Addis Ababa University
School of Graduate Studies
Institute of Technology
Department of Chemical Engineering

Influence of Baking Time and Temperature on the Quality of Kocho Biscuit Enriched with Faba Bean and Wheat

BY

KALEKRISTOS YOHANNES

kaleyohan@gmail.com

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Advisor

Dr. Eng. Shimelis Admassu

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Approved by the examining board

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Chair man, Department's Graduate Committee

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Advisor

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Internal Examiner

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Abstract

The production of nutritious biscuit from Kocho of low protein and high carbohydrate, mineral and crude fiber; fortified with faba bean of high protein and moderate fat content; and wheat of good glutenin and gliadin; were the bases for enriched biscuit production. The proximate analysis of enriched Kocho biscuit was done using the AOAC, 2003 analytical procedure. The enriched Kocho biscuit showed an upgrade in protein content from 0.96 of whole Kocho biscuit processed at 170^0C for 10min to 9.7% of KFW_B2 at 170^0C for 10min. This also implies that the consumption of 2 pack of 250g each (one pack contain 21 biscuit of each weighing 12g) of enriched Kocho biscuit of blend KFW_B2 processed at 170^0C for 10min accommodates the daily protein requirement of 39g/day and 50g/day for the age of 1-3 and 4-10; respectively. The mineral content of enriched Kocho biscuit is improved by the presence of Kocho and faba bean. The time and temperature effect of baking the enriched biscuit shows a major change in protein content due to an increase in the faba bean concentration. With increasing temperature and time the value of the protein decreased due to protein denaturation by heat. As can be seen in KFW_B3 processed at 170^0C when the time increases from 7 to 8, 8 to 9, and 9 to 10min the protein decreases from 9.94%-9.51%, 9.51%-9.08%, and 9.08%-8.99% respectively. Correspondingly, at a fixed time of 10min in KFW_B3, an increase in temperature from 160^0C to 170^0C, and 170^0C to 180^0C resulted in decrease from 9.56%-9.08%, and 9.08%-8.98% respectively. The result obtained from the SPSS analysis revealed that biscuit KFW_B2 processed at 170^0C for 10 min. gave best result for protein content of 9.7% on dry basis. This implies that the enriched Koch biscuit is a good source of protein and can support problem solving in protein malnutrition in the country. The farinograph data for various blends of flour revealed that faba bean has 206 FQN which is better than that of wheat of 108FQN. Combination of this faba bean with Kocho flour improves its farinograph quality number from 7 to 200 of KFW_F3 and makes it more suitable for biscuit production. The flour property like water and oil adsorption for whole Kocho flour (K_F) were 2.29ml/g and 0.93ml/g; respectively which improved to KFW_F2 of 2.05 ml/g and 1.15ml/g; respectively which is not significantly different form wheat flour of 2.2ml/g and 1.18ml/g. This makes the enriched Kocho biscuit comparable in terms of farinograph quality number and dough consistency with the standard whole wheat flour biscuit. The water activities of the whole blended flours were in between 0.47% and 0.55% indicating below the minimum water content required by microorganisms. The water activity for the biscuit is also in the range of 3.7% and 6.5%. The moderately high

amount of water activity in whole wheat flour biscuit (KFW_B5) results in damage by microorganisms. The recommended water activity for the biscuit is in the range of 0.3% and 0.5%.

