EFFECT OF MALTED BUCKWHEAT ON THE SENSORY AND NUTRITIONAL PROFILES OF SEL-ROTI

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Effect of Malted Buckwheat on the Sensory and Nutritional Profiles of *Sel-roti*

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Approval Letter

This *dissertation* entitled *Effect of Malted Buckwheat on the Sensory and Nutritional Profiles of Sel-roti* presented by Archana Bhatta has been accepted as the partial fulfillment of the requirement for the B. Tech. degree in Food Technology.

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Abstract

The aim of this research was to optimize buckwheat flour content and evaluation of effect on quality of *sel-roti*. Different formulations were made by using DOE (Design of Expert) v 7.1.5. D- optimal design is used to formulate the recipe. Buckwheat flour incorporated *sel-roti* was prepared with the incorporation of buckwheat flour in 0 parts, 2.52 parts, 5.04 parts, 10 parts, 12.44 parts, 14.96 parts, 17.48 parts, and 20 parts concentration with rice flour. The buckwheat grains were stepped in water for 20 h and germinated at 26- 28 °C in open environment for 3 days and were kilned at 45 °C. The germinated buckwheat grains were processed into fine flour. The proximate analysis of prepared buckwheat flour and rice flour were carried out in the lab. The sensory analysis of buckwheat flour incorporated *sel-roti* of different concentration was carried out and analyzed statistically to obtain best formulation using Genstat Release 12.1 at 5% level of significance.

12.44 percent malted buckwheat flour incorporated *sel-roti* was found to be superior than other formulation based on sensory quality. Moisture content of *sel-roti* decreased with the increase in malted buckwheat flour incorporation from 0 – 20 parts and had significant effect on it. Likewise, malted buckwheat flour incorporation also had significant effect on the fat-uptake of *sel-roti* and increased with the increase in malted buckwheat flour proportion. The crude protein (% db), total ash (% db), iron content (mg/100 g), crude fat (% db) are found to be 9.73, 0.52, 2.67, 28.28 respectively in 12.44% malted buckwheat flour incorporated *sel-roti* which is higher as compared to values of control sample. Based on the sensory and physicochemical analysis, it was concluded that 12.44% malted buckwheat flour could be incorporated to improve the nutritional and sensory quality of *sel-roti*.

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List of Abbreviations

Abbreviation	Full form
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemist
DFTQC	Department of Food Technology and Quality Control
FAO	Food and Agriculture Organization
FFA	Free fatty Acid
LSD	Least significance difference
MOAC	Ministry of Agriculture and Co-operative
UNICEF	United Nations Children's Fund
USA	United States of America
WHO	World Health Organization

Part I

Introduction

1.1 General introduction

Traditional foods are produced from long time in different communities all around the world. The recipe of these products has been transferred from one generation to another. Nepal is a country of different culture, religions and races. The different races and ethnic groups have their own culture and own food habits oriented from their ancestors since immemorial time. There are many traditional food products found in different parts of the country. Some of them are nutritious, some are used as appetizer, and some have medicinal value while some are used as snack. Some food stands for special occasion such as *sel-roti* for Tihar and *Furoula* in Maghe Sankranti and is equally popular in Holi and *Siruwa* among Tharu culture. Though these products have been produced all around the country, there are slight variations as we move from place to place (Mainali, 2003). Some of the indigenous foods are location (region) specific e.g., *chhurpi* in Mountain or Hilly areas; some are community specific e.g., *chhoyala* and *kachila* in Newar; *kinema* in Limbu; jand and *raksi* in lower caste communities, whereas some food products e.g., *gundruk*, *sinki*, *sel roti* etc. are common to all geographic regions, all tribes and cultures. These indigenous foods have been prepared by traditional methods specific to the products (Subba and Katawal, 2011). Among various traditional food products found in different parts of countries, *sel-roti* is one of the most important indigenous products.

Sel-roti is a circular ring-shaped product prepared from rice flour making batter of proper consistency and frying in oil/ghee at high temperature. The batter is prepared from rice flour, cream or ghee, sugar and water. The frying medium may be different cooking oils (e.g. Mustard oil, refined oils), ghee or may be lard or mutton tallow. *Sel-roti* is popular in almost all geographic regions; in almost all tribes and communities of the country. It is popular and essential item in many festivals e.g., Tihar, Maghe Sakranti and ritual works. It is also a necessary food items in wedding ceremony and Bratabandha; and as Kosheli (Katawal, 2062). The importance of *sel-roti* is also found to be mentioned in Swasthani Brata Katha and Puran. It is very delicious and energy rich food item liked by many people of all ages. It is prepared and sold in local food shops, restaurant and open market as well. *Sel-roti* is also very popular food item in Sikkim, Hills of Darjeeling of India, and in some parts of many other countries where Nepali or the people originated from them reside there. They prepare *sel-roti* in many occasion and festivals, eat and enjoy their happiness with family, neighbours and friends Yonzan and Tamang (2010).

According to Katawal and Subba (2008) *sel-roti* should be ring shaped, puffed, reddish brown color, spongy and having grainy appearance, sweet and delicious in taste. Neither hard nor too soft, crisp or crumbly, somewhat fried flavor and oily or fatty mouth feel are its other eating quality. By a survey study, conducted information has been gathered as which the factors are influencing the quality of *sel-roti*. It was found that the particle size of rice flour influences the quality characteristics such as puffing, bulk density, fat- uptake, sensory attributes like appearance, taste, and texture of *sel-roti* (Subba and Katawal, 2011).

Buckwheat (*Fagopyrum esculentum*) a dicotyledonous plant belonging to Polygonaceae family. Two buckwheat species are commonly cultivated namely, Common buckwheat (*Fagopyrum esculentum*) and Tartary buckwheat (*Fagopyrum tartaricum*), the common buckwheat is known as mithe phapar while the next one is known as tite phapar in local language. Buckwheat is an annual short- season herbaceous plant with many branches. It has a remarkable adaptability to different kinds of soils, including poor soils with low fertility. It grows 60 to 70 cm high and has a primary root and an erect smooth stem. Its flowers vary from white or light green to pink or red (Valenzuela, 2002).

Buckwheat is a gluten free pseudo-cereal having high nutritional value that has been shown to provide a wide range of beneficial effects. The protein content in buckwheat is significantly higher than in rice, wheat, sorghum, millet and maize. Buckwheat has a well-balanced amino acid profile and also recognized as a good source of nutritionally valuable protein, lipid, dietary fiber, vitamins and minerals, and in combination with other health promoting components, such as phenolic compounds, flavonoids, fagopyrins, phytosterols, and also antioxidant capacity, it has received increasing attention as a potential functional food. Buckwheat contains rutin which is absent in other cereals or pseudocereals. Rutin (quercetin-3-beta-D-rutinoside) has antioxidant, anti-inflammatory and anticarcinogenic properties, and it can also reduce the blood pressure and stimulates the utilization of Vitamin C (Gimenez-Bastida and Zielinski, 2015). Cholesterol-lowering effects that lessen the problems of constipation and obesity are important health benefits that can be achieved through the functional substances of buckwheat. In comparison with other cereals such as rice, wheat or maize, buckwheat contains higher level of zinc (Zn), copper (Cu) and manganese (Mn) (Steadman *et al.*, 2001).

1.2 Statement of the problem

Sel-roti is a circular ring shaped product prepared from rice flour making batter of proper consistency and frying in oil/ghee at high temperature (Katawal and Subba, 2013) and also deep fried indigenous food product of Nepal (Subba and Katawal, 2011). In present context, increasing interests in the study of products, which are health beneficial as well as nutritious, has encouraged researchers to discover new ingredients and new ways for their incorporation into the diet. There are few written documents and only few articles published in journals about traditional processing of *sel-roti*. Scientific information regarding the production, nutritive value, and quality of *sel-roti* is also lacking.

There is a need to explore and familiarize *sel-roti* about its quality and nutritional value to the people of country and abroad, so that the *sel-roti* can be commercialized and can be export as nutritious indigenous food of Nepal. Proper documentation is important to authenticate its origin, preserve its culture and improve its technology and standardize the technological parameters for eventual successful commercialization. Therefore, this research was undertaken. As the traditional method of *sel-roti* preparation technology has been commercialized these days, there needs the product verification in *sel-roti* (Duarte *et al.*,1996). Malting alters the nutritional composition of food. So, for the production of more nutritious *sel-roti* with accretion in the organoleptic properties there is need to study on *sel-roti* for quality and nutritional value with incorporation by malted cereals with acceptable level. This study was a part of an effort on the improvement of the nutritional quality of indigenous food.

Rice flour contain mainly carbohydrates but are poor in proteins and other essential nutrients such as vitamins and minerals as well as fibres. So, the need of this study has been focused in order to fulfill the shortcoming in *sel-roti* of rice flour by partial incorporation of buckwheat flour which has a well-balanced amino acid profile with good quality of lysine (limiting amino acid in rice) and also contains higher level of Zn, Fe, Cu, Mn in comparison to rice flour and prepare nutritious and acceptable *sel-roti* (Aoki and Koizumi, 1986).

1.3 Objectives

1.3.1 General objective

General objective of this work is to prepare malted buckwheat incorporated *sel-roti* and its quality evaluation.

1.3.2 Specific objectives

a) To prepare malted buckwheat flour.

b) To prepare *sel-roti* from composite flour (rice and malted buckwheat) according to recipe.

c) To optimize buckwheat flour content in *sel-roti* based on sensory and nutrient analysis.

d) To evaluate chemical composition of control and optimized *sel-roti*.

e) To evaluate cost of optimized *sel-roti* sample.

1.4 Significance of the study

The present study helps to disseminate the important information about *sel-roti*. This study is focused on the documentation of output of the research which helps to find out the suitable proportion of malted buckwheat flour incorporation into rice flour for the production of malted buckwheat flour incorporated *sel-roti* with accretion in acceptability.

Buckwheat grain is a highly nutritional food component that has been shown to provide a wide range of beneficial effects. Health benefits attributed to buckwheat include plasma cholesterol level reduction, neuroprotection, anticancer, anti-inflammatory, antidiabetic effects and improvement of hypertension conditions. The incorporation of buckwheat can be justified in composite flour based *sel-roti* as it has beneficial nutraceutical properties and its gluten-free nature can play important role in preventing celiac problem. Buckwheat flour addition into *sel-roti* formulation has been observed to show considerable effects on sensory properties and color values of *sel-roti*. High fibre *sel-roti* can be obtained from the incorporation of buckwheat flour and appears to be a key source of minerals and polyphenolic compounds.

1.5 Limitations of the work

a) Complete nutrient analysis was not done due to lack of facility.
b) Study of batter consistency and microbiological analysis of *sel-roti* was not done.

Part II

Literature review

2.1 Nomenclature and origin of *sel-roti*

Sel-roti is a popular fermented rice-based ring shaped, spongy, pretzel like, deep fried food item commonly consumed in Sikkim, Darjeeling hills in India, Nepal and Bhutan. The name *sel-roti* is given to the ring-shaped deep-fried rice bread from the word saela, which means anything lifted with *suiro* because *sel-roti* is lifted by *suiro* turning during frying and taking out from hot oil after complete frying. There is other hypothesis on the nomenclature of *sel-roti* that it is prepared from a variety of rice called *seli* which is cultivated in foothills of Nepal and probably the roti prepared from that rice is called *sel-roti*. Some people believe that the word *sel-roti* is originated from the word 'Saal' whose meaning confectionary bread prepared during festival i.e., Tihar, once a year. Different ethnic groups call it by various names: *selsoplay* by the Mukhia, *selgaeng* by the Tamang, *selpempak* by the Rai, etc. (Yonzan and Tamang, 2010).

The antiquity of *sel-roti* remains a myth; no historical documents were available. In older days, *sel-roti* prepared did not include the use of spices or condiments but nowadays, because of the development of diversified taste, people prefer to add spices during preparation (Yonzan and Tamang, 2009). *Sel-roti* is a homemade circular-shaped bread prepared during Tihar, a widely celebrated Hindu festival in Nepal. Traditional processing and product characterization of *sel-roti* has not been documented. It is something like a doughnut, but less fluffy. They are deep-fried rings of sweet bread made from rice.

Sel-roti was mostly prepared at home (76.5%), and market purchased amount to 14%. The *sel-roti* was served as confectionary bread with *aalu dam* (boiled potato curry),and simi ko achar. It can be consumed hot or cold. It can be stored at room temperature for 2 weeks (Yonzan and Tamang, 2009).

2.2 Ingredients for *sel-roti* preparation

Sel-roti is rice based non-alcoholic fermented indigenous food of Nepal. *Sel-roti* is familiar among almost all Nepalese, even though the ingredients used for the preparation of *sel-roti* differ among the Nepalese of different tribe, races, culture and religion. Ingredients are of two types: (a) Main ingredients and (b) Optional ingredients. The quality of *sel-roti* depends on main ingredients. Most of the people used rice flour, sugar, water, ghee (animal ghee) and oils as main ingredients. In addition to the main ingredients, the substances used to make *sel-roti* more puffy, soft, flavorful, delicious, tasty, good appearance are called optional ingredients. The ingredients used for those purposes collectively are also called '*Daun*'.The minor ingredients may be dahi, spices, soda, milk, some plant materials etc. (Dahal, 2012). In addition to rice flour, maize, white millet, sorghum, buckwheat flour is also used to prepare *sel-roti* in mountain areas where rice is scare. The optional ingredients are used to impart and improve certain quality parameters such as dimensional expansion, texture, taste and appearance as well as for nutritional improvement (Katawal and Subba, 2008) .

2.2.1 Rice

Rice (*Oryza sativa* L.) is the second largest crop in the world, and feeds nearly half of the entire population (Chen and Zeng, 2007). Fifty-five percent of the cultivated land of Nepal is covered with rice. Ninety percent of the rice grown in the world is produced and consumed in Asia. Rice is cultivated since before the Vedic time in Nepal. The description of rice is found in the Veda written 1500 B.C. and in other Nepalese literature. Even in the ancient literature of 2800 B.C. rice cultivation were mentioned. Historians believe that it was first domesticated in the area covering the foot –hills of the Eastern Himalayas (North- Eastern India), and stretching through Burma, Thailand, Laos, Vietnam and Southern China.

Rice is a plant of the grass family, and one of the oldest food crops. Rice probably originated in South-East Asia, where it has been grown for many centuries. The earliest record of rice production in China dates back to about 2800 BC (Ghose *et al.*, 1956) and in India to 1000 BC. Rice cultivation is well suited to countries with low labor costs and rainfall, as it is very labor intensive to cultivate and requires plenty of water for irrigation. The modern English word rice originates from ancient Greek word " *arizi*" which in turn was burrowed from the Tamil word of the same pronunciation, strongly indicating trade relationship between ancient Greeks and Tamils (Nationmaster.com, 2005).

In the world food economy, rice plays important role such as:

a) It is staple food for half to two third of the population.
b) In many Asian countries, it accounts for one third to half of the daily calorie intake and also a major protein source.

2.2.1.1 Variety of rice for the preparation of *sel-roti*

Kanchhi mansuli is the variety of rice used for the *sel-roti* preparation. The other coarse varieties such as attay, anadi, tauli, B40 rice are also used depending on the availability for its preparation. Year aged old rice is preferred to obtain the good quality of *sel-roti*. The aged rice gives soft and well puffed *sel-roti*.

2.2.1.2 Composition of paddy

Rice grain consists of an edible portion, which is a fruit of the grass plant known as caryopsis and an inedible covering hull or husk (Fig. 2.1). The caryopsis is called brown rice because of its brownish appearance (pericarp). The hull is composed of cellulosic and fibrous tissues. The pericarp layer is thin with cross layer of varying cell shapes (Santos, 1933).The pericarp layer is highly impermeable to foreign material and gives protection against enzymatic deterioration of the underlying tissues. Beneath the pericarp is tegmen, rich in oil and protein. Both the endosperm and embryo are enclosed by the aleurone layer, which lies beneath the tegmen. The aleurone layer may be composed of one to seven layer of parenchyma cell. The embryo or germ is extremely small and is located on ventral side of the caryopsis. The parenchyma cells of plumule and radicles together with epithelial cells are filled within the minute protein granules and fat globules. Starch granules are present only in the endosperm of mature rice grain. Proteins and fats are uniformly distributed in the aleurone layer. During the milling operation, seed coat, germs and the aleurone layer of the endosperm along with starchy endosperm are also removed (Little and Hilder, 1960).

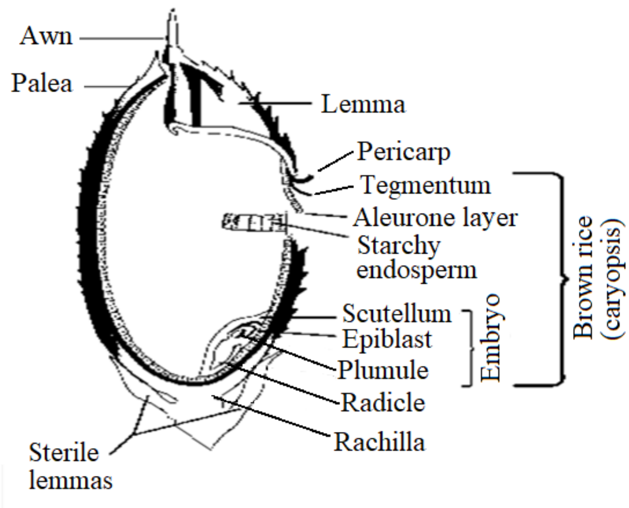


Fig. 2.1 Rice grain showing its different parts

Source: Bhattarai (2009)

2.2.1.5 Chemical composition of rice

The nutrient composition of brown rice and white rice is as shown in the Table 2.2.

Table 2.2 Composition of brown and white rice

Constituents	Brown rice	White rice (milled rice)
Moisture (g/100 g)	10.37	11.62
Protein (g/100 g)	7.94	7.13
Fat (g/100 g)	2.92	0.66
Fiber (g/100 g)	3.5	1.3
Total carbohydrate (g/100 g)	77.24	79.95
Calcium (mg/100 g)	23	28
Phosphorous (mg/100 g)	333	115
Iron (mg/100 g)	1.47	0.8
Sodium (mg/100 g)	7	5
Potassium (mg/100 g)	223	115
Thiamine (mg/100 g)	0.401	0.07
Riboflavin (mg/100 g)	0.093	0.049
Niacin (mg/100 g)	5.091	1.6

Source: Upadhyay and Karn (2018)

The grain of rice consists of carbohydrate, nitrogenous compounds (mainly proteins), lipids (fat), mineral salts and water together with small quantities of vitamins, enzymes and other substances, some are important in the human dietary. Carbohydrate is, quantitatively, the most important constituent forming about 83% of total dry matter of rice. Rice grain is composed of cellulose, hemi cellulose, pentosans, fiber, dextrin and sugar. The main carbohydrate present in rice grain is starch. Starch, a polymer of glucose, occurs in the endosperm as compound polyhedral granules 3 to 10 µm in size. Amylopectin is the major and branched fraction of starch; amylose is the linear fraction of starch. Amylose is absent in waxy (glutinous) rice, but in non-waxy rice it consists of 7 to 34% (dry basis), of the milled rice or 8 to 37% of the starch (Juliano *et al.*, 1964).

Protein is the second most abundant constituent of rice grain and is unique among the cereal protein because it contains at least 80% glutelin (alkali-soluble protein). The protein contents decreased linearly with increase in the degree of polish,as these constituents were mainly concentrated in the peripheral layers of the kernel. The protein content of milled rice is low in comparison with other cereals, although milled rice contain from 5 to 14% protein at 14% moisture content. The protein found in the kernel of rice, within the same variety, shows a variation of 6% due to environment (Juliano *et al.*, 1964).

The nutritive value of protein depends upon its amino acid content and is reported that eighteen different amino acids occur in the protein of cereals. The protein is rich in arginine but poor in lysine and threonine. The amino acids in protein of six Indian type of husked rice were found to be argenine, histidine, lysine, cysteine, tryptophan, metheonine, leucine, isoleucine, phenylalanine.The lipid content of rice is very low i.e. 1-2%. Rice mainly contains phospholipids; palmitic, steric, oleic, lenoleic and lenolenic acids. The kernel of rice consists of the phosphate and sulphate of potassium (K), magnesium (Mg) and calcium (Ca) (Grist, 1975).

The important minor elements found in rice are iron (Fe), magnesium (Mg) and zinc (Zn). Generally, husk of the rice has a higher content of mineral matter than that of kernels (Kent, 1982).The human nutritional requirements of iron is estimated to be about 10-15 mg daily where husked rice will supply about 19 mg and polished rice not more than 6 mg. (Grist, 1975). Rice flour contains ferulic and p-coumaric acids as the main polyphenols (Harukaze *et al*., 1999).

In relation to vitamin, the amount of fat soluble vitamins A and D in rice is negligible, but the vitamin E content of whole rice is considerable. The average of the vitamin B complex, particularly thiamine (B1), riboflavin and niacin are found in rice. It has been found that high milling of rice resulted in the incidence of beriberi, assuming that thiamine content of the rice is mainly present in the pericarp and aleurone layer which is completely removed during polishing.The total fat content of milled rice remained constant in either ordinary or hermetically storage under a wide range of moisture and temperature conditions, but its gross composition nevertheless changed with an increase in FFA and a decrease in natural fats and phospholipids (Pillaiyar, 1988).

2.2.2 Buckwheat

Buckwheat (*Fagopyrum esculentum* Moench*)* is derived from the Anglo-Saxon boc (beech) and whoet (wheat) because it resembles the beech nut (Edwardson, 1995). Buckwheat is a dicotyledon and belongs to the family Polygonaceae.It is classified as a pseudocereal because of the similarity to conventional cereals in its use and chemical composition. Its seeds vary from dark brown to dark grey in color, irregularly shaped and have four triangular surfaces (Byoung *et al*., 2004) . The most widely grown buckwheat species include common buckwheat *(Fagopyrum esculentum)* and tartary buckwheat (*Fagopyrum tataricum*) (Zhang *et al.*, 2012).

