nutritional values of *Moringa oleifera* leaves. *Pakistan J. Nutr.* **10** (3), 264-268.

Yang, L., Wang, X., Wei, X., Gao, Z. and Han, J. (2018). Values, properties and utility of different parts of *Moringa oleifera*: an overview *Chinese Herbal Med.* **10** (3). [doi:10.1016/j.chmed.2018.09.002].

Yu, L. J. (2003). Noodle dough rehology and quality of instant fried noodles. B.Tech Dissertation. McGill Univ, Canada.

Zhang, S., Zhou, W., Liao, L., Li, J., Lin, L. and Guo, C. (2017). Study on the formula of Moringa noodles. *J. Adv. Mater. Machinery, Electrical Eng.*, 758-762. [doi:10.2991/ammee-17.2017.143].

Zula, A. T., Ayele, D. A. and Egigayhu, W. A. (2021). Proximate Composition, Antinutritional Content, Microbial Load, and Sensory Acceptability of Noodles Formulated from Moringa (<i>Moringa oleifera</i>) Leaf Powder and Wheat Flour Blend. *Int. J. Food Sci.* **2021**, 6689247. [doi:10.1155/2021/6689247].

Appendices

Appendix A

Sensory Analysis Score Card

Name of the panelist: ………………………………………… Date: …………………

Product: Moringa leaves powder incorporated Noodles.

Dear panelist, you are given 7 coded samples of Moringa incorporated noodles on each proportion with variation of Moringa leaves powder, please give points for your degree of preference on the following parameter using the table given;

Quality attributes	Sample code						
	A	B	C	D	E	F	G
Colour							
Texture							
Taste							
Aroma							
Overall acceptance							

Judge the characteristics on the 1-9 scale as below:

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

Any comment:

Signature:

Appendix B

A.1 Chemicals used:

- Absolute Alcohol
- Acetic acid
- Ammonia
- Ammonium oxalate
- Ammonium hydroxide
- Acetone
- Boric acid
- Catalyst mixture
- Calcium chloride
- $FeSO_4(NH_4)SO_4.6H_2O$
- Folin-Ciocalteu reagent
- Ferric chloride
- Hydrochloric acid
- Methyl red
- Bromocresol green
- Phenolphthalein
- Methanol
- Oxalic acid
- Petroleum ether
- Potassium permanganate
- Potassium persulfate
- Potassium thiocyanate
- Potassium chloride
- Silver nitrate
- Sodium carbonate
- Sodium hydroxide
- Sodium oxalate
- Sulfuric acid

Appendix C

C.1 Equipments used:

- Water bath
- Spectrophotometer
- Weighing Balance
- Hot air Oven
- Dessicator
- Centrifuge
- Cabinet dryer
- Kjeldahl Digestion set
- Muffle Furnace
- Buchner's filter assembly
- Beakers
- Conical flask
- Volumetric flasks
- Burette
- Incubator
- Pipettes
- Micropipettes
- Mortar and Pestle
- Test tubes
- Stands
- Filter paper
- Filter aids
- Thermometer
- Crucible
- Measuring cylinders
- Petridish
- Porcelain Basin
- Crucible
- Soxhlet apparatus
- Heating arrangement

Appendix D

D 1:ANOVA for sensory characteristics of noodles samples

D 1.1 Two way ANOVA (No blocking) for Colour

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	6	257.6857	42.9476	73.72	<.001
Panelist	9	56.3429	6.2603	10.75	<.001
Residual	54	31.4571	0.5825		
Total	69	345.4857			

D 1.2 Two way ANOVA (No blocking) for Aroma

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	6	90.9929	15.1655	42.29	<.001
Panelist	9	8.6607	0.9623	2.68	0.012
Residual	54	19.3643	0.3586		
Total	69	119.0179			

D 1.3 Two way ANOVA (No blocking) for overall Acceptance

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	6	150.3357	25.0560	57.70	<.001
Panelist	9	7.2000	0.8000	1.84	0.081
Residual	54	23.4500	0.4343		
Total	69	180.9857			