List of Abbreviations and Acronyms

AACC – Americans Associations of Cereal Chemist

AOAC - Association of Analytical Chemist

ANOVA - Analysis of Variance

BU - Brabender Unit

CSAE -Central Statistical Authority of Ethiopia

CHO- Carbohydrate

EARO – Ethiopian Agricultural Research Organization

E.C. - Ethiopian Calendar

EHNRI - Ethiopian Health and Nutrition Research Institute

ERH – Equilibrium Relative Humidity

FAO - Food and Agricultural Organization

F_F - Faba bean flour

FCI - Fixed Capital Investment

FU - Farinograph Unit

FQN - Farinograph Quality Number

IAR – Institute for Agriculture Research

Kcal - Kilo calorie

K_F - Kocho flour

KFW_B1 - Kocho 50%faba bean25% wheat25% Biscuit

KFW_F1 - Kocho 50%faba bean25% wheat25% Flour

KFW_B2 - Kocho 50%faba bean30% wheat20% Biscuit

KFW_F2 - Kocho 50%faba bean30% wheat20% Flour

KFW_B3 - Kocho 50%faba bean35% wheat15% Biscuit

KFW_F3 - Kocho 50%faba bean35% wheat15% Flour

KFW_B4 - Kocho 100% Biscuit

KFW_B5 - Wheat100% Biscuit

Kwh^{-1} -Kilo watt per hour

LAB - Lactic acid bacteria

MoA - Minister of Agriculture

NRC – National Research Council

OL- Operating Labor

RDA - Recommended Dietary Allowance

SNNPR - Southern Nations and Nationalities peoples Region

TEC - Total Equipment Cost

TDC - Total Direct Cost

TPC - Total Product Cost

UNIDO - United Nations Industrial Development Organization

W_F - Wheat flour

WFP- World Food Program

WHO- World Health Organization

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Chapter One

1. Introduction

1.1. Background

In a country with dominating agrarian economy like Ethiopia, alleviating food security is one of the most important objectives to be attained by the agriculture system. However, the agriculture system in Ethiopia is dominated by rain feed agriculture, where the performance of the sector is highly dependent on the timely on set, duration, amount and distribution of rainfall that males the system highly vulnerable to drought and other natural calamities (CSA, 2008).

Ethiopia has different feeding habits due to wide variety of cultures among different region. Depending on the season and weather condition the feeding also varies. During the drought season's people are not accustomed to eat the locally available drought resistance plants to fill their stomach. These drought resistance plants are sometimes eaten by one culture and in the other cultures may not. Among these drought resistance plants Enset is the one.

Three Enset (*Enset Ventricosum*) derived foods; bulla, Kocho, and Amicho; are popular but the most common is Kocho. The plant cut before flowering, the pseudostem and leaf midribs are scraped, the pulp is fermented for 10-15 days and finally steam-baked flatbread is prepared. As many as 7 million people consume the low-protein Enset products as staple or co-staple foods, sometimes solely with Vitamin A foods but commonly without the needed protein supplement. Leaf, fiber and other remain are used for food wrapping, cattle feed, ropes and house construction materials (Robert and Chernet, 1996).

Pulse crops, which are annually assessed, account for the highest grain production in Ethiopia. They are the basis of non-meat national dishes, are a vital protein supplement to the cereal diet. Unlike pulses, Enset and root crops are simple basic starch crops, quite low in protein, not very adaptable to varying food dishes but very high in productivity, and may account for more than ten percent of the cereal equivalent consumption. The implications of heavy dependence on these poor nutrition crops may have serious implications on the physical and mental health of the Enset consuming and planting people.

The fortification of Kocho with different cereals and legumes results in the improvement of its nutritional value. Kocho can be fortified in the form of flour, bread, and biscuit. Among these, biscuit has longer shelf life than the rest. Kocho as biscuit can be processed at household level without the application of sophisticated processing and unit operations in oven; and it can also be prepared at a factory level by keeping the quality and quantity.

Wheat is the major raw material for biscuit production due to its elasticity and comparable nutritional composition. The substitution of the wheat with legume results in an increase of the protein value of the biscuit. The same thing is also true for Kocho; if partially legumes are added in the Kocho it can solve the protein problem in the raw Kocho. Legumes are of different type among these legumes faba bean (*Vicia faba*) is mostly grown in different regions especially in Southern Nations Nationalities People Region where the production of the Enset plant is very high. A great deal of attention has been paid to the potential use of legume flours as bread fortifiers. Although legume flours appear promising in terms of fortification, their use is not straightforward due to its content of digester inhibiters (Youssef and Bushuk, 1986). The digester inhibitors can be minimized by different processing methods.

Biscuits are popular as hot bread for breakfast and other meals. Biscuits are also considered to be a quick bread. Biscuits can be plain; part of a main dish; served as breakfast rolls; or made into coffee cakes, desserts, or beaten biscuits. Biscuits can be flavored with fruits, vegetables, cheese, meat, herbs, or spices (Burrier, 2003). Enriched Kocho biscuit is proposed to be used both as desert and as a whole nutrient diet particularly for children. Therefore the production of biscuit from Kocho, faba bean, and wheat is more nutritious, long shelf life, easily distributable and accepted by all age people.

1.2. Statement of the problem

Enset plant is used to make many locally known food products among this are Kocho, Bulla, and Amicho are well known. All they have low protein content, which results in protein malnutrition and kwashiorkor in the country especially in Enset consumers regions. Ethiopia is a country, which has high production of Enset plantation. Even though, the production is high, the utilization of Enset plant is significant. Kocho by its self is a good source of starch and provides high calorie.

Ethiopia has the capacity to produce more to be self-food secure, which can fully give every person the daily requirement of the balanced diet. The main problem is the inability to produce at a whole scale and the loss of its product during harvesting, processing and the improper storage of the final product before consumption and lack of knowledge about nutrition. Even though there is enough food, the people are not costumed to vary their meal to fulfill their nutritional requirement. This is due to the lack of knowledge of the people on the balanced diet, the lack of income to purchase foods, and to use different raw materials as a source of food.