Buckwheat contains many important bioactive compounds such as protein rich in essential amino acids, oil rich in essential fatty acids (Horbowicz and Obendorf, 1992) starch with a low glycemic index, polyphenol compounds (including rutin, quercetin, orientin, vitexin, isovitexin and isoorientin) and many essential minerals (Steadman *et al.*, 2001). Buckwheat is rich in vitamins, especially those of the B group (Fabjan *et al.*, 2003) they are an important source of micro-elements (Zn, Cu, Mn, Se) and macro elements (K, Na, Ca, Mg) (Bonafacia and Fabjan, 2003) and they offer a high nutritional quality of proteins (Watanabe, 1998), but have a relatively low true digestibility . The amino acid composition is well balanced and of a high biological value. Buckwheat proteins are rich in arginine and lysine, the primary amino acids limiting the content of proteins in cereals, whereas the contents of methionine and threonine in buckwheat proteins are low. Buckwheat proteins have different characteristics in comparison to wheat, barley and rye prolamins enabling the application of buckwheat grains in prophylactics for gastrointestinal tract diseases, mainly celiac disease (Kreft *et al.*, 1996).

Buckwheat grains and hull consist of some components with healing properties and biological activity, flavonoids, phenolic acid, condensed tannins, phytosterols and fagopyrins. Flavonoids are a class of secondary plant phenolic compounds with significant antioxidant and chelating properties (Bojnanska *et al.*, 2009). 1000 kernel weight is the weight ,in grams, of 1000 seeds from a random sample and weight of thousand buckwheat seeds is 26.14 g (Kaliniewicz *et al*., 2015 ; Unal *et al*.,2017).

Taxonomically, buckwheat can be classified as:

Kingdom: Plantae

Division: Magnoliophyta

Class: Magnoliopsida

Order: Caryophyllales

Family: Polygonaceae

Genus: *Fagopyrum*

Species: *esculentum*

Source: Ahmed *et al* (2013)

2.2.2.1 Buckwheat in Nepal

Nepal (26°–31°N latitudes to 80°–89°E longitudes) is a landlocked country dominated by huge mountains with varied climate and topography. The climate ranges from tropical to temperate and alpine due to its topography and elevation. Buckwheat is a sixth staple food crop after rice, wheat, maize, finger millet, and barley in Nepal. It is considered as an alternate cereal and poor man's crop, representing an important food supply in remote places of Himalayas. It is the best crop in higher altitude in terms of adaptation to different climatic variables and easily fitted to different cropping patterns due to short duration. There are mainly two species of buckwheat cultivated in Nepal. The sweet buckwheat or Mithe Fapar (*Fagopyrum esculentum*) and Tite Fapar is also called tartary buckwheat (*Fagopyrum tataricum*). The bitter buckwheat is high yielder, cold tolerance and grown mainly in the high hills and mountain in small areas for medicinal purposes (Luitel, 2017).

In Nepal, buckwheat cultivation ranges from 60 m in Terai to 4500 m above sea level. *Fagopygrum esculentum* is generally grown in lower altitude (Terai and mid-hills) but in higher altitude *Fagopyrum esculentum* is replaced with *Fagopyrum tataricum* in different cropping pattern. It has been occupying an important place in the Nepalese agriculture system and contributing greatly in food supply especially remote places in Himalayas, though it is popularly considered as pseudocereals, poor man's crop, and under-exploited and neglected crops in Nepal (Joshi, 2008). It is commonly grown in hilly and mountain regions especially in Rukum, Rolpa, Jajarkot, Dolpa, Kavre, Dolakha, Okhaldhunga, Mustang, Solukhumbu, and Taplejung districts regularly since time immemorial. But recently it has been grown in some Terai districts like Chitwan, Jhapa, and Nawalparasi for commercial purposes especially for green vegetable which has very high demand due to rutin contents (farmers interview) (Li and Zhang, 2001).

2.2.2.2 History and origin of buckwheat

The exact place of origin of common buckwheat is considered as Yunnan province and in between Yunnan and Sichuan provinces of China. Buckwheat was cultivated nearly 5000–6000 years ago in China and it entered Europe through Russia and spread to North America through immigrants. Buckwheat is cultivated in hilly areas in Europe (also in lowlands), east Asia, and the Himalayan region. China is the biggest producer and exporter of buckwheat followed by USSR, and Japan is a principal importer of buckwheat up to 2000 (Ohnishi, 2010) but the scenario has changed, and USA became main exporter and Japan remains a major importer of American buckwheat although China, Russia, and Canada are leading sources of buckwheat flour in 2012.

Buckwheat is also a traditional crop in Asia and Central and Eastern Europe. Over the last 40 years, China, Russia and Ukraine are the largest producer of buckwheat. In 2017, Russia produced 1,524,280 tons, followed by China and Ukraine which produced 1,447,292 tons and 180,440 tons (FAO., 2017), whereas Nepal produced 12,039 tons. Nepal has a world share of 0.3% on buckwheat production.

2.2.2.3 Buckwheat food products

Buckwheat has been listed as health protection food in many countries, and many nutritional meals related to buckwheat have been developed, such as buckwheat bread, noodles, soft drinks, beverages, tea, and buckwheat sprouts (Xiao, 2003). At present, the demand for buckwheat is high because of its excellent properties and nutritional value based on its favourable composition. Due to its excellent nutritional value, buckwheat can be added to rice or corn flours to enhance their nutritional quality. Sakac *et al* (2011) reported that the presence of flavonoid content in buckwheat flour increase the total flavonoid content in product. The content of total flavonoid content in flour was about 2-4 fold higher than the product (Chlopicka *et al*., 2012). There is a list of 34 food items prepared from buckwheat in Nepal such as dhindo (thick porridge), roti (bread), momo (Chinese pancake), lagar (very thick bread), dheshu (thicker than lagar), fresh vegetables, dried vegetables, Kancho pitho (raw flour), *chhyang or jaand* (local beer), *raksi* (alcohol), salad (leaves), pickle (fresh and dry leaves), soup, *ryale roti*, noodle, *sel roti*, bhat (rice), sausage, dorpa dal, tea,vinegar, jam, macaroni, biscuit, cakes, mithai (sweet), haluwa, puri, puwa, bhuteko Phapar (roasted grain), satu, *phuraula*, porridge, and pakauda (Luitel, 2017).

2.2.2.4 Health benefits of buckwheat

Buckwheat is an excellent medicinal plant as well as a nutrient-abundant crop. Its flour and leaf contain large quantity of flavonoid compounds. The rutin contain reaches a proportion of 0.8-1.5% and in auto tetraploid tartary buckwheat it even reaches as high as 2.41%. Rutin contributes to a multitude of physiological functions, which can maintain the resistance of blood capillary and promote the proliferation of cells. It can further serve as anti-inflammatory and anti-allergic, as diuretic and spasmolytic and serve for depression of cough, reduction of lipemia and for cardiac stimulation (Gang *et al.*, 2001).

Buckwheat contains plentiful vitamins. Vitamin B1 can help to enhance digestive function to resist neuritis and to prevent beriberi. Vitamin B2 can enhance human body's development and is a vital element for protection against perleche, glossitis and eyeliditis.Tartary buckwheat contains fairly rich common elements and microelements (Mg, Ca, Se, Mo, Zn, Cr, etc.), which serve protection against coronary heart disease. The microelement selenium (Se) contained in tartary buckwheat could combine with minerals into an unstable 'mineral selenium-protein' compound which helps to decompose and excrete toxins (eg, Pb, Hg, Cd, etc.) in human body.Tartary buckwheat food possesses apparent functions of three reductions, namely the reductions of lipemia, blood sugar and Glucosuria. It still possesses certain radiation-resistant property, hence an extremely curative food for radiation sufferes (Gang *et al.*, 2001).

Buckwheat is rich in dietary fiber which has a positive physiological effect in the gastrointestinal tract and also significantly influences the metabolism of other nutrients. Buckwheat seeds contain no gluten so they are safe for people with celiac disease. Buckwheat seeds contain very rare D-chiro-inositol, which is mainly found in the form of fagopyritols. This compound has acquired a lot of interest due to its glucose-lowering capacity in animal models . Buckwheat groats contain important resistant starch and it could be useful in preventing the colon cancer. Rutin (quercetin-3-rutinosid) is a flavonol glycoside synthesized in higher plants as a protectant against ultraviolet radiation and diseases (Vojtíšková, 2015). Kreft *et al* (2006) reported that the rutin retention is affected by the activity of the rutin degrading enzyme, flavonol 3- glucosidase. The presence of rutin-degrading enzymes in buckwheat transform rutin to quercetin and the quercetin concentration increased and remained stable during processing (Merendino *et al.*, 2014). Buckwheat is rich in folate, it helps your body produce and maintain new cells, especially red blood cells. Buckwheat does not contain gluten so it is edible by celiac disease patients. The gluten-free diet is unbalanced in carbohydrates, proteins and fat and deficient in certain essential nutrients. Due to the limitation of some nutrients, the fortification of basic gluten-free formulations is recommended to develop value added products. In literature, it has been reported that gluten-free based products have been enriched by buckwheat flour in order to achieve better functionality in the final product.

2.2.2.5 Nutritional composition of buckwheat

Chemical components of buckwheat include protein/ amino acids, starch, lipids, fiber, minerals, vitamins, and other functional components (e.g., flavonoids, phytosterols, and fagopyrins). These are distributed in different parts of the buckwheat grain, e.g., protein mainly occurs in the aleurone layer and embryo, starch in the endosperm, and fiber, ash, and flavonoids are normally in testa and pericarp. The chemical composition of buckwheat is as shown in Table 2.3.

Table. 2.3 Nutritional composition of buckwheat

Components	Buckwheat seeds (%)	Buckwheat groats (%)
Moisture	12-14	12.3
Carbohydrate	58.5-73.5	70.9
Protein	10-14.5	9.7
Fat	2.0-2.6	1.8
Fiber	9.3-10.9	3.7
Ash	2.0-2.5	1.7

Source: Cai *et al* (2004)

2.2.2.6 Anti-nutritional factor and allergy of buckwheat

Anti-nutritional factors have been found in buckwheat grain, such as trypsin inhibitors (I, II, and III) and tannin. They may influence digestibility of buckwheat protein. Also, a high level of fiber in buckwheat may be considered as an anti-nutritional factor (Cai *et al.*, 2004). Buckwheat allergy can sometimes cause severe reactions that are similar to those caused by soybean or peanut. Symptoms are asthma, wheezing, and anaphylactic shock. In addition, people who are daily in contact with buckwheat or buckwheat products are likely to become allergic to buckwheat. Besides asthmatic symptoms, buckwheat is the cause of various skin disorders (Wijngaard and Arendt, 2006).

2.2.3 Sugar

Sugars are simple carbohydrates, and gives sweet solution when mixed with water. Ordinary sugar is pure sucrose, and is made from either sugarcane or sugar beet. Sugar has properties which are responsible for some of the changes /reactions which take place in food when it is being manufactured and processed (Kidd, 2001).

Sucrose is the most economically significant sugar and is produced industrially in the largest quantity. Sucrose is known under many trade and popular names. These may be related to its purity grade, to its extent of granulation or crystal size (icing, crystal, berry and candy sugar, and cube and cone sugar) and to its use (canning, confectionery or soft drink sugar). Liquid sugar is a sucrose solution in water with at least 62% solids. The chemical composition of a given type of sugar depends on the extent of sugar refination. The sucrose content of sugar ranges from 96 – 100 %. Sucrose has maximum stability in alkaline pH. The thermal stability of sugars is also quite variable. Sucrose and glucose can be heated in neutral solutions up to 100℃, but fructose decomposes at temperatures as low at 60℃. Sugar alcohols are very stable in acidic or alkaline solutions (Belitz *et al.*, 2009).

Sugar is a basic ingredient of sel-roti and is used to provide sweetness in sel-roti and adds the calories value. Sugar dissolves at the time of kneading. Sugar develops the characteristic color which is due to caramelization during frying. *Shakkhar* or *mishri* can be used as alternatives for sugar. Addition of *shakkhar* gives more intense dark appearance. The quantity of sugar used depends on the taste but higher sugar burst the crumb and it also burns the crust fast. Terai tribes use jaggery in *sel-roti* in place of sugar (Pulami, 2014).

Sugar performs the following functions (Lawson, 1997)

- Adds caloric food value
- Improves keeping quality. High amount of sugar as well as the use of invert sugar and glucose, honey may further improve keeping quality.
- Improve the grain and texture. Product containing ample amount of sugar have a softer, richer texture and a more uniform grain.
- Improve flavor and
- Helps in color formation from carmelization.

2.2.4 Ghee and other fats

Ghee is a clarified butter without any solid milk particles or water which originated in South Asia, and is commonly used in South Asian (Indian, Bangladeshi, Nepali and Pakistani), North African (Egyptian and Berber) and Horn African cuisine (Somali, Ethiopian and Eritean). A good quality ghee adds a great aroma, flavor and taste to the food . The word ghee comes from Sanskrit (*ghrita*) and has several names around the world (Punjabi:*ghyo*, Hindi: ghi, Nepali: ghyu,Oriya: gheeo,Tamil: ney,Somali: subaag, Arabic: samna). Ghee is used for different Hindi religious purposes.e.g: Pooja, Hawan, Arati etc. Ghee is widely used in different food preparation such as *sel-roti, halwa, laddu,* sweets, *kadhi, biryani* etc.It is used as ingredients and for frying medium.

Ghee is an ideal fat for deep frying because its smoke point (where its molecules begin to break down) is 250℃ (485°F), well above desired cooking temperatures- around 200℃ (400°F) and above most vegetable oils (Katawal and Subba, 2015).

2.2.5 Frying fats and oils

Fats and oils are chemical units commonly called “triglycerides’’ resulting from the combination of one unit of glycerol with three units of fatty acids. They are recognized as essential nutrients in both human and animal diets and also contribute to food flavorand mouth-feel as well as to the sensation of product richness. Frying fats and oils can be divided into three classes: liquid, fluid and plastic (Katawal and Subba, 2015).

The liquid oil is usually unhydrogenated soya, corn or peanut oils. Unhydrogenated soybean oil tends to form off flavors readily at frying temperatures. Slightly hydrogenated, winterized soybean oil is acceptable as frying oil and is available commercially. The same oil without winterization becomes fluid fat. It is not considered to be liquid since it contains suspended solid fats resulting from the hydrogenation. The plastic frying fats have a general acceptance by commercial fryers. The fats whether of animal or vegetable origin are usually partially hydrogenated, giving these fats greater stability against darkening and gum formation in the frying kettle and greater stability against oxidative rancidity in the fried foods. The frying fats are usually of short plastic range since the base oil are hardened further than for long plastic range products and are therefore more resistant to oxidation. In addition, short plastic range fats have a lower melting point than long range shortenings and thus impart less apparent greasiness of foods fried in them. The greasy feeling is due to the hardened fats setting up in the mouth and coating it with a layer of fats (Held and Joslyn, 1963). The frying medium is generally ghee, refined oil, and sometimes lard. About three hundred and fifty milliliter oil is needed for 1 kg of rice (Dahal, 2012).

2.3 Malting

Malting is controlled germination which produces a complement of enzymes which are able to convert cereal starches (endosperm) to fermentable sugars, to secure an adequate supply of amino acids and other minor nutrient for yeast and modify the quality of the micro - molecules which have such important effects on physical quality of beer (Kent, 1982). Malting can be defined as the process of steeping, germination and drying (kilning) of cereal grains to advance the production of hydrolytic enzymes (responsible for converting starch into simple sugars and other hydrolytic activities), which are absent in ungerminated grains. Malting has an impact on the abundance and profile of phytochemicals in cereals and pseudocereals, which in turn has an influence on the potential health effects of the finished product (Khoddami *et al.*, 2017a). Malting is the controlled germination followed by controlled drying of the kernels. The main objective of malting is to promote the development of hydrolytic enzymes, which are not present in non-germinated grain. Malting caused an improvement in protein digestibility. Other benefits of the malting process include increased vitamin C content, phosphorus availability, and synthesis of lysine and tryptophan. Also during malting, both starch and protein are partially degraded allowing for better digestibility. Furthermore amylases are elaborated and as a result, the viscosity of gelled starch decreases. Malting has produced improvement in flavor profile and color (Mella, 2011).

2.3.1 Malting process

The process of malting comprises of three-unit operations: steeping, germination and Kilning (drying).

2.3.1.1 Steeping

Steeping involves soaking buckwheat grains in water. The fundamental reason is to hydrated the grain and initiate metabolism of living tissues, which are habitually dormant when the grains are dry. For efficient production of good quality buckwheat malt, a steep out moisture level of 40-43 % is recommended (Poudel, 2012).

2.3.1.2 Germination

Germination is the beginning of the development of seed embryo in which viable seed is wetted, water is taken up, respiration, protein synthesis and other metabolic activities begin and after a certain period of time the radicals emerges through the seed coverings which mark the end of the process. Germination is such a process that allows enhancing the palatability and digestibility as well as improve the nutrient composition and functional properties. In addition, germination has been found to decrease the levels of anti-nutrients compounds present in cereals, therefore maximizing the levels of utilizable nutrients. An increase in the bioavailability of minerals and vitamins has been observed due to germination (Brajdes and Vizireanu, 2012). The germination percentage of buckwheat at 24.5℃ is 84 % (Aliyas *et al.*, 2015). Higher temperature during germination may affect germination percentage. This might be due to the damage to seed structure. Higher temperature might alter enzymatic activity and reduce quantity of amino acids available (via RNA synthesis),thereby modifying metabolic reactions that reduce embryo development (Rai, 2013).

2.3.1.3 Kilning (drying)

During kilning water is removed from the green malt. Malt is kilned to produce a friable, stable-on-storage product, from which roots can be easily removed. Kilning consists of passing a flow of warm dry air through a bed of malt at various rates and at increasing temperatures to dry the malted grain. The survival of enzymes in malt is greatly influenced by the temperature and time of the kilning regime. Common buckwheat is normally kilned at 40℃ for about 40 h. All enzymatic activities were found to decrease during the kilning stage. After prolonged kilning at 40°C, inactivation of hydrolytic enzymes occurred; two-stage kilning for shorter periods is recommended (Nic Phiarais *et al.*, 2005).

2.3.2 Physical changes during malting

During steeping the grains swell and increase in its volume by about a quarter. Space is allowed in the steep tanks to accommodate the swollen grains. The first microscopic indication of germination after casting is the appearance of chit. The white coleorhizae or root-sheath breaks through the pericarp and testa and produces from the base of the corn.In time seminal roots also called rootlets, culms,or malt sprouts brusts through root sheath and form a tough at end of the grain. Starch appears in small amounts in the embryonic structures after the onset of germination. Coincident with the appearance of this starch the first sign of the breakdown of the starchy endosperm are seen as enzymes partial dissolution of some cell walls. This process cytolysis begins in the compressed layer, and progressively spreads through starchy endosperm towards the apex of the grains (Poudel, 2012).

2.3.3 Chemical changes during malting

2.3.3.1 Carbohydrate

The percentage of starch decreases and the composition of the remaining starch alter. The proportion of amylase increases. The amount of sugar declines during kilning but the sucrose often increases in amount. Maltose also increased (Shrestha, 1995). The decrease in carbohydrate content on malting could be attributed to metabolism. The carbohydrates may have been digested into simple sugars by amylolytic enzymes which are rapidly taken up by the growing embryo to serve as its energy source during germination as reported in Ogbonna *et al* (2012). During germination, there was a decrease in storage carbohydrates and an increase in total soluble and reducing sugars (Colmenares *et al.*, 1990). As a result, the taste and digestibility of buckwheat can be improved because of the increase of reducing sugar. The decrease in carbohydrate content might be due to active respiration process during soaking and germination. On the other hand, total sugar, reducing and non-reducing sugar contents increased after germination which might be due to increase the activities of α-amylase and β-amylase enzymes (Devrajan *et al.*, 2017b).

2.3.3.2 Protein

One of the most important chemical changes that occur during germination is the degradation of the protein and their conversion into soluble peptides and amino acids to provide substrates for the plants development, which can result in the changes in protein content and size distribution, as well as protein properties without any chemical modifications. During germination the content of crude protein increased and protein was degraded to increase the soluble protein content and free amino acids (Li and Xu, 2015). The increase in protein content after malting was found in buckwheat and amaranth (Chauhan and Singh, 2013). The increase in proteins might be attributed to the dry weight losses through respiration during malting (Urbano *et al.*, 2005).

The protein of the germinated cereals was more soluble than the un-germinated cereals. This might be due to the high proteolytic activity during germination, which will lead to an increase in the protein solubility resulting from hydrolysis of the storage proteins (Sakac *et al*., 2011). Germination causes activation of intrinsic amylases, proteases, phytases and fiber-degrading enzymes, thereby increasing nutrient digestibility. The activity of intrinsic proteases in germinated grains leads to an increase in-vitro protein digestibility (Manukumar *et al.*, 2014).

2.3.3.3 Lipids

During germination, extensive hydrolysis of triacylglycerol occurred which demonstrated this behavior by observing that the lipolytic potential increases markedly during the malting process (Bravi *et al.*, 2012). The reduction in total lipids was probably correlated with the lipolytic activity. During germination, there is a need for a large amount of energy and building materials that must be produced by respiration and other metabolic processes. In the final step of malting, the total lipid content does not vary significantly. During kilning, the humidity is lowered, the germination and the structure modification are stopped, the activity of lipases is stopped too and, as a consequence, the lipid content remains unaltered. In the germinating seeds the stored fats are metabolized by lipase enzymes. Neither fatty acids nor the glycerol accumulate in large concentration during germination (Rai, 2013).