D 1.4 Two way ANOVA (No blocking) for Taste

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	6	156.8857	26.1476	72.78	<.001
Panelist	9	8.8000	0.9778	2.72	0.011
Residual	54	19.4000	0.3593		
Total	69	185.0857			

D 1.5 Two way ANOVA (No blocking) for Texture

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	6	66.5714	11.0952	12.63	<.001
Panelist	9	32.0714	3.5635	4.06	<.001
Residual	54	47.4286	0.8783		
Total	69	146.0714			

Appendix E

E.1.T-test for proximate parameters of superior and control noodles samples

E.1.1 T-test for moisture content

	Variable 1	*Variable 2*
Mean	8.83	10.75667
Variance	0.0025	0.007633
Observations	3	3
Pearson Correlation	-0.28614	
Hypothesized Mean Difference	0	
df	2	
t Stat	-29.6899	
P(T<=t) one-tail	0.000566	
t Critical one-tail	2.919986	
P(T<=t) two-tail	0.001133	
t Critical two-tail	4.302653	

E.1.2 T-test for crude fat

	Variable 1	*Variable 2*
Mean	0.51333	0.426667
Variance	0.00063	0.003233
Observations	3	3
Pearson Correlation	0.98998	
Hypothesized Mean Difference	0	
df	2	
t Stat	4.66974	
P(T<=t) one-tail	0.02146	
t Critical one-tail	2.91999	
P(T<=t) two-tail	0.04293	

E.1.3 T-test for crude protein

	Variable 1	*Variable 2*
Mean	9.92666667	10
Variance	0.00203333	0.0225
Observations	3	3
Pearson Correlation	0.55441595	
Hypothesized Mean Difference	0	
df	2	
t Stat	-0.9732227	
P(T<=t) one-tail	0.21654756	
t Critical one-tail	2.91998558	
P(T<=t) two-tail	0.43309512	
t Critical two-tail	4.30265273	

E.1.4 T-test for fiber

	2.03	*0.58*
Mean	1.985	0.64
Variance	0.00045	0.0008
Observations	2	2
Pearson Correlation	-1	
Hypothesized Mean Difference	0	
df	1	
t Stat	38.42857	
P(T<=t) one-tail	0.008281	
t Critical one-tail	6.313752	
P(T<=t) two-tail	0.016563	
t Critical two-tail	12.7062	

E.1.5 T-test for carbohydrates

	85.29	*87.98*
Mean	85.29	87.98
Variance	0.1152	0.0128
Observations	2	2
Pearson Correlation	1	
Hypothesized Mean Difference	0	
Df	1	
t Stat	-16.8125	
P(T<=t) one-tail	0.018911	
t Critical one-tail	6.313752	
P(T<=t) two-tail	0.037821	
t Critical two-tail	12.7062	

E.1.6 T-test for ash

	Variable 1	*Variable 2*
Mean	2.266667	0.97
Variance	0.084233	0.0004
Observations	3	3
Pearson Correlation	0.809703	
Hypothesized Mean Difference	0	
df	2	
t Stat	8.188113	
P(T<=t) one-tail	0.007295	
t Critical one-tail	2.919986	
P(T<=t) two-tail	0.01459	
t Critical two-tail	4.302653	

E.1.7 T-test for calcium

	Variable 1	*Variable 2*
Mean	6.07	3.67
Variance	0.04	0.0784
Observations	3	3
Pearson Correlation	1	
Hypothesized Mean Difference	0	
df	2	
t Stat	51.96152423	
P(T<=t) one-tail	0.000185082	
t Critical one-tail	2.91998558	
P(T<=t) two-tail	0.000370165	
t Critical two-tail	4.30265273	

E.1.8 T-test for iron

	Variable 1	*Variable 2*
Mean	1.633	0.20333333
Variance	0.039	0.00243333
Observations	3	3
Pearson Correlation	1	
Hypothesized Mean Difference	0	
df	2	
t Stat	16.74	
P(T<=t) one-tail	0.002	
t Critical one-tail	2.92	
P(T<=t) two-tail	0.004	
t Critical two-tail	4.303	