Now day industrialization is growing at a much faster rate and among this, food and beverage processing industries cover most of the percentages. Therefore utilization of different raw materials, which are locally available, at a processing scale is necessary. Among this are different roots and tubers cover lower part in the food and beverage sector. This roots and tubers include potato, carrot, beat root, sweet potato, yam, garlic, and others. The utilization of the stem of the Enset plant is also categorized under this group. The Enset plant has multi functional uses starting from the leaf to the steam and finally to the root of the plant. Until now no research, shows that the fruit of this plant is used for the purpose of food preparation and it make this topic open for research.

As reported by Tilahun et al., (2005) the energy supply of resource-poor households in the Enset root crop-based system was only 75% of the recommended daily dietary allowance (RDA) of the World Health Organization (WHO). Extremely high deficiency was found in zinc, calcium, vitamin A, and vitamin C, which provided only 26.5%, 34%, 1.78%, and 12%, of the RDA, respectively.

The Enset plant is drought resistance and it gives the people a good source of calorie during the drought seasons. The only problem is that this plant does not have the necessary protein and fat content of the daily requirement for a normal person. Especially the people living in the rural area do not have enough income to purchase animal products for their daily consumption. Instead, the use of different legumes is more practiced.

The time-temperature dependence of biscuit production is also another factor that affects the quality in terms of color, taste, aroma and the availability nutritional composition; and the quantity in terms of the amount of nutrient in the biscuit. By varying the temperature and time of the processing, it is possible to achieve to a good quality biscuit.

Some of the problems are listed below:

- Lack of nutritious food in the rural and urban area
- The need for extra processing unit operations

- Ø The increasing price of the food raw materials in comparison to the increasing demand
- Ø The availability of the raw material throughout the season
- Ø The utilization of the locally available raw material like Kocho is low at processing scale
- Ø Quality of biscuit dependency on different parameters like granular size of the flour, kneading time, dough raising time, thickness of the dough sheet, time-temperature range of heating and packaging and storage condition of the biscuit.

From these problems it can be concluded that the protein deficiency in Enset processing and consuming regions results in kwashiorkor. Choosing the appropriate time-temperature for baking biscuit, utilization of locally available raw materials, application of the locally growing plants at industrialization level and insuring food security in the country should be given attention.