2.3.3.4 Vitamins

Cereal grains have been reported as rich source of certain B-vitamins, and tocols (vitamin E). Ascorbic acid has been found in pseudo-cereals i.e., buckwheat. Germination has been investigated to increase the content of tocols in cereal products and an increase in vitamin E during the germination. Germination has been repeatedly reported as way to improve folate content. Germination increased the beta-carotenes in buckwheat which is present in small amounts (Hubner and Arendt, 2013).

2.3.3.5 Minerals

During germination and seedling development mineral elements are released from their storage compounds in grains to be available for the growing embryo. The beneficial effect of germination on iron and calcium availability may probably be attributed to the decrease in phytate content as a result of germination (Luo *et al.*, 2013). The increase in ash content during malting reported that germination would increase the mineral content due to an increase in fitase enzyme activity during germination (Narish *et al.*, 2012). Buckwheat flour contains high mineral content in comparison to rice flour (Francischi *et al*., 1994). The increase in calcium content may be due to dry matter loss of water-soluble constituents during steeping and washing. The phosphorous content increases during malting (Abdelrahaman *et al.*, 2007). Increased mineral availability during germination may be due to increased phytase activity, which resulted in decreased content of phytate in sprouts. Antinutrients like polyphenols and saponins are also known to hinder the availability of minerals, which are catabolized during germination leading to improvement in mineral availability. The iron content might be decreased during malting. The decrease in iron content during malting may be due to the leaching of minerals during soaking (Kumari *et al.*, 2014).

2.3.3.6 Crude fiber

Crude fiber increases after malting. The increase in crude fiber after malting may be due to the synthesis of carbohydrates such as hemicellulose and cellulose (Banusha and Vasantharuba, 2013).The increase in crude fiber after malting is also found in (Chowdhury and Rahman, 2017).

2.3.3.7 Other changes

The tannin content decreased significantly during germination. The decrease in tannin content during malting might be due to tannins leaching out of the grain into water during soaking and germination and binding of polyphenols with other organic substances such as carbohydrate or protein (Khoddami *et al.*, 2017b). Germination increases antioxidant activity of buckwheat. The increase of antioxidant activities such as polyphenolics seemed to be related to many metabolic changes such as increase in the activity of the endogenous hydrolytic enzymes during germination (Zhang *et al.*, 2015). The antioxidant activity of common buckwheat was 7.75 % which increases after malting (Alvarez-Jubete *et al.*, 2010).

The total polyphenol content may decrease or increase after malting. The decrease in TPC upon malting might be due to leaching of polyphenols into the soaking medium during the malting process (Khoddami *et al.*, 2017b). The total polyphenol content might be increased. The increase in polyphenol content during malting might be due to the action of endogenous esterase activated during germination which can lead to the release of cell wall bound phenolic compounds (Carciochi *et al.*, 2014).The flavonoid content increases after malting . The increase in flavonoid content may be attributed to the bound flavonoid compounds becoming free by the action of enhanced hydrolytic enzyme activity. The flavonoid content has been increased from 13.66 mg/100 g to 283.43 mg/100 g during malting (Brajdes and Vizireanu, 2012). Mustafa *et al* (1986) and Jan *et al* (2015) reported that the moisture content of products decreased with the increase proportion of buckwheat flour.

2.4 Role of ingredient in quality of *sel-roti*

Good *sel-roti* is made from good ingredient. Therefore, the selection of raw materials in making of *sel-roti* is very important to achieve expected quality of the final product.

2.4.1 Flour

The main ingredient in making of *sel-roti* is flour. Flour used for preparation of *sel-roti* must be of better quality. Also, the preparation of *sel-roti* was not technically feasible from the flour having mean particle size smaller than 120 μ and greater than 890 μ. The flour comprised of more coarse particles produced dense product with very less or no puffiness. Likewise, the batter made from the flour of finer particle size puffed excessively during frying but collapsed instantaneously upon cooling and turned leathery in texture. So, the flour used must contain (coarse: medium: fine:::30:50:20 part) for the *sel-roti* preparation (Subba and Katawal, 2013).

2.4.2 Sugar

Sugar is a basic ingredient of *sel-roti*, is used to provide sweetness in *sel-roti* and adds the calories value. Sugar dissolves at the time of kneading. Sugar develops the characteristic color, which is due to caramelization during frying and also improves the flavor. Sugar contributes structure, bulk and texture to the most baked and fried products (Lawson, 1997).

2.4.3 Ghee and fats

Ghee is also one of the basic ingredients of *sel-roti* preparation. These ingredients were found to add flavor, lubricity to *sel-roti*. During mixing, ghee also helps in entrapment and retention of the air, which is highly necessary for a product for its good texture. It also plays vital role in the softness, texture palatability and keeping quality of the product (Manley, 2000). Amount and adequacy of ghee kneaded along with sugar and flour is the determining factor of *sel-roti* puffing (Pulami, 2014).

2.4.4 Water

The function of water is to be a dissolve agent and distributes the other materials in batter to be well blended and controls the structure of batter.

2.5 Deep fat frying

Fried foods have continued to be popular in spite of the current guidelines which recommend a decrease in the content of fat in our diet (Li, 2005). Frying is a fast and convenient technique for the production of foods with unique sensory properties including color, flavor, texture, and palatability that are highly appreciated by consumers. Frying can be distinctly divided into three types, i.e., pan, shallow and deep frying. Deep fat frying is a process in which the food is cooked by immersion in hot oil. During deep-frying of food the oil used come under a heavy temperature region of 150-200℃ and a heavy three-prong attack (Suman, 2012).

It is known to be one of the most energy extensive food processes, and there are a number of health concerns related to fried products, principally relating to the amount of oil absorbed in the process. But it cannot be denied that fried products are universally liked and consumed. During frying, simultaneous heat and mass transfer occurs. Heat is transferred from the frying medium to the products surface by convection and from the surface to the inside by conduction. The moisture, on the other hand, is evaporated and transported from the interior to the surface of solid by diffusion, which then migrates from the surface through the frying medium. Moisture content decreases with frying time while the oil content of fried samples increased with frying time (Katawal and Subba, 2015). Totani *et al.* (2006) found that oil absorption in commercial deep-fried food ranged between 22 and 48%. It is evident that the vegetables had oil absorption value in lowest than battered deep-fried products. Higher oil retention improves the mouth feel and retains the flavor of the product (Rufeng *et al*., 1995).

During deep fat frying, thermal, oxidative and hydrolytic reactions take place resulting in physical and chemical changes in the oil and the formation of new compounds. Physical changes in oils that occur during heating and frying include increased viscosity, color darkening, increased foaming, and decreased smoke point as the frying time continues. Chemical changes during frying increase free fatty acids, carbonyl compounds, and polymeric compounds and decrease fatty acid unsaturation. With continued heating and frying, these compounds further decompose until breakdown products accumulate to levels that produce off-flavors and potentially toxic effects, leaving the oil no longer suitable for frying. In addition, these chemical reactions (hydrolysis, oxidation and polymerization) are interrelated, producing a complex mixture of products (Suman, 2012).

As the product is deep fried, fat uptake is one of the most important parameter. Fat has both beneficial as well as adverse effect on the product. Fat has high calorific value but has high satiety value as well. It gives flavor to the product but reduces the shelf life of the product. During deep-fat frying, water in the crust will evaporate and move out of the food. In order for the flow of vapor to continue, sufficient water has to be able to migrate from the core of the food to the crust and the crust has to remain permeable. The fact that the vapor leaves void for the fat to enter later is the reason why fat uptake is largely determined by the moisture content of the food (Mehta and Swinburn, 2001). Similarly, sections of the food with more moisture loss also show more fat-uptake. Choy *et al* (2013) reported that the fat uptake increased with the increment of buckwheat flour. Some even argue that the total volume of fat will equal to the total volume of water removed (mass balance) (Pinthus *et al.*, 1993). Indirect proof of increased evaporation resulting in more damage to the crust is given by the observation that porosity and fat uptake are inversely related to moisture content at various time-stages during deep frying (Moreira *et al.*, 1995).

Since oil can only penetrate where water has evaporated, oil penetration only occurs where the temperature has been sufficiently high, i.e., in the crust. There is abundant proof that oil hardly penetrates in the cooked core and that the microstructure of the crust is the main determining factor in fat-uptake (Pinthus *et al.*, 1993). The total fat uptake is considered to be the sum of both fat penetration(through condensation or capillary mechanisms) in the crust and fat crystallization on the surface (Mellema, 2003).

Katawal and Subba (2013), found the 35% fat uptake of *sel-roti* prepared from fresh batter and Dahal (2012) reported the 27.01% fat uptake. Subba and Katawal (2011) also reported that *sel-roti* made from rice flour containing smaller or finer particles absorbs more oil or fat and vice versa. Therefore, fat-uptake is primarily a surface phenomenon involving equilibrium between adhesion and drainage of oil upon retrieval of the slice from the oil bath (Ufheil and Escher, 1996).

2.6 Changes on frying

(a) Physical changes: In cooking process with heat and water, the hydrogen-bond network are altered and reformed. In case of starch containing materials, the starch granules swell and eventually burst releasing the polysaccharide components. This 'gelatinization' phenomenon is of very great importance, for it is this changing which is the essence of the conversion of raw starch to metabolize carbohydrate. The starch granule is not chemically homogenous, and can be separated into at least two distinct fractions: amylose and amylopectin. On cooking rice, these two components are released (Priestley, 1997).

(b) Chemical changes: First, Maillard reaction occurs when carbohydrates are heated in the presence of amino acids. In this reaction, the reducing part of a sugar molecule reacts with suitable nitrogen compounds such as amino acids and proteins. The reaction may be inhibited by certain food additives such as sulphur dioxide and is dependent on such factors as temperature, acidity and water activity. The reaction rate can double or triple for every 10°C rise in temperature. As pH increases, browning increases and the browning rate is also much influenced by water activity. Second, there is the chemical change brought about by interaction with lipids. Not much is known of the nature of these interactions, but it is thought that an amylose-lipid complex may control many of the physical changes undergone by rice starch on heating such as gelatinization and solubility. Third, there is the chemical change brought about by interaction with enzymes. The solubility of amylases during cooking of starch is important, since this governs the course of dextrinization and saccharification, which occurs in baking. Lastly, there is the chemical change brought about by interaction with minerals. As the rice is heated the granules swell and burst above gelatinization temperature releasing amylose and amylopectin (Spicer, 1975).

(c) Biological changes: The most important biological change in starch brought about by heating is that of making the carbohydrate accessible to enzyme in the digestive tract. Another important biological change in heating is the loss of nutritional value of the food (Springer-Verlag, 1999).

2.7 Traditional and improved methods of *sel-roti* preparation

The *sel-roti* preparation method is differing from place to place. According to Yonzan and Tamang (2009) for *sel-roti* preparation, local variety of rice (*Oryza sativa*, L.) attey is sorted, washed and soaked in cold water for overnight or 4 to 8 h at ambient temperature, water is then drained with the help of bamboo made sieve called *chalni* and spread over a woven tray made up of bamboo locally called nanglo and dried for one hour. The soaked rice is pounded into coarse powder in a wooded mortar and pestle known as okhali and mushli, or in dhikki respectively. Larger particle of pounded rice flour are separated from the rest by winnowing using bamboo tray i.e., nanglo. Then rice flour is mixed with nearly 25% refined buckwheat flour, 25% sugar, and 10% butter or fresh cream and 2.5% of spices/condiments containing large cardamom (*Amomumsubulatum* Roxb), cloves (*Syzygium granatium* Marr.), coconut (*Cocos nucifera* L.), fenel (*Foeniculum vulgare*), nutmeg (*Myristica fragans*), cinnamon (*Cinnamomum verum* Bl.), and cardamom (*Elletaria cardamomum*) and mixed thoroughly. Some people add table spoon full of honey or unripe banana or baking powder (Sodium bicarbonate) to the mixture, depending on quantity of the mixture. Milk (boiled/unboiled) or water is added, kneaded into soft dough and into batter with easy flow. Batter is left to ferment naturally at ambient temperature (20 – 28℃) for 1 to 4 h during summer and 10 – 18℃ for 6 – 8 h during winter. The fermented batter is squeezed by hand or *daaru* (metallic serving spoon) deposited as continuous ring onto hot edible oil and fried until golden brown and is drained out from hot oil by poker locally called *jheer* or *suiro* or by spatula locally called *jharna*. Deep fried *sel-roti* is served as confectionary. Some flow charts for *sel-roti* preparation traditionally are shown in Fig. 2.2, 2.3, 2.4 and 2.5.

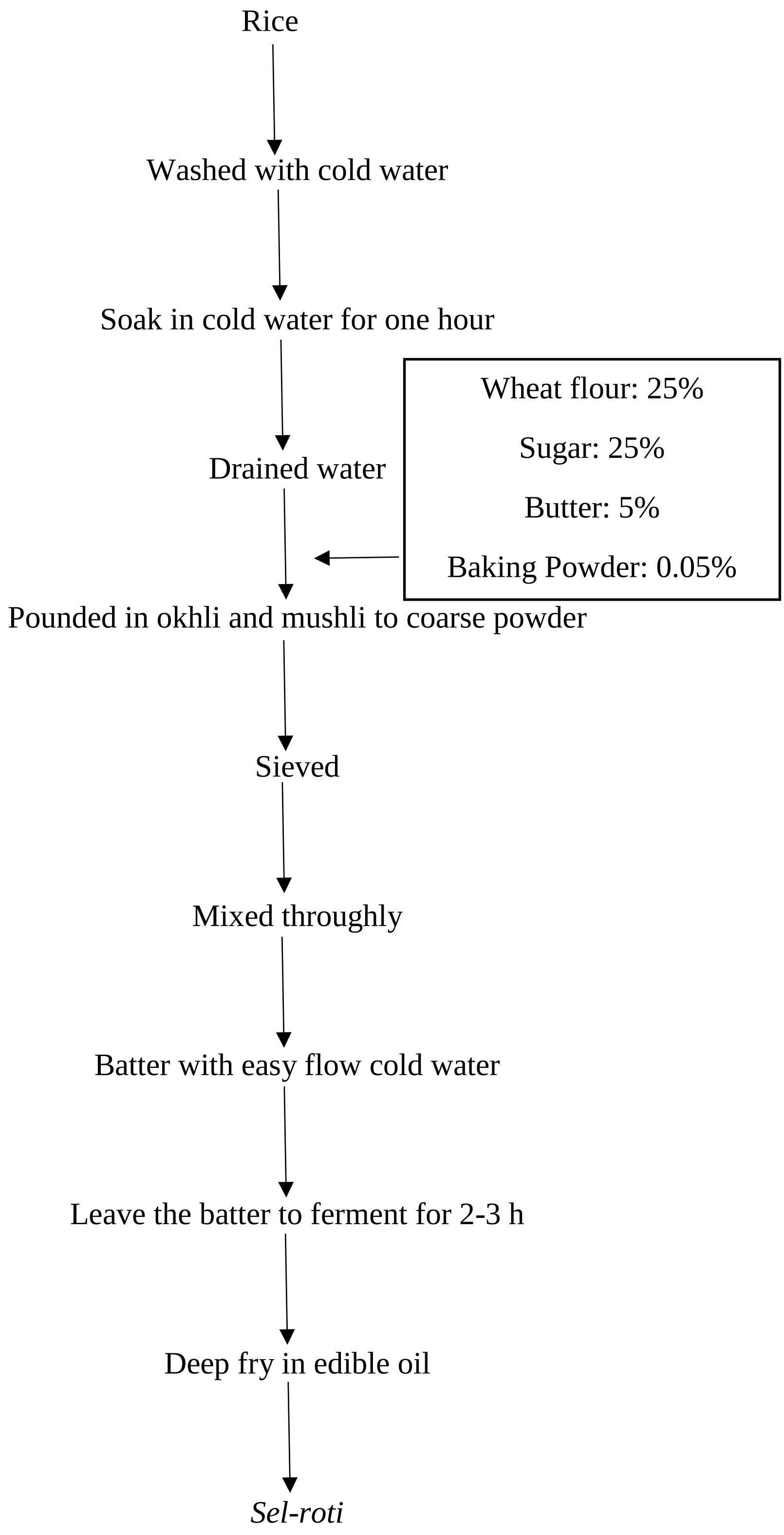


Fig. 2.2 *Sel-roti* preparation in South Sikkim and Nepal (Yonzan and Tamang, 2009).

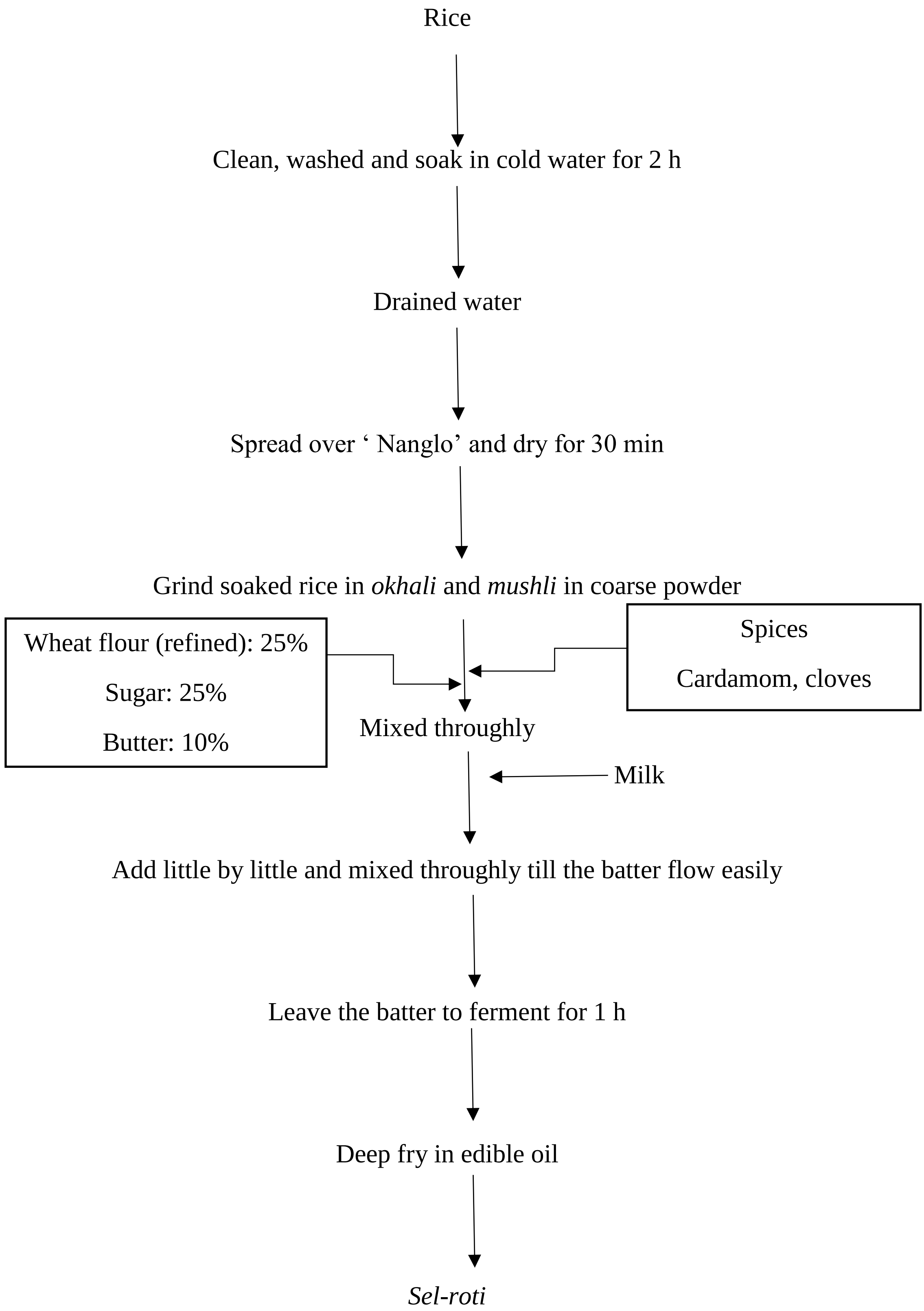


Fig. 2.3 *Sel-roti* preparation in East Sikkim (Yonzan and Tamang, 2009).