E.1.9 T-test for antioxidant

	Variable 1	*Variable 2*
Mean	26.88	23.94
Variance	0.01	0.09
Observations	3	3
Pearson Correlation	1	
Hypothesized Mean Difference	0	
df	2	
t Stat	25.46114687	
P(T<=t) one-tail	0.000769504	
t Critical one-tail	2.91998558	
P(T<=t) two-tail	0.001539007	
t Critical two-tail	4.30265273	

E.1.10 T-test for chlorophyll

	Variable 1	*Variable 2*
Mean	0.82	0.46
Variance	0.0361	0.0036
Observations	3	3
Pearson Correlation	1	
Hypothesized Mean Difference	0	
df	2	
t Stat	4.79644839	
P(T<=t) one-tail	0.02041191	
t Critical one-tail	2.91998558	
P(T<=t) two-tail	0.04082383	
t Critical two-tail	4.30265273	

E.1.11 T-test for phytate

	Variable 1	*Variable 2*
Mean	3.88	3.54
Variance	0.01	0.0144
Observations	3	3
Pearson Correlation	1	
Hypothesized Mean Difference	0	
df	2	
t Stat	29.44486373	
P(T<=t) one-tail	0.000575705	
t Critical one-tail	2.91998558	
P(T<=t) two-tail	0.001151411	
t Critical two-tail	4.30265273	

E.1.12 T-test for for tannin

	Variable 1	*Variable 2*
Mean	1.52	0.94
Variance	0.09	0.04
Observations	3	3
Pearson Correlation	1	
Hypothesized Mean Difference	0	
df	2	
t Stat	10.04589	
P(T<=t) one-tail	0.004882	
t Critical one-tail	2.919986	
P(T<=t) two-tail	0.009764	
t Critical two-tail	4.302653	

E.1.13 T-test for cooking time

	Variable 1	*Variable 2*
Mean	7.172	8.33
Variance	0.07127	0.0235
Observations	5	5
Pearson Correlation	0.434332	
Hypothesized Mean Difference	0	
df	4	
t Stat	-10.6404	
P(T<=t) one-tail	0.000221	
t Critical one-tail	2.131847	
P(T<=t) two-tail	0.000442	
t Critical two-tail	2.776445	

E.1.14 T-test for cooking loss

	Variable 1	*Variable 2*
Mean	3.452	1.214
Variance	0.01177	0.01108
Observations	5	5
Pearson Correlation	0.274961	
Hypothesized Mean Difference	0	
df	4	
t Stat	38.8762	
P(T<=t) one-tail	1.31E-06	
t Critical one-tail	2.131847	
P(T<=t) two-tail	2.62E-06	
t Critical two-tail	2.776445	

E.1.15 T-test for water absorption capacity

	Variable 1	*Variable 2*
Mean	170.07	121.6267
Variance	2.4811	1.266633
Observations	3	3
Pearson Correlation	-0.22516	
Hypothesized Mean Difference	0	
df	2	
t Stat	39.35304	
P(T<=t) one-tail	0.000323	
t Critical one-tail	2.919986	
P(T<=t) two-tail	0.000645	
t Critical two-tail	4.302653	

Appendix G

G.1 Cost of moringa incorporated stick noodles.

Particulars	Cost (NRs/kg)	Weight in a lot (g)	Cost (NRs)
Wheat Flour*	60	1295	77.7
Moringa leaf*		105	0
Salt*	25	14	0.35
Water, ml		32	0
Raw material cost			78.05
Processing and labor cost (10% of raw material cost)			7.805
Profit (10%)			7.805
Grand total Cost			93.66
Total weight of noodles formed		952	
Total cost of noodles/ 100g			9.83

Color plates

Color plates A

Color Plate 1: Raw material (moringa leaves)

Color Plate 2: Cabinet drying of moringa

Color Plate 3: Sheeting of dough

Color Plate 4: Cutting of sheeted dough

Color plates B

Color plate 5: Drying of stick noodles in closed room

Color plate 6: Sample B (Superior sample) after boiling