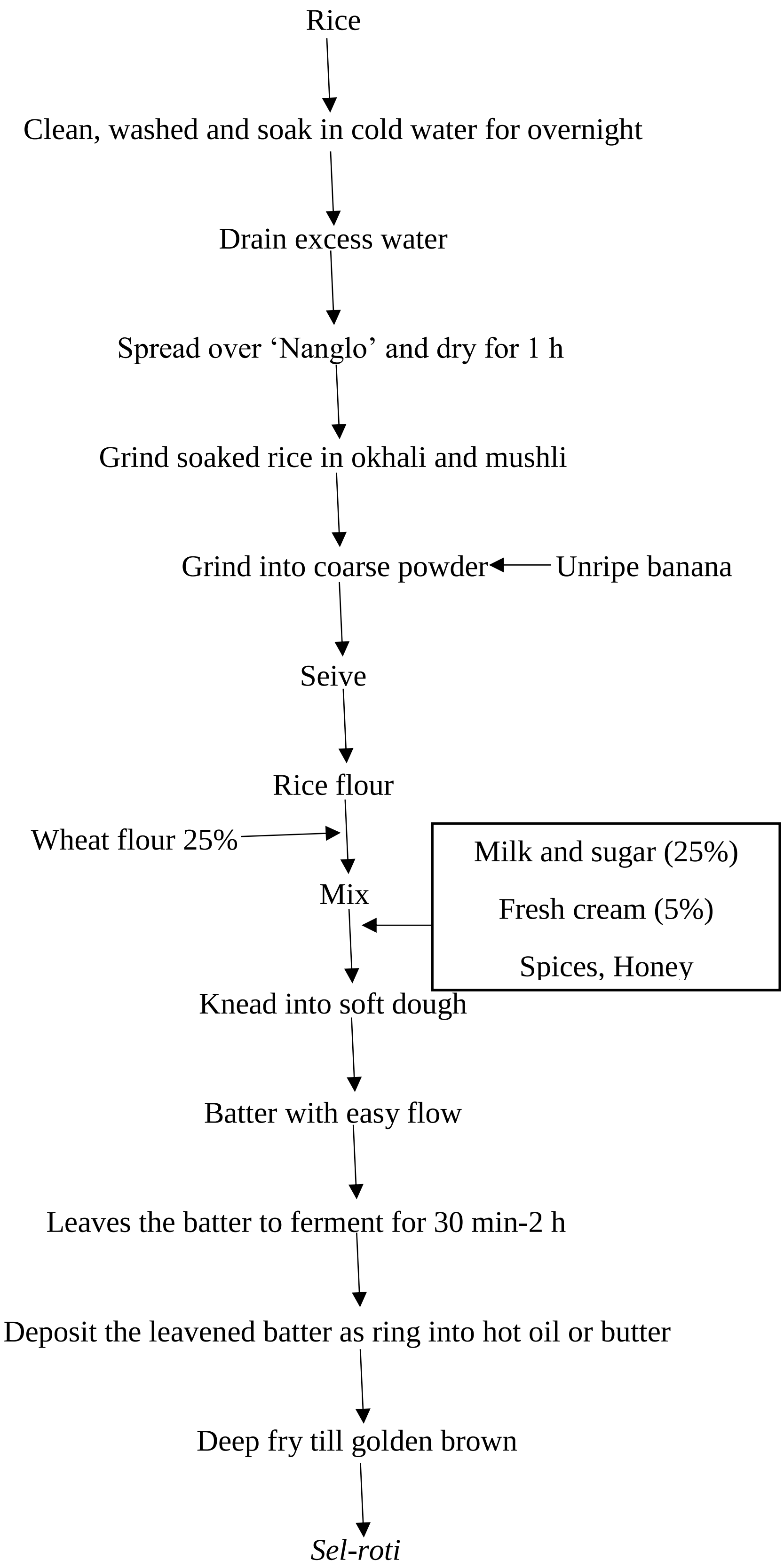


Fig. 2.4 *Sel-roti* preparation in Darjeeling hills (Yonzan and Tamang, 2009).

Rice

↓

Soaking overnight in adequate amount of water

↓

Draining the water

↓

Pounding in *dhiki* or *okhali* into coarse flour

↓

Ageing, for 1-2 days

↓

Kneading and mixing

↓

Batter, viscous

↓

Allow to stand for some time

↓

Frying in hot oil in tai till yellowish brown

↓

Draining – lifting by *jheer* (bamboo skewer)

↓

Sel-roti

Fig. 2.5 Improved method of *sel-roti* preparation (Kharel *et al.*, 2007).

According to Katawal and Subba (2013), the improved method and recipe of *sel-roti* preparation is given in Fig. 2.6.

a) **Recipe:** 1 kg rice, 125 g Ghee, 250 g sugar and 300± 9.6 ml water

b) **Processing parameters:**

   a. Soaking time: Two hour (minimum) at room temperature.

   b. Particle size of flour: 30 parts coarse,50 parts medium and 20 parts fine

   c. Kneading time: 10 min, for 250 g flour.

   d. Ageing time of batter: 1 hour at room temperature.

   e. Frying temperature and time: 210℃ (initial) for 33 s

The refined soybean oil should be used for frying of *sel-roti* for commercial purpose and ghee for ritual or religious purposes.

Rice

↓

Cleaning- by winnowing and washing

↓

Soaking in clean water, for 2 h (minimum)

↓

Draining water

↓

Pounding (using *dhiki/okhli* or *khal-bachha*)

↓

Flour (Coarse:Medium:Fine: 30: 50:20)

↓

Sugar (21%) and Ghee (10.5%) Optional ingredients → Mixing and kneading well (10 min for 250 g flour)

↓

Batter preparation by adding water (25 ml/ 100 g flour)

↓

Allow to stand for 1 h for ageing

↓

Deep frying in hot oil in tai at 210℃ (initial) for 33 s

↓

Intermittent turning upside down

↓

Draining oil lifting by *Jhir* or *Sinko*

↓

Piling on dish

↓

Sel-roti

Fig. 2.6 Optimized method of *sel-roti* preparation (Katawal and Subba, 2013)

2.8 Evaluating qualities of *sel-roti*

Acceptability of the product is affected by flavor, taste, texture and appearance. The sensory characteristics of *sel-roti* are very important because consumers like or dislike on the basis of these sensory attributes. *Sel-roti* has no set up standard quality characters for uniformity of the product. Nobody can say *sel-roti* should have such characteristics and there are varied opinions about the characteristics. According to Katawal and Subba (2013), *sel-roti* should have the following sensory characteristics:

Appearance: Ring shaped, puffed with grainy surface.

Color: Light to reddish brown

Taste: Moderate sweet.

Flavor: Sweetish and slightly burnt flavor.

Texture: Soft and little crispy

As other many foods, *sel-roti* is a food based on cereal and on top of that it is superior in that it is delicious, ethnical, cultural, and secret food item liked and consumed by almost all people of different age, sex, caste/tribes, religions and geographical locations.

In appearance, *sel-roti* should be ring shaped with grainy appearance on the surface. In addition, color should be reddish brown. The major part of the reddish-brown color is due to the non-enzymatic reaction i.e., caramelization of the sugar and Maillard reaction between sugar and protein in the outer layer. The sweet taste is mainly due to sugars. Ghee or fats and oils also contribute the taste. Texture of *sel-roti* should be neither so hard nor so soft. The flavor of *sel-roti* should be good, slightly sweetish and fried. The flavor is mainly contributed by ghee or fats/oils and sugar and optional ingredients (Katawal and Subba, 2013). The non-enzymic browning especially caramelization are responsible for the fried and slightly burnt smell and taste of *sel-roti*. The happening of similar type of phenomenon in baking of bread was mentioned by Matz (1996).

2.9 Factors affecting sensory quality of *sel-roti*

Sel-roti is a circular ring shaped product prepared from rice flour making batter of proper consistency and frying in oil/ghee at high temperature. Some of the factors that affect the sensory quality of *sel-roti* are as follows:

2.9.1 Effect of soaking

Rice is soaked in cold water for minimum 2 h to overnight. Longer the time of soaking better is the result. The soaked rice should contain about 35% moisture, in this moisture content grinding is easy and less damage to starch which gives the better flour and the better puffed product (Katawal and Subba, 2013).

2.9.2 Effect of particle size

The preparation of *sel-roti* was not technically feasible from the flour of finer and coarser particle size. The larger and coarser particles absorb less oil/fat, dries up faster during frying, and contains less moisture. On the other hand, *sel-roti* made from flour containing smaller or finer particles absorbs more oil or fat and becomes soft and gives oily mouthy feel. At the same time, *sel-roti* made from very fine flour puffs excessively on frying and instantaneously collapses on subsequent cooling and moreover becomes leathery in texture. The particle size, and particularly size distribution of flour has pronounced effect on the sensory quality of *sel-roti* (Subba and Katawal, 2011).

2.9.3 Effect of kneading and ageing

The main puffing quality of *sel-roti* is controlled by the kneading activity. Kneading is done for the uniform distribution of the basic ingredients. 10 min kneading gives better *sel-roti*. The fat uptake by *sel-roti* increased with increase in kneading time if other things remain constant. The ageing of batter is necessary for good *sel-roti*, the minimum ageing time of batter should be one hour at room temperature for good *sel-roti* preparation provided that other conditions remain same. More ageing time gives good sensory quality (Katawal and Subba, 2013).

2.9.4 Effect of consistency

The consistency of batter depends on the ratio of dry solid/matter and liquid i.e., water. The proper quantity of water is of utmost importance in obtaining proper batter consistency and ultimate product quality. If too much water is used, the product have a distorted appearance, hollow inside and poor expansion. If less water is used, the products have a rough broken surface, cracks developed during frying. The consistency of batter had effect on the texture and sensory attributes of *sel-roti* (Lawson, 1997).

2.10 Chemical composition of rice and *sel-roti*

The chemical composition of rice and *sel-roti* is given in Table 2.4. This table includes the proximate composition, sugar and energy value of rice and *sel-roti*. The rice is the good source of carbohydrate whereas *sel-roti* is the good source of carbohydrate and fat but poor source of protein. It can supply high calorie i.e., 532 Kcal/100 g *sel-roti* on dry basis.

Table 2.4 Chemical composition and energy value of rice and *sel-roti*

Component	Rice	*Sel-roti*
Moisture (%)	11.98±0.11	11.41±0.30
Crude protein (% DM)	9.41±0.18	4.68±0.10
Crude fat (% DM)	1.20±0.30	26.46±1.35
Total Ash (% DM)	0.70±0.02	0.30±0.02
Crude fibre (% DM)	0.26±0.03	0.12±0.02
Carbohydrate (% DM)	88.42±0.16	68.41±1.44
Starch (% DM)	85.31±0.18	57.43±0.50
Sugar as sucrose (% DM)	ND	16.49±0.46
Reducing sugar as dextrose	0.33±0.01	0.30±0.01
True protein (%)	8.22±0.16	4.04±0.10
Water activity	----	0.65-0.68
Energy (kcal/ 100 g)	401	532

Mean of triplicate analysis ± standard deviation of triplicate sample. (DM = Dry matter) and (ND=not detected) Source: Katawal and Subba (2013)

2.11 Sensory evaluation

Sensory evaluation has been defined as a scientific method used to evoke, measure, analyze, and interpret those responses to products as perceived through the senses of sight, smell, touch, taste, and hearing (Stone and Sadel, 2004). Sensory analysis (or sensory evaluation) is a scientific discipline that applies principles of experimental design and statistical analysis to the use of human senses (sight, smell, taste, touch and hearing) for the purposes of evaluating consumer products. The discipline requires panels of human assessors, on whom the products are tested, and recording the responses made by them. By applying statistical techniques to the results it is possible to make inferences and insights about the products under test (Lawless and Heymann, 2010). Sensory evaluations are usually classified according to their primary purpose and most valid use. Three types of sensory testing are commonly used, each with a different goal and each using participants selected using different criteria.

According to Lawless and Heymann (2010), sensory analysis can mainly be broken down into three sub-sections:

- Difference testing
- Descriptive analyses
- Affective testing

The central principle for all sensory evaluation is that the test method should be matched to the objectives of the test (Lawless and Heymann, 2010).

9-Point Hedonic Testing

One scale with approximately equal subjective spacing is the 9-point category scale used for like–dislike judgments, the 9-point hedonic scale (Peryam and Girardot, 1952). The 9-point scale is very simple to use and is easy to implement. It has been widely studied and has been shown to be useful in the hedonic assessment of foods, beverages, and non-food products for decades. The US military has studied its applicability, validity, and reliability and the positive aspects of this scale have been widely accepted. Peryam and Girardot (1952) noted that the hedonic rating can be affected by changes in environmental conditions (for instance, under field conditions versus cafeteria conditions) but the relative order of sample preference was usually not affected.

The phrases used for sensory evaluation are shown in the following paragraphs:

These response choices are commonly entered as data by assignment of the numbers one through nine.

Like extremely	Like slightly	Dislike moderately
Like very much	Neither like nor dislike	Dislike very much
Like moderately	Dislike slightly	Dislike extremely

The development of the 9-point hedonic scale serves as good illustration of what can be realized when there is interaction between experimental psychologists and food scientists. The danger with hedonic testing is that the results are almost always multidimensional. This means that your decision as to whether you prefer or like something is dependent on more than one thing. Everyone who does the test will have a different opinion about how much they like what's being tested, and you may not be able to figure out what attribute of the things being tested contribute to the person liking something or not, because it's possible that the reason they like it or not might have nothing to do with anything you know about what's being tested. Of course, you also have to consider that different people have different preferences. For this reason, you have to use a very large group of subjects when you do a hedonic test. It's not unusual to require something on the order of hundreds of people doing the test until you can get some reliable data that indicates what the general population will think about what you're testing (Lawless and Heymann, 2010).

2.12 Storage and shelf-life of *sel-roti*

Sel-roti is a semi stable product. Normally *sel-roti* can be stored for 1 week. Shelf life or storage life of *sel-roti* depends on

(i) Ingredients used: e.g., banana, curd, egg, soda, plant bark etc. decrease shelf life whereas ghee, sugars increase shelf life.

(ii) Frying condition

(iii) Storage condition

Sel-roti containing rice flour, ghee, and sugar; well fried; stored at dry and cold condition will have comparatively longer shelf life (Regmi, 2008). The use of proper packaging materials increases the shelf life of *sel-roti*. The quality of vacuum packed *sel-roti* is acceptable up to 4 week, whereas *sel-roti* packed under nitrogen condition remains upto 3 weeks only (Goit, 2008).

Part III

Materials and methods

3.1 Materials

3.1.1 Collection of raw material

Raw materials required for the preparation of the *sel-roti* was purchased from local market of Dharan, Sunsari. ‘Kanchhi mansuli’ rice was taken for the preparation of *sel-roti*. The ghee used in the preparation of *sel-roti* was the product of Dairy Development Corporation, Biratnagar. The frying oil used was Cello brand refined soybean oil, available in the local market of Dharan. The common buckwheat *(Fagopyrum esculentum)* was bought from the local market of Chitwan.

3.1.2 Other materials and equipments

Equipments and other required materials were taken from laboratory of Central Campus of Technology, Dharan, Nepal. *Sel-roti* was prepared and all the analysis were done in the laboratory of Central Campus of Technology. The main utensil for frying of *sel-roti* is called ‘tai’. It is a flat iron pan with a raised side. Most of the people used Tai however, some people used ‘*Karahi*’ (a pan of iron with holding ring in either sides) putting a brass bowl inside the ‘*Karahi*’.

Other utensils used for different purposes in *sel-roti* preparation are as follows:

‘Aari’ or ‘dekchi’: It is made up of stainless steel or aluminum and used for soaking of rice; mixing of rice flour with sugar, ghee or other ingredients; rubbing or kneading and preparing batter.

A Flat dish: It is made up of stainless steel and used for keeping the fried or prepared *sel-roti* just after removing from Tai.

Jhir: A pointed stick made up of iron or bamboo. A bamboo pointed stick is also called ‘*Sinko*’. It is used to turn the *sel-roti* upside down and to remove from hot oil of frying pan.

Nanglo: Winnowing tray made up of bamboo hands. It is used to get the flour of varied particle size.

Weighing Machine: Used to measure the weight of rice flour, sugar, buckwheat flour.

Vernier Caliper: Used to measure the diameters of *sel-roti*.

Timer/ Clock: Used to measure time interval of frying.

Electric Grinder: Used to prepare the flour. Some used *Okhli* and *musli*, *Silouto*, *Dhiki* to pound the soaked rice.

Gas stove was used as fuel or heating source for *sel-roti* preparation.

3.2 Methodology

3.2.1 Preparation of buckwheat malt

3.2.1.1 Cleaning

Seeds were screened to remove impurities such as stones, strings, weed seeds, etc. The sample was divided with sampling method. The sample was roughly screened by passing through a coarse sieve to retain large impurities and over a fine sieve to retain grain and to allow small impurities such as sands to pass through. Seeds were then washed to remove impurities which have attached with the grains.

3.2.1.2 Steeping

The cleaned seeds were then immersed in water in a bucket. The light material present in the sample was skimmed off. Steeping was done for 20 h in room temperature which brought moisture content to the required level of 45-50%.

3.2.1.3 Draining and germination

Steeped water was drained off. The steep grain was first collected in a muslin cloth and swirled in order to drain excess water. The grains were spread over the tray and covered with the muslin cloth and kept for germination in open environment at temperature 26-28°C for 3 days. During germination the grains were moisturized by sprinkling water at 6 h interval and mixed gently in order to equalize temperature and to aerate the mass.

3.2.1.4 Kilning

The common buckwheat variety germinated in open environment was taken in cabinet dryer to stop further germination. Drying was carried out at 45°C for 24 h. The grains were then rubbed and sprouts were removed with the help of screen. The malted grains were then grind in the mixture and the flour is then taken for analysis.

The malted buckwheat flour was prepared according to the Fig. 3.1.

Raw materials (Buckwheat)

↓

Cleaning/ washing (to remove impurities)

↓

Steeping in water (20 h to moisture content of 45-50%)

↓

Germination of seed (in open environment at 26-28°C for 3 days)

↓

Kilning (to stop growth, 45°C, 24 h)

↓

Removal of acrospires

↓

Grinding

↓

Malted Buckwheat flour

Fig. 3.1 Flow diagram for preparation of malted buckwheat flour Subedi (2018).

3.2.2 Method of *sel-roti* preparation

3.2.2.1 Recipe formulations

Design Expert v 7.1.5 software is used to create the recipe. D-optimal design is used to formulate the recipe. The independent variable for the experiment is the concentration of malted buckwheat flour. Initially, different random trials with wide range of fortification levels have been undertaken to find maximum and minimum proportion of buckwheat flour.

The recipe formulation for the buckwheat flour incorporated *sel-roti* was carried out as given in Table 2.5.

Table 2.5 Recipe formulation for *sel-roti* preparation

	A	B	C	D	E	F	G	H
Rice flour (parts)	100	97.48	94.96	90	87.56	85.04	82.52	80
Buckwheat flour (parts)	0	2.52	5.04	10	12.44	14.96	17.48	20
Ghee (parts)	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5
Sugar (parts)	21	21	21	21	21	21	21	21
Water(parts)	25	25	25	25	25	25	25	25

The *sel-roti* was made as per the recipe formulation done and coded name A, B, C, D, E, F, G, and H were given to each recipe.

Although there are variations in addition of ingredients, time of soaking of rice, coarseness of flour, some treatment procedure prior to frying, frying medium, batter consistency etc., major steps in method of preparation remain the same. The method used for *sel-roti* preparation was based on the method prescribed by Katawal and Subba (2013). Fig. 3.2 shows the flow sheet for the preparation of *sel-roti*.

Rice

↓

Cleaning- by winnowing and washing

↓

Soaking in clean water for overnight

↓

Draining water

↓

Grinding using electric grinder

↓

Sugar (21 g), Malted buckwheat flour and Ghee (10.5 g) → Rice flour (Coarse:Medium:Fine:::30:50:20 part)

↓

Mixing and kneading (about 15 min)

↓

Batter preparation by adding water (25 ml/ 100 g flour)

↓

Allow to stand for 1 h (Ageing)

↓

Deep frying in oil in tai at 210 ℃ (initial) for 33 s

↓

Intermittent turning upside down

↓

Draining oil lifting by suiro

↓

Piling on dish

↓

Sel- roti

Fig. 3.2 Flow sheet for slight modification on the method of sel-roti preparation given by Katawal and Subba (2013)

The rice was winnowed with the help of *Nanglo* and cleaned with water for 2 times. Water was added and was allowed to stand overnight. The water was drained from the soaked rice and ground into flour with the help of electric grinder. The flour was sieved by using three different ASTM standard set of sieves (Supreme Commercial Concern Kathmandu, Nepal). The flour retained in sieve was collected and weighed. Based on the particle size the rice flour was divided into three groups as coarse, medium and fine. For the preparation of *sel-roti*, 30% coarse flour 50% medium and 20% fine flour were mixed and taken. Sugar, ghee and a little water was added to the flour. It was kneaded with palm for about 15 min. Sufficient water was added and whipped with hand. Then, the batter was left for ageing for

1 h. Then the batter was poured into heated oil, giving into the circular shape. Frying was done at 210°C (initial). Total time of frying was 27 s; upside was turned down after 17 s and finally removed with the help of *suiro*, a pointed bamboo stick used to turn *sel-roti* upside down and then to lift and remove the fried *sel-roti* from the oil. The same steps were followed in case of fine malted buckwheat flour incorporation. The flour was mixed with sugar, ghee, water and different percentage (0, 2.52, 5.04, 10, 12.44, 14.96, 17.48 and 20 of malted buckwheat flour). Finally, fat –uptake, flavonoid content, ratio of ring diameter to cross section diameter and moisture content was determined.

3.3 Experimental procedure

3.3.1 Physical analysis of buckwheat seeds

3.3.1.1 1000 kernel weight

The 1000 kernel weight of raw materials and final products were determined by measuring the weight of 1000 kernels of buckwheat grains after selecting the appropriate sample size by quartering method as stated in Buffo *et al.* (1998).

3.3.1.2 Bulk density

The bulk density was measured as mentioned in Clementson *et al.* (2010) by pouring the grains into the funnel-shaped hopper, the hopper was centered over the measuring bushel, the hopper valve was opened quickly, and the grains were allowed to flow freely into the measuring bushel. After the bushel was filled, the excess material was leveled off with gentle zigzag strokes using the standard Seedburo striking stick. The filled measuring bushel was then weighed, and the mass of grains in the bushel was determined by subtracting the mass of the measuring bushel itself. The bulk density (ρ) of grain was then calculated using the following expression:

$$\text{Bulk density} = \frac{\text{Mass of grain}}{\text{Volume of bushel}}$$

3.3.2 Analysis of product

Sel-roti sample was ground in uniform particle size by using electric grinder and packed into polythene bag and sealed. The samples were used for proximate and other analysis.

3.3.2.1 Physical analysis

3.3.2.1.1 Fat-uptake

Fat content of *sel-roti* was determined as per AOAC official method AOAC (2005)and fat content and fat-uptake were calculated as follows:

$$\text{Perent fat-uptake} = \text{Weight of fat / Weight of sample } \times 100$$

$$\text{Percent fat-uptake (dry and fat-free)} = \frac{\text{Percent fat content}}{100 - (\%\text{Moisture content} + \%\text{Fat})} \times 100$$

3.3.2.1.2 Ring diameter to cross-section diameter ratio

Ring diameter and cross section diameter of *sel -roti* was measured using vernier caliper and their ratio was calculated.

3.3.2.2 Chemical analysis

3.3.2.2.1 Moisture

The moisture content of rice and *sel-roti* samples was determined by following Ranganna (1986) and AOAC (2005) method as follows:

Ten gram of well ground sample in uniform particle size was taken into cleaned, dried and petri dish. The sample in container was dried at 100± 2°C till constant weight in hot air oven. The moisture content was calculated and expressed as percentage. The triplicate analyses were carried out.

$$\text{Percent moisture content} = \frac{\text{Loss of weight}}{\text{Weight of sample}} \times 100$$

3.3.2.2.2 Crude protein content

For crude protein estimation nitrogen content in a sample was determined by micro Kjeldahl method following the method Ranganna(1986) and the protein was calculated by multiplying the percentage of nitrogen by a factor i.e., AOAC (2005).

3.3.2.2.3 Crude fat

It was determined by soxhlet extraction method using petroleum ether (boiling point, 40 – 60°C) as in AOAC (2005) and Ranganna (1986).

3.3.2.2.4 Ash

Ash is the residue remaining after food stuff is ignited until it is carbon free, usually at a temperature not exceeding red heat. Ash content was determined by ashing in muffle furnace at 500℃ as described in Ranganna (1986).

3.3.2.2.5 Determination of iron

The iron content of the sample was determined as per Ranganna (1986). The iron in foods was determined by converting the iron to ferric form using oxidizing agents like potassium persulphate or hydrogen peroxide and then treating with potassium thiocyanate to form the red ferric thiocyanate which was measured colorimetrically at 480 nm.

3.3.2.2.6 Determination of flavonoid (quercetin) content

The seeds are milled to flour. 5 g of malted flour was taken and 30 ml of 80 % methanol was added to sample. The mixture was rotated in hot plate and filtered. This process was repeated for 2 times and then final filtered sample was made to 100 ml for analysis (Amorim *et al.*, 2008).

0.5 ml of extract was taken and 2 ml of distilled water was added. After that 0.15 ml of 5% $NaNO_2$ solution was added in it and allowed to stand for 6 min. After 6 min 0.15 ml of 10% $Alcl_3$ added in it and again it was left for 6 min. After leaving for 6 min 2 ml of 4% $NaNO_2$ solution was added in it and after that 0.2 ml of distilled water was added and finally it was allowed to leave for 15 min. Finally absorbance was taken at 510 nm (Samatha *et al.*, 2012). From the standard curve, flavonoid content was determined.

3.4 Sensory analysis

Sensory evaluation for the laboratory prepared samples was performed by 9 point hedonic scoring test (9 = like extremely, 1 = dislike extremely) for appearance, flavor, color, texture, taste and overall acceptance. The evaluation was carried out by 14 panelists comprising of teachers and students of Central Campus of Technology, Dharan. Duplicate analysis was carried out. Each panelist was provided with coded samples in a plastic plate and a sheet of sensory evaluation card was provided in a class room at a day light condition. Each panelist was asked to evaluate the sample according to quality attributes like appearance, taste, texture, flavor and overall acceptability. They are also provided warm water to rinse mouth between tests. The specimen of score card is given in Appendix A.

3.5 Statistical analysis

The experiment was conducted with two replications. All calculations were performed in Microsoft Office Excel (2016). The experimental data was analyzed using ANOVA and t-test using GenStat Release 12.1 (2009). The means were compared by L.S.D. method at 5% level of significance. LSD was obtained to determine whether the samples were significantly different from each other and also to determine which one is superior between them.

Part IV

Results and discussion

This work was carried out for the preparation of different *sel-roti* formulation with varying proportion of buckwheat flour with rice flour. As *sel-roti* is the product mostly consumed by Nepali people, buckwheat incorporated *sel-roti* adds value to the nutritional profile of the product. At first, the major raw materials were subjected to physical and chemical analysis.Then, sensory evaluation of *sel-roti* followed by chemical analysis of optimized and control sample was performed. The obtained results were presented and discussed in the following suitable headings:

4.1 Proximate composition of rice

The proximate composition of rice flour was determined. The results obtained are presented in Table 4.1.

Table 4.1 Proximate composition of rice

Component	Rice
Moisture (%)	10.95 (0.10)
Crude protein (% db)	8.45 (0.13)
Crude fat (% db)	1.19 (0.24)
Total Ash (% db)	0.64 (0.01)
Iron (mg/100 g)	1.12 (0.01)
Crude Fibre (% db)	0.21 (0.02)

The values are the mean of triplicates and the values in parenthesis indicates standard deviation .

The moisture content of rice was found to be 10.95% which is slightly lower as reported by Upadhyay and Karn (2018). Similarly, the protein content of rice was found to be 8.45 % whereas the protein content in white rice is 7.13% as reported by Upadhyay and Karn (2018). The ash content and fat content of rice were higher than the value reported by Matz (1996).

4.2 Physical properties of buckwheat grain

In order to characterize buckwheat, different physical parameters viz.colour, shape, 1000 kernel weight, bulk density, etc. were investigated and data on these physical properties are presented in Table 4.2.

Table 4.2. Physical attributes of buckwheat grain

Physical Attribute	Buckwheat grains
Color	Dark grey
Shape	Triangular with sharp edges
1000 Kernel Wt. (g)	23.92 (0.60)
Bulk Density (Kg/HL)	83.90 (2.81)

Values are the mean of triplicates and the values in parenthesis indicates standard deviation.

The seed color of buckwheat was found to be dark grey while the shape of seeds was triangular with sharp edges. Shape of seed is a distinguishing characteristic of buckwheat. Color of buckwheat has been reported to vary from dark brown to dark grey depending upon cultivar and geographical conditions (Byoung *et al.*, 2004). 1000 kernel weight of common buckwheat is similar to the result as reported in Kaliniewicz *et al.* (2015) and Unal *et al.* (2017). The bulk density of common buckwheat is similar to the result as reported in Unal *et al.* (2017).

4.3 Proximate composition of raw buckwheat flour and malted buckwheat flour

The proximate composition such as moisture content, crude protein, crude fiber, crude fat and ash content of raw and malted common buckwheat flour in open environment were determined as per the standard procedure and results are expressed in (% dry basis except moisture) in Table 4.3.

Table 4.3 Proximate composition of raw and malted buckwheat flour (% dry basis except moisture)

Parameters	Raw buckwheat flour	Malted buckwheat flour
Moisture (%)	12.80 (0.09)	7.05 (0.04)
Total Ash (% db)	2.43 (0.01)	2.51 (0.08)
Crude Fat (% db)	3.05 (0.01)	2.55 (0.03)
Crude Protein (% db)	13.59 (0.02)	14.44 (0.31)
Crude Fibre (% db)	0.96 (0.02)	1.69 (0.01)
Carbohydrate (% db)	79.96 (0.02)	78.92 (0.33)
Iron (mg/ 100 g)	3.68 (0.24)	3.53 (0.04)

Values are the means of triplicates determination and the values in parenthesis indicates standard deviation.

The moisture content of raw common buckwheat was found to be 12.8%. The moisture content is found to be slightly higher than reported by Poudel (2012), who analyzed moisture content for common buckwheat (11.81%). The moisture content of raw common buckwheat has found to be 11.4% as reported by Devrajan *et al.* (2017a). The variation in moisture content may be due to genetic and environmental factors.

The ash content of raw common buckwheat was 2.43 % similar to the research that was conducted by Qin *et al.* (2010) and 1.4 %-2.5% by Dogra and Awasthi (2015). During malting, the common buckwheat percentage increased to 2.51% in open environment. During malting, ash content of buckwheat varieties seem to be increased which has been found in similar other findings by Chowdhury and Rahman (2017). The increased in ash content during malting is reported that germination and fermentation would increase the mineral content due to an increase in fitase enzyme activity during germination. The enzyme will hydrolyze the bond between the protein-enzyme minerals become free, therefore increasing the availability of minerals as reported in Narish *et al.* (2012).

The fat content of raw common buckwheat was found to be 3.05%. The fat content of common buckwheat was reported to 3.06% in Zhang *et al.* (2015) and 1.6 %- 2.9% by Dogra and Awasthi (2015) .The fat content of common buckwheat after malting in open environment was found to 2.553 % . It has been reported that the decrease in fat content might be due to increase activity of lipase enzyme (Devrajan *et al.,* 2017b) .

The crude fiber content of raw common buckwheat was found to be 0.96 %. This content is found in the range of 0.77%-0.96% that has been reported by Khan *et al.* (2013). The crude fiber content of malted common buckwheat was found to be 1.68% .This increase in fiber percentage after malting is similar to the result reported in Chowdhury and Rahman (2017) .

The protein content in raw common buckwheat was found to be 13.59%. This result is similar to the result that has reported by Sindhu and Khatkar (2016). The protein content of malted common buckwheat is increased to 14.44% .Here, protein content has been increased after germination or malting which has been similar to other findings reported by Devrajan *et al.,* (2017a). Increase in protein content has been found in buckwheat and amaranth flour after germination as reported by Chauhan and Singh (2013) . The differences in protein content in various buckwheat cultivars may be due to cultivars variability and growing conditions has reported in Qin *et al.* (2010). The increase of these proteins might be attributed to the dry weight losses through respiration during malting as reported in Singh *et al.* (2015).

The carbohydrate content of raw common buckwheat was found to be 79.958 % which is similar to the result as reported in Khan *et al.* (2013). The carbohydrate content of malted common buckwheat was 78.917 %. The decrease in carbohydrate content on malting could be attributed to metabolism. The carbohydrates may have been digested into simple sugars by amylolytic enzymes which are rapidly taken up by the growing embryo to serve as its energy source during germination as reported in Ogbonna *et al.* (2012).

The iron content of raw common buckwheat is similar to the result reported by Steadman *et al.* (2001). The decrease in iron content may due to leaching of minerals during soaking as reported in soybean by Kumari *et al.* (2014).

4.4 Effect of buckwheat flour content on sensory attributes of *sel-roti*

Sel-roti is an important fermented cereal-based food in the local diet of Nepali of the Himalayas. In present investigation, efforts were made to utilize buckwheat flour in *sel-roti* to evaluate the influence of buckwheat flour on quality of *sel-roti* and contents of functional components as a result of supplementation. The consumer acceptability of *sel-roti* may be assessed with the help of sensorial evaluation of the products. In order to study the effect of buckwheat fortification on sensorial quality characteristics, different random trials with wide range of fortification levels have been undertaken following the sensorial evaluation using 9 point hedonic scale for the organoleptic characteristics like colour and appearance, taste, flavour, texture, and overall acceptability.

4.4.1 Appearance

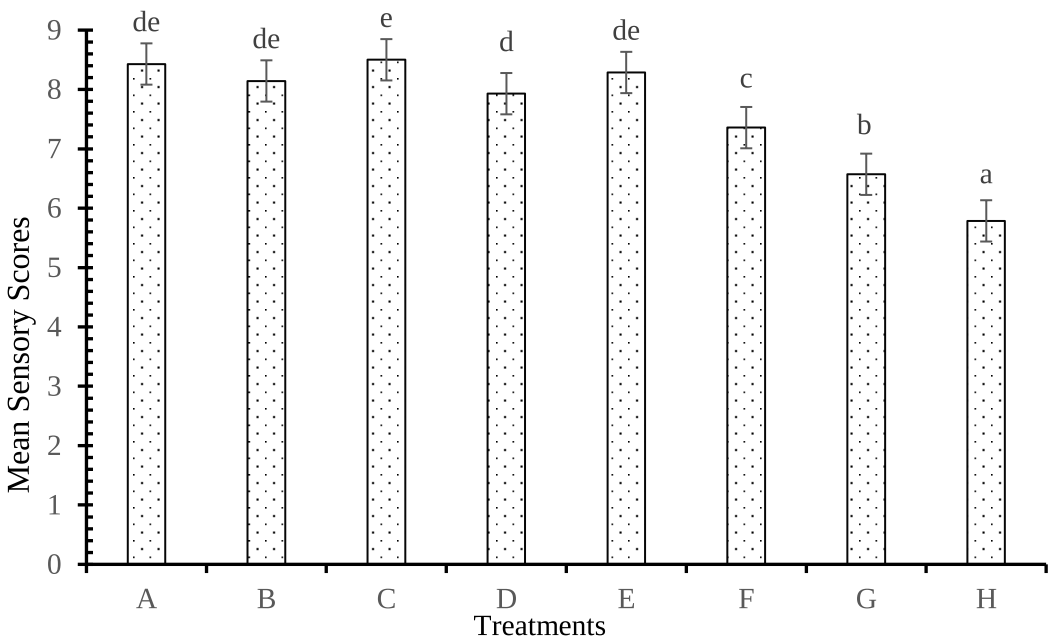


Fig. 4.1 Mean scores for appearance of *sel-roti* samples of different formulations. Bars with similar alphabets at the top are not significantly different.

The mean sensory score for appearance of *sel-roti* samples of different formulations are shown in Fig. 4.1. Statistical analysis showed that partial substitution of malted buckwheat flour with rice flour had significant effect ($p < 0.05$) on the appearance. The mean sensory score for appearance of sample A (control) was found to be 8.429 which was the highest score of all the *sel-roti* formulations. Also sample A (control) is not significantly different with samples B, C, D, and E respectively. The score for appearance of samples F, G and H reduces by increasing the ratio of malted buckwheat flour. This was because of cracks formed with the addition of gluten free buckwheat flour which are in accordance with the findings of Baljeet *et al.* (2010). Similar results were also shown by Schober *et al.* (2003).

4.4.2 Taste

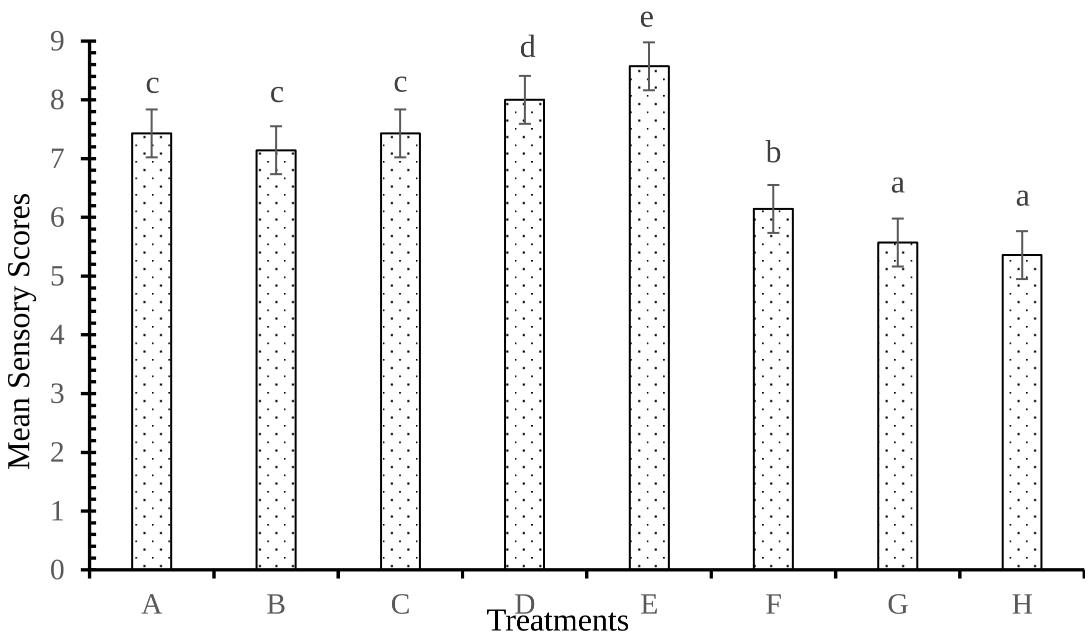


Fig. 4.2 Mean scores for taste of *sel-roti* samples of different formulations. Bars with similar alphabets at the top are not significantly different.

The mean sensory score for taste of *sel-roti* samples of different formulations are shown in Fig 4.2 . The mean sensory score for taste of sample E was found to be 8.571 which was the highest score of all the *sel-roti* formulations. Samples B and C were not significantly different from sample A (control). Statistical analysis showed that partial substitution of malted buckwheat flour with rice flour had significant effect ($p < 0.05$) on the taste. Samples G and H were not significantly different and scored low in terms of taste which are in accordance with the findings of Bilgicli (2009) who revealed that taste scores increased up to the (10-13) % buckwheat flour level while the further increase in buckwheat flour proportion led to a decrease in taste scores which was possibly due to presence of flavonoid compounds (quercetin, rutin, and protocatechuic acid) having bitter taste .

4.4.3 Flavor

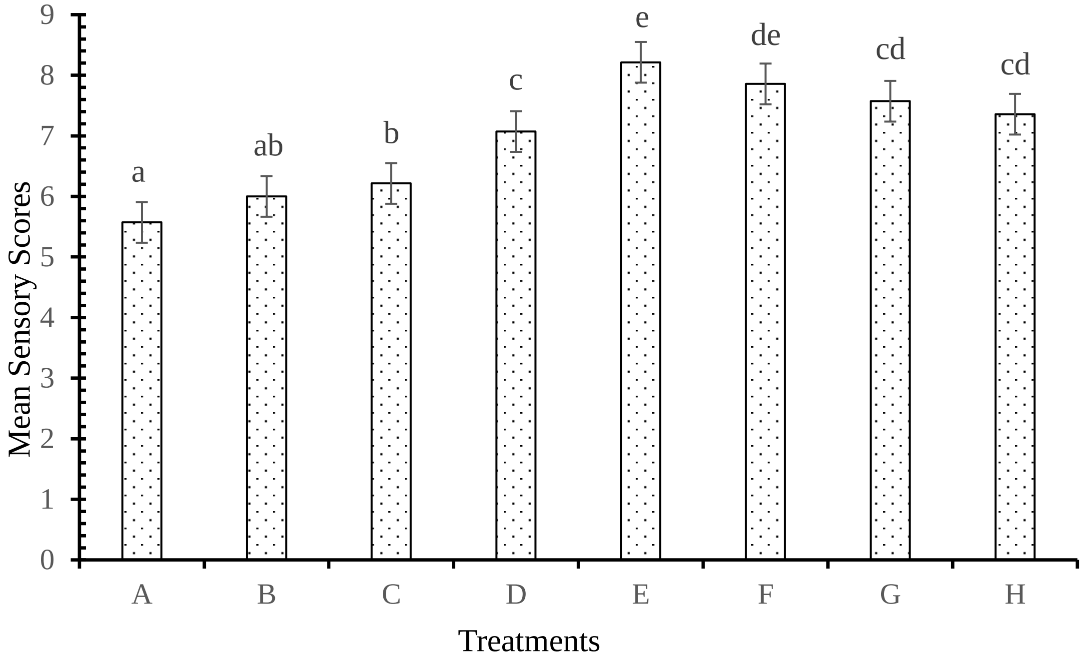


Fig. 4.3 Mean scores for flavor of *sel-roti* samples of different formulations. Bars with similar alphabets at the top are not significantly different.

The mean sensory score for flavor of *sel-roti* samples of different formulations are shown in Fig. 4.3. Statistical analysis showed that partial substitution of malted buckwheat flour with rice flour had significant effect ($p < 0.05$) on the flavor. The mean sensory score for flavor of sample E was found to be 8.214 which was the highest score of all the *sel-roti* formulations. Samples A and B are similar in nature and has lower score than other samples due to the least use of buckwheat flour, as buckwheat flour has higher oil absorption capacity which leads to good flavor development and better mouth feel as stated by Taira (1974). Also Aoki and Koizumi, (1986) indicated that nonanal, octanal, and hexanal are important aroma compounds of buckwheat because of their low odour threshold values in water. On contrary, polyphenols, an aromatic compound, are commonly found in buckwheat flour and they are responsible for giving the pleasant aroma (Luthar, 1992) and masking the bland and neutral rice flour taste.

4.4.4 Color

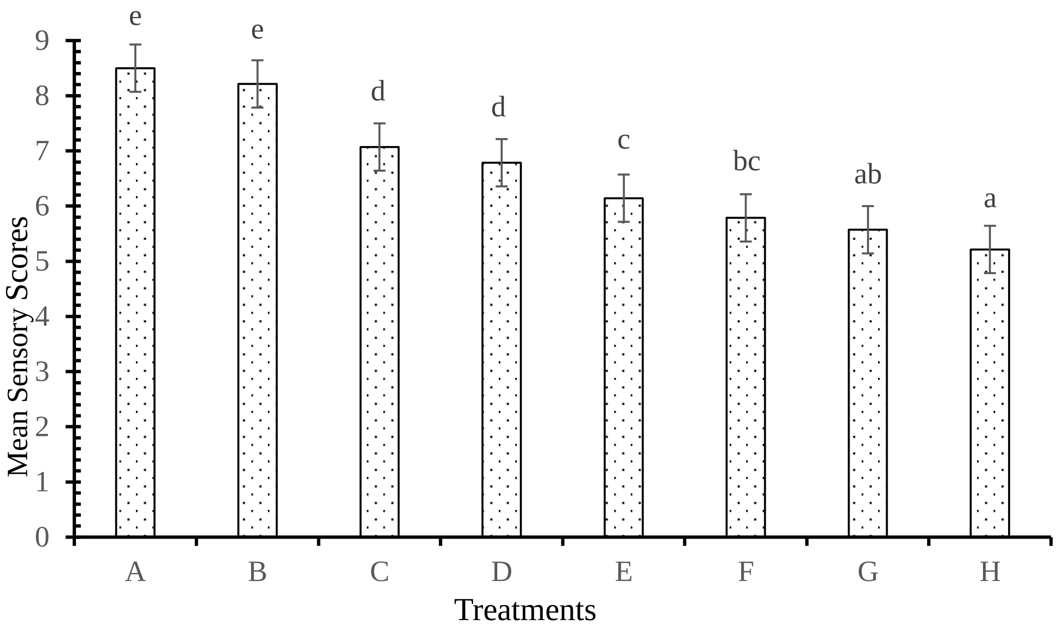


Fig. 4.4 Mean scores for color of *sel-roti* samples of different formulations. Bars with similar alphabets at the top are not significantly different.

The average mean scores of colors are shown in Fig. 4.4. Statistical analysis showed that partial substitution of rice flour with malted buckwheat flour had significant effect ($p < 0.05$) on the color. The mean sensory score for color of sample A (control) was 8.5 and was the highest score scored among the different formulations. Samples A (control) was not significantly different to sample B. The lowest mean sensory score was of sample H. It can be also noticed that samples F and G were not significantly different from sample H. However, the acceptability of color decreased of samples F, G, and H because of the increment of malted buckwheat flour which has lower lightness and higher yellowish value than control (Duarte *et al.*, 1996). This was caused by rutin (also called rutoside, quercetin-3-O-rutinosode) contents. Rutin is described as a yellow or yellow-green, crystalline, photosensitive substance, well-soluble in water-free alcohol, methyl alcohol and in alkali hydroxides solution (Sweetman, 2005).

4.4.5 Texture

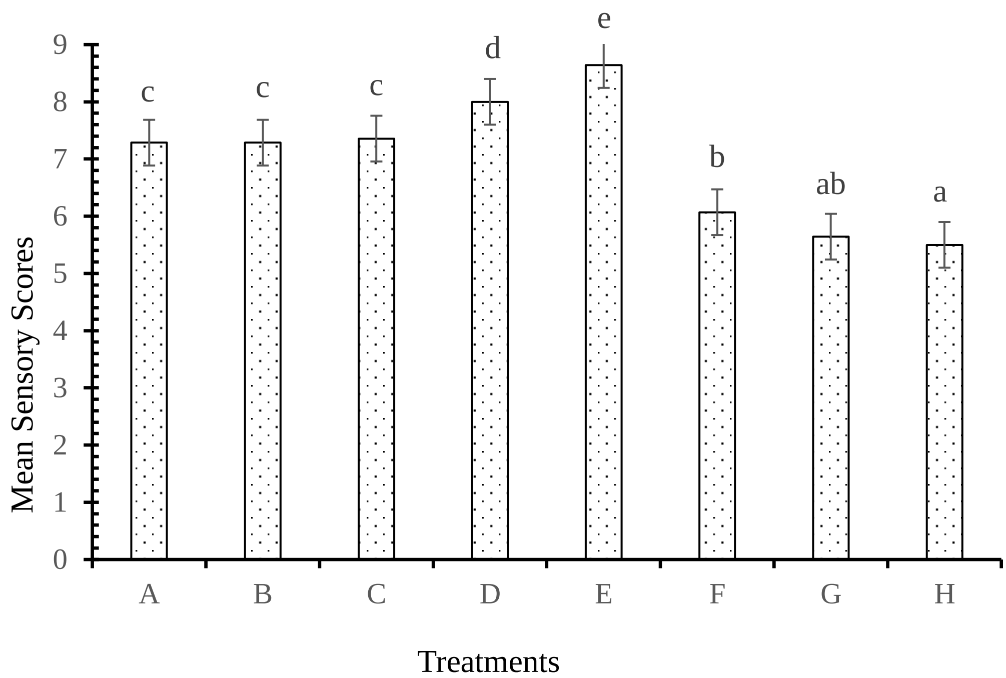


Fig. 4.5 Mean scores for texture of *sel-roti* samples of different formulations. Bars with similar alphabets at the top are not significantly different.

The mean sensory score for texture of *sel-roti* samples of different formulations are shown in Fig. 4.5. The mean sensory score for texture of sample E was found to be 8.64, which was the highest score of all the bread formulations. Samples B and C were not significantly different from sample A (control). Statistical analysis showed that partial substitution of malted buckwheat flour with rice flour had significant effect ($p< 0.05$) on the texture. Soft and crunchiness is the texture quality of *sel-roti* (Katawal and Subba, 2013). The incorporation of wheat flour in the recipe of rice flour batter reduces the brittle and hard to chew property of the final deep fried product because of the high viscosity of the wheat flour as compared to the rice flour and due to the increase in fat-uptake (Pray and Pillsbury, 2010). In the present study, product G and H were not significantly different to each other and scored lowest in texture since similar result is obtained in case of buckwheat flour as well.

4.4.6 Overall acceptance

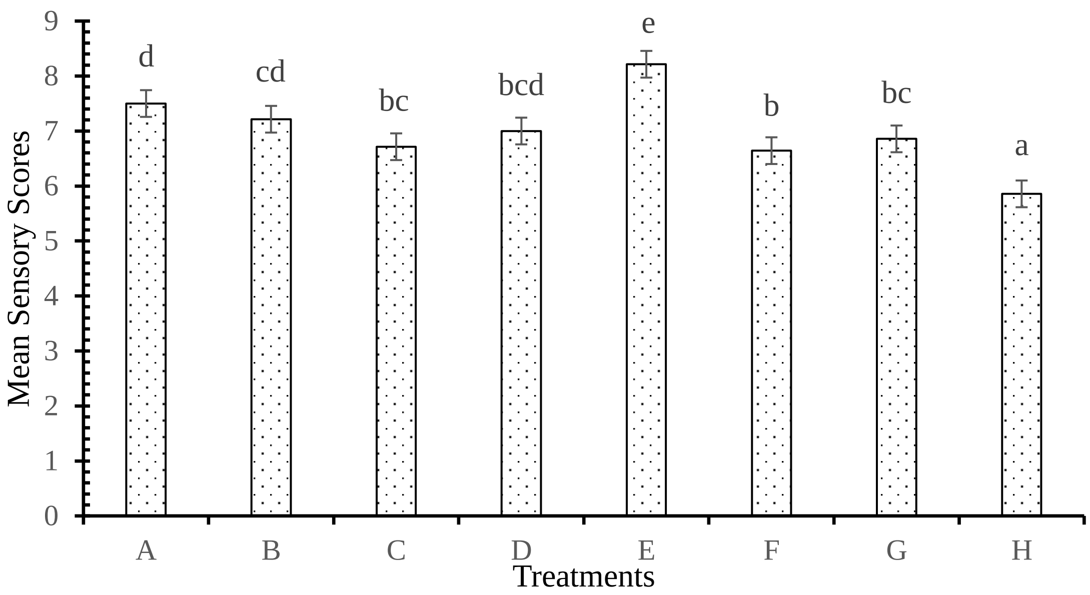


Fig. 4.6 Mean scores for overall acceptability of *sel-roti* samples of different formulations. Bars with similar alphabets at the top are not significantly different.

The mean scores of overall acceptability of *sel-roti* of different formulations are shown in Fig 4.6. Statistical analysis showed that partial substitution of malted buckwheat flour with rice flour had significant effect ($p< 0.05$) on the overall acceptance.The mean sensory score of the s*el-roti* prepared from the 12.44% malted buckwheat flour incorporation was highest (8.2).The mean sensory score in terms of overall acceptance increased upto the addition of 12.44% malted buckwheat flour and decreased then after. Flavor, taste, texture and appearance of the 12.44% malted buckwheat flour incorporated *sel-roti* was very much liked, therefore sample E got the high score in terms of overall acceptance.So sample E is best in terms of sensory attributes.

4.5 Effect of malted buckwheat flour addition on physicochemical properties of *sel-roti*

Different proportion of malted buckwheat flour viz. 0, 2.5, 5, 10, 12.4, 15, 17.4, 20 parts per 100 parts by weight of rice flour were mixed with rice flour and then *sel-roti* was prepared. Effect of malted buckwheat flour addition on physicochemical properties of *sel-roti* is prepared.

4.5.1 Effect on moisture content

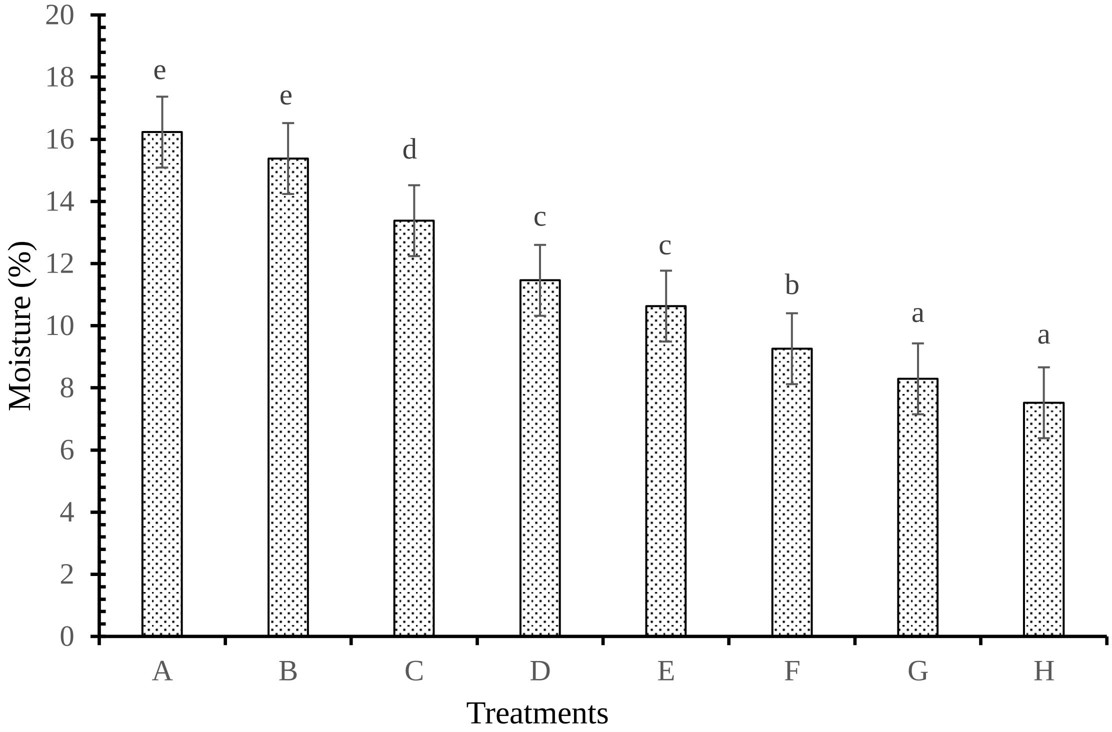


Fig. 4.7 Effect of malted buckwheat flour incorporation on moisture (%) of *sel-roti.*Columns with different alphabets are significantly different (p< 0.05).

The moisture content of *sel-roti* as affected by malted buckwheat flour incorporation was analyzed and is presented in the Fig. 4.7. The mean values of moisture content of samples A, B, C, D, E, F, G, H were 16.23, 15.38, 13.38, 11.46, 10.63, 9.26, 8.29 and 7.52 respectively. The value for the 0% (control ,sample A) malted buckwheat flour incorporation was slightly higher than the value reported by Katawal and Subba (2013), (11.41 ± 0.30). The statistical analysis showed that malted buckwheat flour incorporation had significant effect (p <0.05) on the moisture content of *sel-roti* among samples of different formulations.

The highest moisture content was found in 0 % malted buckwheat flour incorporation and the lowest moisture was found in 20 % malted buckwheat flour incorporation. Moisture content of the formulations decreased linearly with the increase in addition of buckwheat flour. Decreased water content of finished *sel-roti* may be a consequence of depleted water absorption capacity of batter due to addition of buckwheat flour, which weakens the gluten and starch network to retain less moisture. Results of present investigation are well in accordance with those reported by Mustafa *et al.* (1986) and Jan *et al.* (2015) who has reported that the moisture content of finished product made from the blends decreased with the increase in the ratio of buckwheat flour.

4.5.2 Effect on fat- uptake

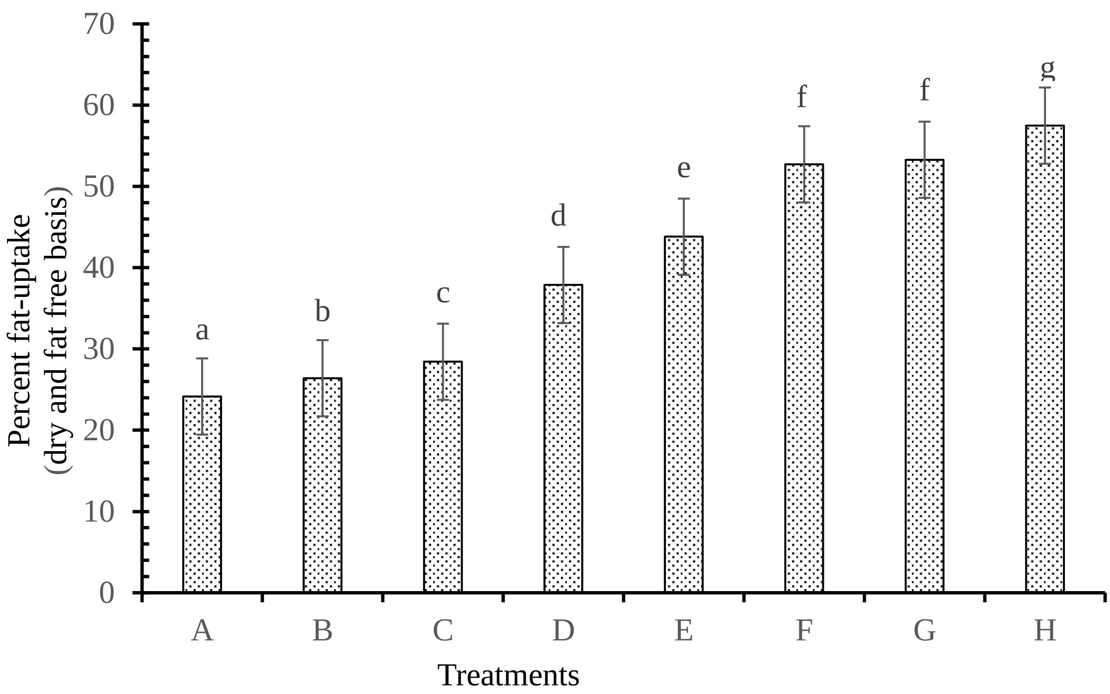


Fig. 4.8 Effect of malted buckwheat flour incorporation on fat uptake of *sel-roti*.

Columns with different alphabets are significantly different ($p < 0.05$).

The percent fat –uptake of *sel-roti* as affected by malted buckwheat flour incorporation was analyzed and presented in the Fig. 4.8. The mean values of fat –uptake in samples A, B, C, D, E, F, G, H were 24.15, 26.40, 28.43, 37.87, 43.81, 52.72, 53.28, 57.48 respectively (in dry and fat free basis). The statistical analysis showed that malted buckwheat flour incorporation had significant effect ($p < 0.05$) among samples of different formulations. Samples F and G are not significantly different.

The larger and coarser particles absorbs less oil/fat and dries up faster during frying and contains less moisture .Similarly, smaller or finer particles absorbs more oil or fat and it is soft. The value for the *sel-roti* from freshly prepared batter was 27.01%. The obtained value was quite lower than that found by Subba and Katawal (2011). The reason of lower fat uptake of control sample was probably due to presence of course particle of flour in the recipe. In the current study, it has been found that when more buckwheat flour was added, the fat uptake increased which is similar to the results shown by Choy *et al.* (2013).

4.5.3 Effect on ring diameter to cross section diameter ratio

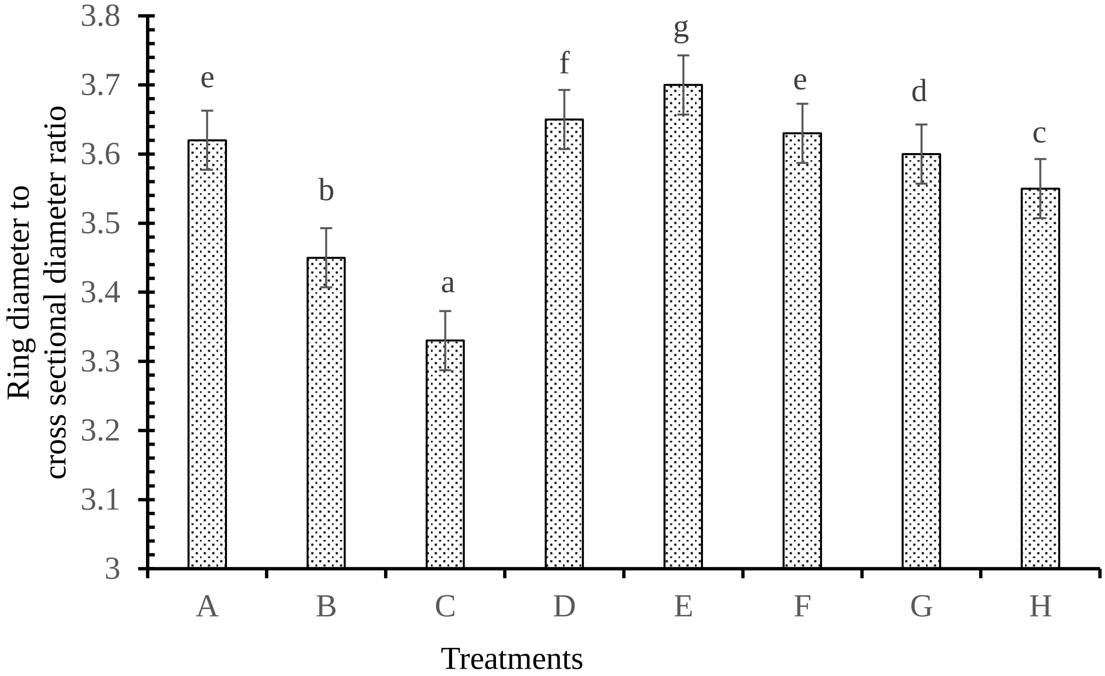


Fig. 4.9 Effect of malted buckwheat flour incorporation on ring diameter to cross sectional diameter ratio of *sel-roti*. Columns with different alphabets are significantly different ($p < 0.05$).

The mean value of ring diameter to cross section diameter ratio is presented in the Fig. 4.9. The mean values of the ratio were 3.62, 3.45, 3.33, 3.65,3.70, 3.63, 3.60 and 3.55 respectively. Katawal and Subba (2013) also determined ratio of ring diameter to cross section diameter to be 5.42. The obtained values were a bit different as compared to Katawal and Subba (2013). There was no definite trend in increase or decrease in these values among the formulations that may be due to the experience of cook, amount of batter pour in tai, batter consistency and temperature fluctuation during cooking.

4.5.4 Effect on flavonoids content of *sel-roti*

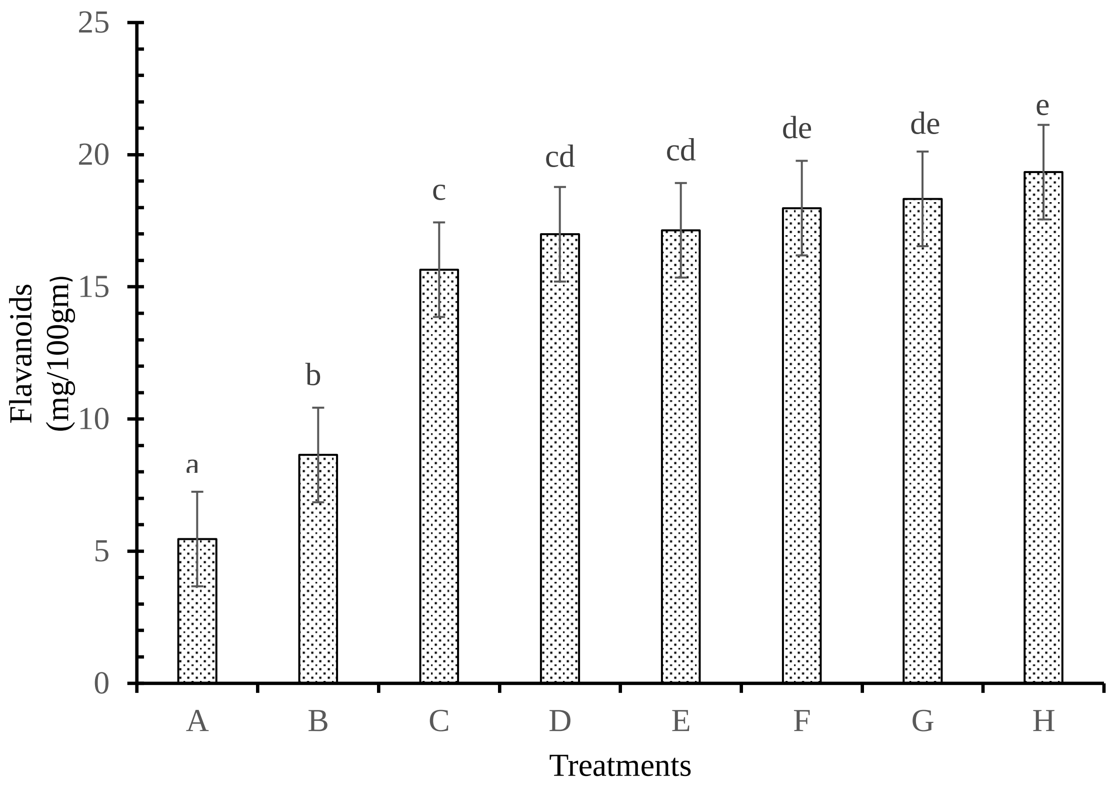


Fig. 4.10 Effect of malted buckwheat flour incorporation on flavonoid content of *sel-roti*. Columns with different alphabets are significantly different ($p < 0.05$).

The flavonoid content of *sel-roti* as affected by malted buckwheat flour incorporation was analysed and presented in Fig. 4.10. The mean values of flavonoid content in samples A, B, C, D, E, F, G, and H were 5.46, 8.64, 15.65, 16.99, 17.14, 17.98, 18.33, and 19.34 respectively. The statistical analysis showed that malted buckwheat flour incorporation had significant effect ($p < 0.05$) among the samples of different formulations. Rutin, well known as a potent antioxidant, present in buckwheat flour, but is not present in rice flour which contains ferulic and p-coumaric acids as the main polyphenols (Harukaze *et al.*, 1999). Due to higher total flavonoid content of buckwheat flour than of rice flour as it was determined by Sakac *et al* (2011), a significant increase in total flavonoid content of gluten-free rice and buckwheat *sel-roti* was found in comparison with the control sample A. Although, there are few reports with which to compare the results from the current study, in a study of a variety of foods enriched with buckwheat flour. The content of total flavonoids in flour was about 2-4 fold higher when compared to final product in all cases (Chlopicka *et al.*, 2012). The flavonoid content of unmalted common buckwheat flour was found to be 84 mg/100 g, and malted common buckwheat was found to be 91.2 mg/100 g . Here, the flavonoid content of unmalted common buckwheat was found to be similar to the result reported by Qin *et al.* (2010). The results indicated that germination is a good way for accumulation of bioactive flavonoids, such as quercetin.

Rutin retention is affected by the activity of the rutin degrading enzyme, flavonol 3-glucosidase as well as certain processing parameters (Kreft *et al.*, 2006). Rutin degrading enzyme has been found in common buckwheat grain, particularly in the testa (Suzuki *et al.*, 2002). Kreft *et al.* (2006) reported that hydrothermal treatment of buckwheat grain during the preparation of product reduced rutin content. The transformation of rutin to quercetin is expected due to the presence of rutin-degrading enzymes in the buckwheat grain, indeed it has been proven that the quercetin concentration increased and remained stable during processing (Merendino *et al.*, 2014). Therefore, from the nutritive point of view, the addition of buckwheat flour in rice flour resulted in an increased concentration of the important flavonoid, quercetin.

4.6 Comparison of nutritional quality between control Sample A (0%) and optimized Sample E (12.44%) sel-roti

The composition of the best product and the control *sel-roti* from chemical analysis was carried out. The result of the analysis is given in the Table 4.4.

Table 4.4 Nutritional composition of control (Sample A) and optimized (Sample E)

Particulars	Control (0%)	Sample E (12.44%)
Moisture %	$16.23^{a} \pm 0.19$	$10.86^{b} \pm 0.47$
Crude protein, (%, db)	$4.44^{a} \pm 0.24$	$6.53^{b} \pm 0.02$
Crude Fat (%, db)	$24.22^{a} \pm 0.31$	$28.28^{b} \pm 0.49$
Total Ash (%, db)	$0.32^{a} \pm 0.05$	$0.52^{b} \pm 0.04$
Iron (mg/100 g, Dry basis)	$1.44^{a} \pm 0.09$	$2.67^{b} \pm 0.31$

Values are the mean of triplicate analysis ± standard deviation of triplicate sample. Values for different superscript are significantly different ($p<0.05$).

The crude fat content of control A (0%) and best E (12.44%) *sel-roti* as affected by malted buckwheat flour incorporation was analyzed and presented in Table 4.4. The statistical analysis showed that buckwheat flour incorporation had significant effect (p< 0.05) between control and best sample.It could be observed from the table that crude fat content of malted buckwheat flour incorporated *sel-roti* was found to be increased with increasing level of buckwheat flour. This was probably due to the oil retention ability of buckwheat flour during baking process (Rufeng *et al.*, 1995). Higher oil retention improves the mouth feel and retains the flavor of the product.

The total ash in *sel-roti* was increased with the incorporation of malted buckwheat flour, and statistical analysis showed that there was a significant effect (p<0.05) between the control A (0%) and Best E (12.44%). The increase in ash content may be due to the high mineral content in the buckwheat flour in comparison to rice flour (Francischi *et al.*, 1994).

The protein content of control A (0%) and best E (12.44%) sel-roti as affected by malted buckwheat flour incorporation was analyzed and presented in the Table 4.4. Protein in *sel-roti* was increased with incorporation of malted buckwheat flour. The statistical analysis showed that there was a significant effect (p< 0.05) between the control A (0%) and best E (12.44%). Protein content is one of the most important qualities of any food. The crude protein content was increased to 6.53 % (db) in 12.44% malted buckwheat flour incorporated *selroti* from 4.44 % (db) in control. This increment could have contributed due to higher protein content of buckwheat flour compared to rice flour (Sakac *et al.*, 2011).

The iron content of control A (0%) and best sample E (12.44%) as affected by malted buckwheat flour incorporation was analyzed and the statistical analysis showed that there was a significant difference (p< 0.05) between the control (A) and Best sample (E).The addition of malted buckwheat flour to rice flour for *sel-roti* formulation contributed to the significant increase in their mineral content, especially magnesium, potassium, iron and copper due to their significantly higher amounts in buckwheat flour compared to rice flour. It is assumed that the consumption of gluten-free rice and buckwheat product with the improved mineral profile can contribute to the reduction of mineral deficiency in gluten-free diet.

4.7 Cost of the *sel-roti*

The cost of the developed buckwheat incorporated *sel-roti* was NRs. 18.21 per 100 g which was slightly expensive than the control *sel-roti* including overhead cost and profit of 10% (calculation is given in Appendix F).

Part V

Conclusions and recommendations

5.1 Conclusion

Despite some limitations, the research was completed and on the basis of research, following conclusions can be drawn:

1. The moisture content of *sel-roti* decreased with the increase in malted buckwheat proportion whereas fat-uptake and flavonoids content increases with the increase in buckwheat flour content.
2. Preparation of buckwheat incorporated *sel-roti* can be carried out successfully by replacement of rice flour with 12.44 % malted buckwheat flour.
3. The formulation with 12.44% buckwheat flour is found typically highest in sensory attributes and 12.44% buckwheat flour incorporated *sel-roti* (Sample E) is superior in crude fat, crude protein, total ash as compared to the control *sel-roti*.
4. The buckwheat flour incorporated *sel-roti* enhanced the nutrients content and is expensive against *sel-roti* sample made up of rice flour only.

5.2 Recommendations

The following recommendations for further research work can be drawn.

1. 12.44% buckwheat flour can be successfully incorporated to obtain best *sel-roti* without compensating sensory quality and nutritional quality.
2. Further analysis on antioxidant properties, shelf life and amino acid profile of buckwheat *sel-roti* can be done.

Part VI

Summary

The proposed study was carried out on the supplementation of rice flour with different proportion of malted buckwheat flour to produce high protein, nutritious and acceptable *sel-roti* to people as important indigenous foods of Nepal. The study was also aimed to determine the effect and food value of *sel- roti* after malted buckwheat flour incorporation. D- optimal design was used for the formulation of recipe and for this, Design Expert v7.1.5 software was used.

Eight types of *sel-roti* batter were prepared by replacing rice (100 g) with 0%, 2.5%, 5%, 10%,12.44%, 15%, 17.48%, and 20% malted buckwheat flour. For the preparation of *sel-roti*, 30% coarse flour, 50% medium flour and 20% fine flour were mixed and taken. The malted buckwheat flour was used to replace the proportion of the fine rice flour. Ghee (10.5 g), sugar (21 g) and water (25±0.96 ml) were added to the flour. The prepared batter was left for 1 h for ageing then the batter was poured in ring shape on hot refined soybean oil at 210ºC in tai for deep fat fry until roti become reddish brown (about 33±3s). Standard procedure were used to determine the chemical and nutritional composition of *sel-roti*. ANOVA was used to determine any significant difference in the analytical data for formulated *sel-roti.*

Organoleptic evaluation of the products indicated that the 12.44% malted buckwheat flour incorporated *sel-roti* samples mean value were highest in sensory parameters like flavor, texture, taste and overall acceptance. As the malted buckwheat flour incorporation was increased, the ratio of ring diameter to cross section diameter was also affected. The ratio of ring diameter to cross section diameter was highest (3.80±0.40) in 12.44% malted buckwheat flour incorporated *sel-roti*. As the malted buckwheat flour increased from 0 to 20%, moisture was decreased from 16.23% to 7.52% while the percent fat-uptake was increased from 24.15to 57.48% (in dry and fat free basis) as well as flavonoid content also increased. As the malted buckwheat flour increased from 0 to 12.44%, crude protein was significantly increased from 4.44 to 8.73 (% db), total ash was also increased from 0.32 to 0.52 (% db) and crude fat also increased from 24.21 to 28.28 (% db). Similarly, the iron content increases from 1.44 to 2.67 (mg/100 g, db). Based on the sensory and physico-

chemical analysis, 12.44% malted buckwheat flour could be successfully incorporated to obtain more nutritional quality of *sel-roti* also with increase in organoleptic quality**.**

References

Abdelrahaman, S. M., Elmaki, H. B., Idris, W. H., Hassan, A. B., Babiker, E. E. and Eltinay, A. H. (2007). Antinutritional factor content and hydrochloric acid extractability of minerals in pearl millet cultivars as affected by germination. *Int. J. Food Sci. Nutri*. **58** (1), 6-17.

Ahmed, A., Khalid, N., Ahmad, A., Abbasi, N. A., Latif, M. S. Z. and Randhawa, M. A. (2013). Phytochemicals and biofunctional properties of buckwheat:a Rev. *J. Agric. Sci*. 1-21.

Aliyas, I. M., Kassim, G. Y. and Mutlak, N. N. (2015). Evaluation some germination characteristics for buckwheat seeds under experimental ecology conditions. *Int. J. Sci. Res. Pub. 5*. **1**, 634-638.

Alvarez-Jubete, L., Wijngaard, H., Arendt, E. K. and Gallagher, E. (2010). Polyphenol composition and in vitro antioxidant activity of amaranth, quinoa buckwheat and wheat as affected by sprouting and baking. *Food Chem.* **119**, 770-778.

Amorim, E. L. C., Nascimento, J. E., Monteiro, J. M. and Peixoto Sobrinho, T. J. S. (2008). A simple and accurate procedure for the determination of tannin and flavonoid levels and some applications in ethnobotany and ethnopharmacology. *Funct. Ecosyst. Communities.* **2** (1), 88-94.

AOAC. (2005). "Official Methods of Analysis" (18th ed.). Washington D C. Association of Official Analytical Chemists.

Aoki, M. and Koizumi, N. (1986). Organoleptic properties of the volatile components of buckwheat flour and their changes during storage after milling. *Nippon Shokuhin Kogyo Gakkaishi.*, 769-772.

Baljeet, S. Y., Ritika, B. Y. and Roshan, L. Y. (2010). Studies on functional properties and incorporation of buckwheat flour for biscuit making. *Int. Food Res. J.* **17**, 1067-1076.

Banusha, S. and Vasantharuba, S. (2013). Effect of malting on nutritional contents of fingermillet and mungbean. *Am. Eurasian J. Agric. Environ. Sci.* **13** (12), 1642-1646.

Belitz, H. D., Grosch, W. and Schicberle, P. (2009). "Food Chemistry" (4th revised and extended ed. ed.). Springer. Verlag Berlin Heidalberg.

Bhattarai, K. (2009). Effect of accelerated aging on physico- chemical properties of mansuli rice. B. Tech Dissertation. Tribhuvan Univ., Nepal.

Bilgicli, N. (2009). Effect of buckwheat flour on cooking quality and some chemical, antinutritional and sensory properties of erişte,Turkish noodle. *Int. J. Food Sci. Nutri.* **60** (4), 70-80.

Bojnanska, T., Chlebo, P., Gazar, R. and Horna, A. (2009). Buckwheat-enriched bread production and its nutritional benefits . *European J. Plant Sci. Biotech*.

Bonafacia, G. and Fabjan, N. (2003). Nutritional comparison of tartary buckwheat with common buckwheat and minor cereals. *Reports Biotechnological Faculty of the University of Ljubljana.* **81**, 349-355.

Brajdes, C. and Vizireanu, C. (2012). Sprouted buckwheat an important vegetable source of antioxidants. *Food Technol.36*. **1**, 53-60.

Bravi, E., Marconi, O., Perretti, G. and Fantozzi, P. (2012). Influence of barley variety and malting process on lipid content of malt. *Food Chem. 135*. **(3)**, 1112-1117.

Buffo, R. A., Weller, C. L. and Parkhurst, A. M. (1998). Relationships among grain sorghum quality factors. *Cereal Chem.* **75** (1), 100-110.

Byoung, J. P., Jong, I. P., Kwang, J. C. and Cheol, H. P. (2004). Characteristics of Genetic Resources in Tartary Buckwheat (Fagopyrum tataricwri). *Proceedings of the 9th International Symposium on Buckwheat*, Prague. 342-345.

Cai, Y. Z., Corke, H. and Li, W. D. (2004). Buckwheat. "Encyclopedia of Grain Science" (Colin Walter). Elsevier Ltd.

Carciochi, R. A., Manrique, G. D. and Dimitrov, K. (2014). Changes in phenolic composition and antioxidant activity during germination of quinoa seeds (*Chenopodium quinoa* wild). *Int. Food Res. J. 21*. **(2)**, 767-773.

Chauhan, A. and Singh, S. (2013). Influence of germination on physicochemical properties of amaranth (*Amaranthus* spp.) flour. *Int. J. Agric. Food Sci. Technol. 4*. **(3)**, 215-220.

Chen, L. and Zeng, X. D. (2007). Iron deficiency anemia-related factors and interventions. *Chinese J of Current Traditional and Western Medic*. **5**, 423-424.

Chlopicka, J., Paskoa, P., Gorinstein, S., Jedryasa, A. and Zagrodzkia, P. (2012). Total phenolic and total flavonoid content, antioxidant activity and sensory evaluation of pseudocereal breads.. *LWT - Food Sci. Technol.* **46**, 548-555.

Chowdhury, R. and Rahman, M. (2017). Evaluation of buckwheat (*Fagopyrum esculentum*) intrinsic phytase activity to improve phosphorus availability in broilers. *J. Adv. Agric. Technol. 4*. **(1)**, 82-86.

Choy, A. L., Morrison, P. D., Hughes, J. G., Marriott, P. J. and Small, D. M. (2013). Quality and antioxidant properties of instant noodles enhanced with common buckwheat flour. *J. Cereal Sci.* **57**, 281-287.

Clementson, C. L., Ileleji, K. E. and Rosentrater, K. A. (2010). Evaluation of measurement procedures used to determine the bulk density of distillers dried grains with solubles (ddgs). *Am. Soc. Agri. Bio. Eng.* **53** (2), 485-490.

Colmenares, A. S., Ruiz, D. and Bressani, R. (1990). Effect of germination on the chemical composition and nutritive Value of amaranth grain. *Cereal Chem. 67*. **(6)**, 519-522.

Dahal, S. (2012). Effect of batter ageing on physicochemical, microbial changes and sensory quality *sel -roti*. M.Tech Dissertation. Tribhuvan Univ., Nepal.

Devrajan, N., Prakash, P. and Jindal, N. (2017a). Some physico-chemical properties of germinated and ungerminated buck wheat (*Fagopyrum esculentum*) Int. *J. Sci. Environ. Technol.* **6** (2), 1491-1501.

Devrajan, N., Prakash, P. and Jindal, N. (2017b). Some physico-chemical properties of germinated and ungerminated buckwheat(*Fagopyrum esculentum*). *Int.J.Sci. Environ. Technol.* **6** (2), 1491-1501.

Dogra, D. and Awasthi, C. P. (2015). Comparative nutritional evaluation of common buckwheat genotypes with major cereal and pseudocereals crops. *Agric. Sci. Digest.* **35** (1), 36-40.

Duarte, R. P., Mock, C. M. and Satterlee, L. D. (1996). Quality of spaghetti containing buckwheat, amaranth, and lupin flours. *Cereal Chem*. **73** (3), 381-387.

Edwardson, S. E. (1995). Using growing degree days to estimate optimum windrowing time in buckwheat. Shinshu University, Nagano, Japan. [Cited in E. T. Matano and A. Ujihara. (24-29 August 1995). 6th International Symposium on Buckwheat in Shinshu. 509-514].

Fabjan, N., Rode, J., Kosir, I. J., Zhang, Z. and Kreft, I. (2003). Tartary buckwheat (Fagopyrum tartaricum Gaertn.) as a source of dietary rutin and quercetin. *J of Agric Food Chem*. **51**, 6452-6455.

FAO.(2017)."FAOSTAT". Retrieved from http://www.fao.org/faostat/en/#data/QC. [Accessed 11 March, 2019].

Francischi, D., Salgado, J. M. and Leitao, R. F. E. (1994). Chemical, nutritional and technological characteristics of buckwheat and non-prolamine buckwheat flours in comparison of wheat flour. *Plants Foods for Human Nutrition*. **46**, 323-329.

Gang, Z., Yu, T., Rong, M. and Zhu, H. (2001). Nutritonal and medicinal values of tartary buckwheat and its development and application. *The Proc.* **8th ISB**, 503-506.

Ghose, R. L. M., Ghatge, M. B. and Subrahmanyan, V. (1956). Rice in India. Indian council Agr Res. *In:* "The Chemistry and Technology of Cereals as Food and Feed" (2nd ed.). (S. A. Martz, Ed.). p. 215. New Delhi, India. CBS Publishers and Distributors.

Gimenez-Bastida, J. A. and Zielinski, H. (2015). Buckwheat as a functional food and its effects on health. *J. Agric. Food Chem.* **63**, 7896-7913.

Goit, B. (2008). Shelf life extension of Sel-roti by modified atmosphere packaging. M. Tech Dissertation. Tribhuvan Univ, Nepal.

Grist, D. H. (1975). Chemical composition of rice flour. *In:*"Rice". (D. R. Heldman, Eds.) (Vol. 1).pp. 440,450. London. Longman Group Limited.

Harukaze, A., Murata, M. and Homma, S. (1999). Analyses of free and bound phenolics in rice. *Food Sci Technol Res.* **5**, 74-79.

Held, J. L. and Joslyn, M. A. (1963). "Food Processing Operations."AVI Publishing Company. West port, Connecticut.

Horbowicz, M. and Obendorf, R. L. (1992). Changes in sterols and fatty acids of buckwheat endosperm and embryo during seed development. *J. Agr. Food Chem.* **40**, 745-750.

Hubner, F. and Arendt, E. K. (2013). Germination of cereal grains as a way to improve the nutritional value: A review. *Crit. Rev. Food Sci. Nutri. 53*. **(8)**, 853-861.

Jan, U., Gani, A., Ahmad, M., Shah, U., Baba, W. N., Masoodi, F. A., Maqsood, S., Gani, A., Wani, I. A. and Wani, S. M. (2015). Characterization of cookies made from wheat flour blended with buckwheat flour and effect on antioxidant properties. *J. Food Sci. Technol.* **52** (10), 6334-6344.

Joshi, B. K. (2008). "Buckwheat Genetic Resources: Status and Prospects in Nepal,".*Agr. Develop. J.*. **5**, 13-30.

Juliano, B. O., Bautista, G. M., Lugay, J. C. and Reyes, A. C. (1964). Studies on the physiochemical properties of rice. *J. Agri. Food Chem.* **12**, 131-138. [Cited in Juliano. (1985).

Kaliniewicz, Z., Markowski, P., Anders, A. and Jadwisienczak, K. (2015). Frictional properties of selected seeds. *Technical Sci.* **18** (2), 85-101.

Katawal, S. B. (2062). Introduction to *sel-roti*. *Blast Times Daily, Dharan, Nepal*.

Katawal, S. B. and Subba, D. (2008). A survey study of technology of s*el-roti*, a traditional food of Nepal. *J. Food Sci. Technol Nepal*. **4**, 23-30.

Katawal, S. B. and Subba, D. (2013). "Technology of *Sel-roti*; Recipe, Processing and Quality". LAP LAMBERT Academic Publishing. Germany. [ISBN: 978-3-659-39945-9].

Kent, N. L. (1982). "Technology of Cereals" (3rd edition ed.). Perquimans Press. New York.

Khan, F., Arif, M., Khan, T. U., Khan, M. I. and Bangash, J. A. (2013). Nutritional evaluation of common buckwheat of four different villages of *Gilgit-Baltstan*, ARPN. *J. Agric. Biol. Sci.* **8** (3), 264-266.

Kharel, G. P., Acharya, P. P. and Rai, B. K. (2007). "Handbook of Traditional Foods of Nepal". *J. Food Sci. Technol Nepal*. Dharan, Nepal.

Khoddami, A., Mohammadrezaei, M. and Roberts, T. H. (2017a). Effects of sorghum malting on colour, major classes of phenolics and individual anthocyanins. *Mol. 22*. **10**, 1-17.

Kidd, F. (2001). Sugar and its properties. [Press release]. Retrieved from http://www.foodtech.org.uk/fscience/databank.html. [Accessed 20 April,2014].

Kreft, I., Fabjan, N. and Yasumoto, K. (2006). Rutin content in buckwheat (*Fagopyrum esculentum* Moench) food materials and products. *Food Chem*. **98**, 508-512.

Kreft, I., Skrabanja, V., Ikeda, S. and Bonafaccia, G. (1996). Dietary value of buckwheat.. *Research Reports Biotechnological Faculty of the University of Ljubljana*. **67**,73-78.

Kumari, S., Krishnan, V., Jolly, M. and Sachdev, A. (2014). In vivo bioavailability of essential minerals and phytase activity during soaking and germination in soybean (Glycine max). *Australian J. Crop Sci. 8*. **(8)**, 1168-1174.

Lawless, H. T. and Heymann, H. (2010). Sensory evaluation of food, principles and practices. Presented at "Aggregation of Sensory Data Using Fuzzy Logic for Sensory Quality Evaluation of Food".

Lawson, H. (1997). "Baking Technology (including icings for baked goods), Food Oils and Fats (Technology, utilization and Nutrition)" (First Indian ed). CBS Publishers and Distributors. New Delhi, India.

Li, Q. and Xu, J. G. (2015). Changes in nutritive value and in vitro digestibility of proteins from naked oats during germination. *Eur. J. Food Sci. Technol.* **(1)**, 49-57.

Li, S. Q. and Zhang, Q. H. (2001). Advances in the development of functional foods from buckwheat. *Crit. Rev. Food Sci.Nutr*. **41**, 451-464.

Li, Y. (2005). Quality Changes in Chicken Nuggets Fried in Oils with Different Degree of Hydrogenation. Unpublished Ph.D. Thesis. McGill University., Canada.

Little, R. R. and Hilder, G. B. (1960). Differential Response of Rice Starch Granules to Heating in Water. *Cereal Chem.* **37**, 456.

Luitel, D. R., Siwakoti, M., Jha, P. K., Jha, A. K. and Krakauer, N. (2017). An overview: Distribution, production, and diversity of local landraces of buckwheat in nepal. *Adv.Agric.*, 1-6.

Luo, Y. W., Xie, W. H., Jin, X. X., Wang, Q. and He, Y. J. (2013). Effects of germination on iron, zinc, calcium, manganese, and copper availability from cereals and legumes. . *Cyta. J. Food. 12*. **(1)**, 22-26.

Luthar, Z. (1992). Polyphenol classification and tannin content of buckwheat seeds (*Fagopyrum esculentum* Moench). **12**, 36-42.

Mainali, K. P. (2003). "Annual Report 2000/2001". Department of Food Technology and Quality Control, HMG Nepal.

Manley, D. J. R. (2000). "Technology of Biscuits, Crackers and Cookies.". Woodhead Publishing Ltd. Cambridge, England.

Manukumar, H. M., Prathima, V. R., Guru, C. and Kurinji, V. (2014). Impact of germination time on protein solubility, digestibility and in-vitro antioxidant, anti-inflammatory activity of sorghum grains . *Int. J. Pharmtech. Res 6*. **(1)**, 117-128.

Matz, S. A. (1996). Rice. *In:* "The Chemistry and Technology of Cereals as Food and Feed" (2nd ed.). (Dariya Gunj, Ed.). pp. 255-256. New Delhi, India. CBS Publishers and Distributors.

Mehta, U. and Swinburn, B. (2001). A review of factors affecting fat absorption in hot chips. *Food Sci. Nutri.* **41**, 133-154.

Mella, O. N. O. (2011). Effect of malting and fermentation on the composition and functionality of sorghum flour. M.Tech Dissertation. Univ. of Nebraska-Lincoln, United States.

Mellema, M. (2003). Mechanism and reduction of fat uptake in deep- fat fried foods. *Trends Food Sci. Technol.* **14**, 364-373.

Merendino, N., Molinari, R., Costantini, L., Mazzucato, A., Pucci, A., Bonafaccia, F. and Esti, M. (2014). A new “functional” pasta containing tartary buckwheat sprouts as an ingredient improves the oxidative status and normalizes some blood pressure parameters in spontaneously hypertensive rats. . *Food & Function*. **5**, 1017-1026.

Moreira, R. G., Palau, J. E. and Sun, X. (1995). Deep-fat frying of tortilla chips- an engineering approach. *Food Technol.* . **49**, 146-150.

Mustafa, A. I., Alwessali, M. S., Busha, S. I., Mand, O. and Al-Amia, R. H. (1986). Utilization of cowpea flour and protein isolate in bakery products. *Cereal Food World*. **31**, 756-759.

Narish, Yunianta and Harijono. (2012). The study of germination and soaking time to improve nutritional quality of sorghum seed. *Int. Food Res. J. 19*. **(4)**, 1429-1432.

Nationmaster.com.(2005).*Encyclopedia:Rice*.Retrievedfromwww.nationmaster.com/encyclopedia/rice. [Accessed 19 April,2014].

Nic Phiarais, B. P., Wijngaard, H. H. and Arendt, E. K. (2005). The impact of kilning on enzymatic activity of buckwheat malt . *J. Inst. Brew.* **3** (111), 290-298.

Ogbonna, A. C., Abuajah, C. I., Ide, E. O. and Udofia, U. S. (2012). Effect of malting conditions on the nutritional and anti-nutritional factors of sorghum grist. *Food Technol. 36*. **(2)**, 64-72.

Ohnishi, O. (2010). " Diversity of new Fagopyrum species and its implication for the studies of evolution of Fagopyrum and of the origin of cultivated buckwheat". *The Eur. J. of Plant Sci. Biotechnol*. [Cited in Gondola and Papp. (1995). "Origin, geographical distribution and phylogenic relationships of common buckwheat (*Fagopyrum esculentum* Moench).". Global Science Book.

Peryam, D. R. and Girardot, N. F. (1952). Advanced taste-test method. *Food Eng.* **(24)** (194), 58-61.

Pillaiyar, P. (1988). "Quality of Rice, Rice Post Production Manual". Wiley Eastern Ltd. New Delhi, India.

Pinthus, E. J., Weinberg, P. and Saguy, I. S. (1993). Criterion for oil uptake during deep-fat frying. *J. Food Sci.* **58**, 204.

Poudel, P. K. (2012). Study on brewing quality of Nepalese buckwheat varieties. M. tech Dissertation. Tribhuvan Univ., Nepal.

Pray, L. and Pillsbury, L. (2010). Leveraging Food Technology. [Abstract]. The National Academic Press. Retrieved from http://books.google.com.np/books? id= V8kScZNN5IC&printsec=frontcover#v=onepage&q&f=false. [Accessed 29 April, 2014].

Priestley, R. J. (1997). "Effect of Heating on Food Stuffs ". Applied Science Publishers Ltd. London.

Pulami, B. P. (2014). Study on the physico-chemical and sensory quality of soy-fortified *sel-roti*. M. Tech. dissertation. Tribhuvan Univ. Nepal.

Qin, P., Wang, Q., Shan, F., Hou, Z. and Ren, G. (2010). Nutritional composition and flavonoids content of flour from different buckwheat cultivars. Int. *J. Food Sci. Technol.* **45**, 951-958.

Rai, S. (2013). Assessment of biochemical changes of some underutilized cereal crops (*Hordeum vulgare*, *Fagopyrum esculentum* and *Fagopyrum tartaricum*) during germination. B. Tech Dissertation. Tribhuvan Univ. Nepal.

Regmi, P. (2008). Preparation of starter culture using pure culture isolates (yeast and mold) . B. Tech Dissertation. Tribhuvan Univ. Nepal.

Rufeng, N., Enqi, L., Chuangji, C. and Jiangping, Z. (1995). A study of the production of healthy biscuit made with tartary buckwheat grown in North China. *Curr. Adv. in Buckwheat Res*. 861-865.

Sakac, M., Torbica, A., Sedej, I. and Hadnadev, M. (2011). Influence of bread making on antioxidant capacity of gluten free breads based on rice and buckwheat flour. *Food Res Int.* **44**, 2806-2813.

Samatha, T., Shyamsunddarachary, R., Srinivas, P. and Swamy, N. R. (2012). Quantification of total phenolic and total flavonoid content in extracts of *Oroxylum Indicum* L. Kurz. *Asian J. Pharm. Clin. Res.* **5** (4), 177-179.

Santos, J. K. (1933). Morphology of the flour and mature grain of Philippine grain. *Philipp. J. Food Sci.* **52**, 475.

Schober, T. J., Brien, C. M., McCarthy, D., Barnedde, A. and Arendt, E. K. (2003). Influence of gluten free flour mixes and fat powders in the quality of gluten free biscuits. *Euro Food Res Tech.* **5**, 369-376.

Shrestha, R. (1995). To study and compare the finger millet (kodo) malt with barley malt (European variety and local variety) on the brewing aspects. B.Tech Dissertation. Tribhuvan Univ., Nepal.

Sindhu, R. and Khatkar, B. S. (2016). Composition and functional properties of common buckwheat (*Fagopyrum esculentum* moench) flour and starch. *Int. J. Innov. Res. Adv. Studies.* **3** (7), 154-159.

Singh, A. K., Rehal, J., Kaur, A. and Jyot, G. (2015). Enhancement of attributes of cereals by germination and fermentation: A review. *Crit. Rev. Food Sci. Nutri.* **55** (11), 1575-1589.

Spicer, A. (1975). "Bread, Social, Nutritional and Agricultural Aspects of Wheat Bread". Applied Science Publishers Ltd. London, UK.

Springer-Verlag. (1999). Foam. *In:* "Food Chemistry". (Paul Finglas). pp. 210-211, New York. Berlin, Heidelberg.

Steadman, K. J., Burgoon, M. S., Lewis, B. A. and Edwardson, S. E. (2001). Minerals, phytic acid, tannin and rutin in buckwheat seed milling fractions. *J. Sci. Food Agric.* **81**, 1094-1100.

Stone, H. and Sadel, J. L. (2004). "Sensory Evaluation Practices" (3rd ed.). Elsevier Academic Press. London, UK.

Subba, D. and Katawal, S. B. (2011). Effect of particle size of rice flour on physical and sensory properties of *sel-roti*. *J. Food Sci. Technol.* **51** (1) , 182-184.

Subba, D. and Katawal, S. B. (2013). Effect of particle size of rice flour on physical and sensory properties of *sel-roti*. *J. Food Sci. Technol.* **50** (1), 181-185.

Subedi, N. (2018). Changes in phytochemical properties of buckwheat varieties on malting. B. Tech Dissertation. Tribhuvan Univ., Nepal.

Suman, A. B. (2012). Optimization of Formulation and Process for the preparation of Khajuri (A Maithili Indigenous Food). M. Tech Dissertation. Tribhuvan Univ., Nepal.

Suzuki, T., Yutaka, H., Funatsuki, W. and Nakatsuka, K. (2002). Purification and characterization of flavonol 3-glucosidase, and its activity during ripening in tartary buckwheat seeds. *Plant Sci*. **163**, 417-423.

Sweetman, S. (2005). Martindale: the complete drug reference.[Press release]. Pharmaceutical Press, London.

Taira, H. (1974). Encyclopedia of Food Technology. Buckwheat Introduction. Westport.

Totani, N., Ohno, C. and Yamaguchi, A. (2006). Is the frying oil in deep-fried food safe? *J. Oleo Sci 55.* **(9)**, 449-456.

Ufheil, G. and Escher, F. (1996). Dynamics of oil uptake during Deep-fat frying of potato slices. *Lwt-Food Sci. and Technol. 29*. **(7)**, 640-644.

Unal, H., Izli, N., Izli, G. and Asik, B. B. (2017). Comparison of some physical and chemical characteristics of buckwheat (*Fagopyrum esculentum* Moench) grains .*CyTA- J. Food*. **15** (2), 257-265.

Upadhyay, A. and Karn, K. S. (2018). Brown Rice: Nutritional composition and health benefits. *J. Food Sci. Technol.* **10**, 48-54.

Urbano, G., Aranda, P., Vilchez, A., Aranda, C., Cabrera, L., Porres, J. M. and Pez-Jurado, M. L. (2005). Effects of germination on the composition and nutritive value of proteins in pisum sativum. *Food Chem. 93*. **(4)**, 671-679.

Valenzuela, H. (2002). "Green Manure Crops for Sustainable Agriculture. " (2nd ed.). Australian Publishers.

Vojtíšková, P., Kmentová, K., Kubáň, V. and Kráčmar, S. (2015). Chemical composition of buckwheat plant (*Fagopyrum esculentum*) and selected buckwheat products. *J. Microbiol. Biotechnol. Food Sci.* **1**, 1011-1019.

Watanabe, M. (1998). Catechins as antioxidants from buckwheat (*Fagopyrum esculentum* Moench) groats. *J.of Agri. Food Chem*. **46**, 839-845.

Wijngaard, H. H. and Arendt, E. K. (2006). Buckwheat. *Cereal Chem.* **83** (4), 391-401.

Xiao, Z. P. (2003). Prospect of development and exploitation of buckwheat resources. *Modern Agric.* **8**, 35.

Yonzan, H. and Tamang, J. P. (2009). Traditional processing of *sel-roti*- a cereal based ethnic fermented food of the Nepalis. *Indian J. Trad Know.* **8** (1), 110-114.

Yonzan, H. and Tamang, J. P. (2010). Indigenous knowledge of traditional processing of Selroti, a cereal-based ethnic fermented food of the Nepalis *Indian J. Trad Know.* **9**, 271-274.

Zhang, G., Xu, Z., Gao, Y., Huang, X., Zou, Y. and Yang, T. (2015). Effects of germination on the nutritional properties, phenolic profiles, and antioxidant activities of buckwheat. *J. Food Sci.* **80** (5), 1111-1119.

Zhang, Z. L., Zhou, M. L., Tang, Y. and Li FL, e. a. (2012). Bioactive compounds in functional buckwheat food. *Food Res. Int.* **49**, 389-395.

Appendices

Appendix A

Sensory evaluation score sheet for *sel-roti*

Date:

Hedonic rating test

Name of the panelist: ………………………………….

Name of the product*: Sel-roti*

Please test the following samples of *sel-roti* and check how much you prefer for each of the samples. Give the points for your degree of preferences for each parameter for each sample as shown below:

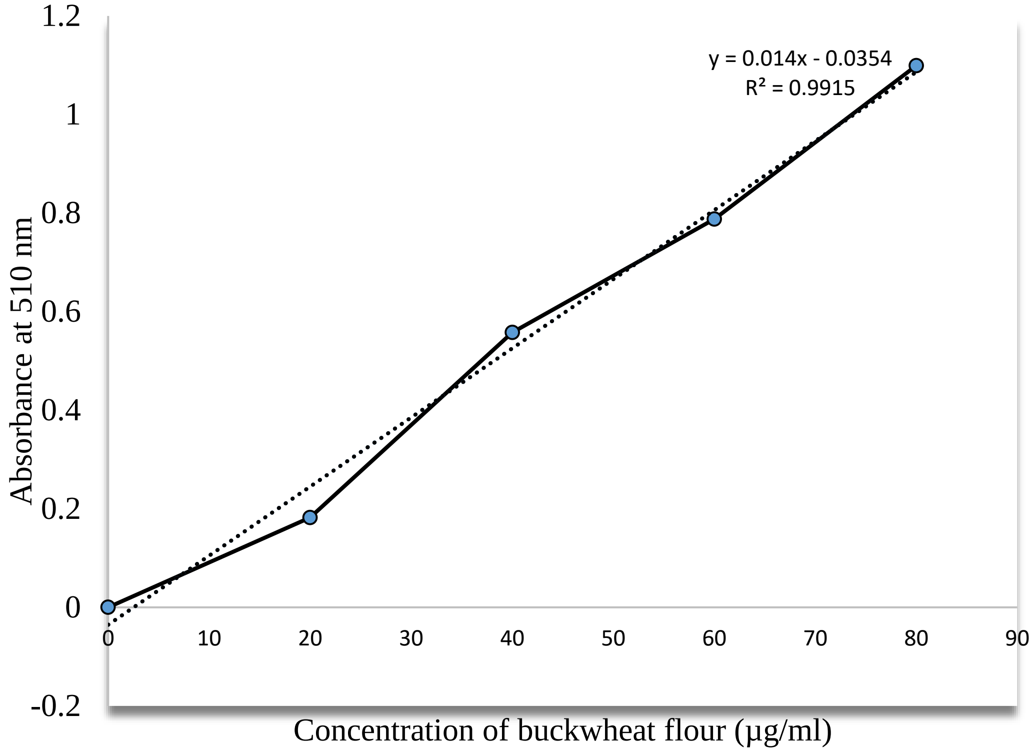
Judge the above characteristics on the 1-9 scale as below:

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

Attributes	A	B	C	D	E	F	G
Crumb							
Color							
Taste							
Texture							
Flavour							
Overall acceptability							

Appendix B

1. Standard curve for flavonoids



Appendix C

ANOVA for sensory analysis of samples

Table C.1 General ANOVA (No blocking) For Appearance

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Formulation	7	144.1071	20.5867	45.81	<.001
Panelist	13	8.1071	0.6236	1.39	0.181
Residual	91	40.8929	0.4494		
Total	111	193.1071			

Table C.2 General ANOVA (No blocking) For Color

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Formulation	7	144.1071	20.586	45.81	<.001
Panelist	13	8.1071	0.6236	1.39	0.181
Residual	91	40.8929	0.4494		
Total	111	193.1071			

Table C.3 General ANOVA (No blocking) For Flavor

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Formulation	7	88.5357	12.6480	24.38	<.001
Panelist	13	10.2143	0.7857	1.51	0.127
Residual	91	47.2143	0.5188		
Total	111	145.9643			

Table C.4 General ANOVA (No blocking) For Taste

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Formulation	7	130.4196	18.6314	46.83	<.001
Panelist	13	8.1518	0.6271	1.58	0.107
Residual	91	36.2054	0.3979		
Total	111	174.7768			

Table C.5 General ANOVA (No blocking) For Texture

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Formulation	7	125.1339	17.8763	43.68	<.001
Panelist	13	6.5446	0.5034	1.23	0.271
Residual	91	37.2411	0.4092		
Total	111	168.9196			

Table C.6 General ANOVA (No blocking) For Overall acceptance

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Formulation	7	46.2857	6.6122	13.23	<.001
Panelist	13	14.2500	1.0962	2.19	0.016
Residual	91	45.4643	0.4996		
Total	111	106.0000			

Appendix D

Table D.1 Paired t test for two sample of means of crude protein content of control and best *sel-roti*

	Variable 1	*Variable 2*
Mean	4.4433333	6.533333
Variance	0.0840333	0.074133
Observations	3	3
Pearson Correlation	-0.99922	
Hypothesized Mean Difference	0	
Df	2	
t Stat	-16.30202	
P(T<=t) one-tail	0.0018709	
t Critical one-tail	2.9199856	
P(T<=t) two-tail	0.0037417	
t Critical two-tail	4.3026527	

Table D.2 Paired t test for two sample of means of crude fat content of control and best *sel-roti*

	Variable 1	*Variable 2*
Mean	24.21667	28.28
Variance	0.143233	0.3733
Observations	3	3
Pearson Correlation	-0.85736	
Hypothesized Mean Difference	0	
Df	2	
t Stat	-7.36546	
P(T<=t) one-tail	0.008969	
t Critical one-tail	2.919986	
P(T<=t) two-tail	0.017939	
t Critical two-tail	4.302653	

Table D.3 Paired t test for two sample of means of crude ash content of control and best *sel-roti*

	Variable 1	*Variable 2*
Mean	0.32	0.523333
Variance	0.0043	0.002633
Observations	3	3
Pearson Correlation	0.772656	
Hypothesized Mean Difference	0	
Df	2	
t Stat	-8.45918	
P(T<=t) one-tail	0.006844	
t Critical one-tail	2.919986	
P(T<=t) two-tail	0.013688	
t Critical two-tail	4.302653	

Table D.4 Paired t test for two sample of means of moisture content of control and best *sel-roti*

	Variable 1	*Variable 2*
Mean	16.22666667	10.8633333
Variance	0.055633333	0.33443333
Observations	3	3
Pearson Correlation	-0.967602034	
Hypothesized Mean Difference	0	
Df	2	
t Stat	11.4867052	
P(T<=t) one-tail	0.003746932	
t Critical one-tail	2.91998558	
P(T<=t) two-tail	0.007493864	
t Critical two-tail	4.30265273	

Table D.5 Paired t test for two sample of means of final iron content of control and best *sel-roti*

	Variable 1	*Variable 2*
Mean	1.443333	2.673333
Variance	0.013733	0.0903
Observations	3	3
Pearson Correlation	-0.7429	
Hypothesized Mean Difference	0	
Df	2	
t Stat	-4.42591	
P(T<=t) one-tail	0.023723	
t Critical one-tail	2.919986	
P(T<=t) two-tail	0.047446	
t Critical two-tail	4.302653	

Appendix E

Table E.1 Effect of malted buckwheat flour addition on physicochemical properties of *sel-roti*

Parameters	A	B	C	D	E	F	G	H
Moisture	16.23^{e} ±0.19	15.38^{e} ±0.73	13.38^{d} ±0.88	11.46^{c}± 0.04	10.63^{c}± 0.01	9.26^{b}± 0.02	8.29^{a}± 0.11	7.52^{a}± 0.05
Fat-uptake	24.15^{a} ±0.83	26.4^{b}± 0.80	28.43^{c} ± 0.78	37.87^{d}± 0.77	43.81^{e}± 0.80	52.72^{f} ± 0.80	53.28^{f}± 0.81	57.48^{g} ± 0.95
D/d	3.62^{e}± 0.008	3.45^{b}± 0.008	3.33^{a}± 0.008	3.65^{f}± 0.008	3.70^{g}± 0.008	3.63^{e}± 0.008	3.6^{d}± 0.008	3.55^{c}± 0.008
Flavonoids content	5.46^{a}± 0.90	8.64^{b}± 0.74	15.65^{c} ± 0.51	16.99^{cd} ± 0.07	17.14^{cd} ± 0.11	17.98^{de}± 0.45	18.33^{de} ± 0.95	19.34^{e} ± 1.29

Values are arithmetic mean of the triplicate samples ± standard deviation. Figures in the row bearing the same superscript are not significantly different ($p>0.05$)

Appendix F

Cost Calculation of Buckwheat incorporated *sel-roti*

Particulars	Cost (NRs/ kg)	Wt in lot (g)	Cost (NRs)
Rice flour	40	87.56	3.5024
Buckwheat flour	75	12.44	0.933
Ghee	600	10.5	6.3
Frying oil	180	250	45
Sugar	80	21	1.68
Raw material cost			57.4154
Processing and labour cost (Overhead cost)			5.74154
Profit (10%)			6.315694
Grand total cost			69.472634
Total weight of buckwheat *Sel-roti*		381.5	
Total cost of buckwheat incorporated *sel-roti* (NRs/ 100 gm)			18.21

Color Plates

P1 Germination of common buckwheat in open environment

P2 Sel-roti preparation in Tai

P3 Sensory evaluation

P4 Measuring absorbance of sel-roti sample