1.3. Objective

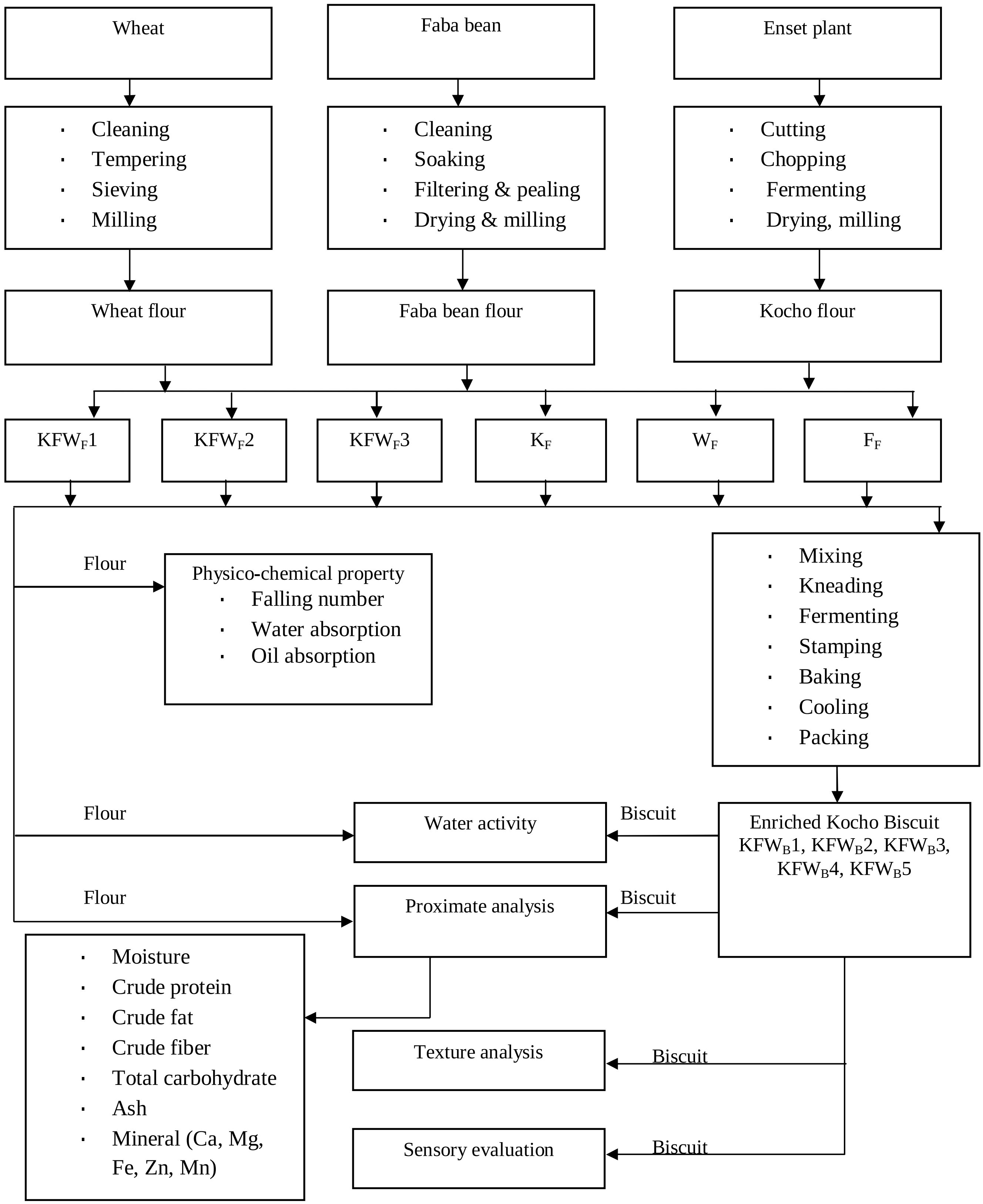
General objective

The general objective of the thesis is to develop biscuit from Kocho supplemented with faba bean, and wheat flour and also, to determine the processing time and temperature effect in quality of biscuit during baking.

Specific objectives were to:

- Ø Develop biscuit from Kocho supplemented with faba bean and wheat flour and to compare with a wheat flour biscuit
- Ø Evaluate the flour and dough properties of the blend
- Ø Upgrade the protein content of raw Kocho
- Ø Determine the effect of baking time and temperature on the proximate composition as well as organoleptic property of enriched Kocho biscuit
- Ø Suggest an process technology for the processing of enriched Kocho biscuit

1.4. Frame work of the experiment



Chapter Two

2. Literature Review

The agricultural production output in the Ethiopia comes from both the private peasant holdings and the large and medium scale commercial farms where the commercial farms consist of the state and the private investment commercial farms (CSA, 2008). The positive and negative influences on the crop production are shown bellow.

Factors that have negative influence on crop production includes

- Too much rainfall and lodging of the crop
- Shortage of rainfall
- Insect (locust disease and other pests (birds) damage
- Hail and frost damage
- Wind and domestic animal damage
- Shortage of seed
- Depletion of soil fertility and others

Factors that have positive influence on crop production

- Favorable weather conditions
- Improved seed and cultural practices
- Application of fertilizers application of pesticides and others

The result of the year 2008 crop production forecast survey indicate that a total land area of about 11 million hectare are covered by grain crops that is cereals, pulses and oil seeds. From which the total volume of about 164.51 million quintals of grains are expected to be produced from private peasant holdings see Table -2.1 (CSA, 2008).

Crop such as teff, maize, sorghum, wheat, and barley within the category of cereals have covered an estimated total cultivated land area of about 2,397,121; 1,891,203; 1,498,199; 1,479,287; and 1,024,706 hectares, respectively. Similarly the total volume of about 27,601,590; 41,661,655; 24,674,517; 27,117,652; and 14,555,029 quintals are expected to be produced in the year 2007/08 Meher season harvest, with an average expected yield of 11.51; 22.03; 16.47; 18.33; and 14.20 qt/ha in that order respectively (CSA, 2008).

Table-2.1. Area under Crop and Expected Production of Grain

Crop type	Total area		Expected production	
	In hectare	%	In quintals	%
Cereals	8,744,096	79.37	141,627,962	86.09
Pulses	1,508,460	13.69	17,714,778	10.77
Oil seed	765,028	6.94	5,167,801	3.14
Total grain	11,017,584	100	164,510,541	100

Source: Central Statistical Agency (2008), statistical bulletin 409

2.1. The food habit in Ethiopia

In Ethiopia, foods are rarely modified to increase nutrient density to meet the needs of calorie for normal person. Traditionally prepared foods made of cereals or tubers may be low in several nutrients including protein, zinc and iron; these nutrients are of special importance due to their impact on physical and cognitive development. Furthermore, the bulkiness of traditional foods and low concentrations of fiber and high concentration of inhibitors are major factors reducing their nutritional benefits.

Children at the age of five to twelve have the incomplete diet. This means most of the children do not have a balanced diet during feeding and results in low weight and slow growth. Moreover, when the malnourished children are grown up they become low resistant to diseases and, most of them will be of lower IQ (i.e. the ability to understand things and making decisions).When we see all these production of nutritious food is a critical importance in Ethiopia (Yewelsew, 2006).

Most of the enriched foods are very expensive and difficult to buy by the consumers. Therefore, the production of infant foods from locally available raw materials is of paramount importance. Most of the time children like to eat sweet products like confectionary, snacks, and biscuits. Out of these products, to do fortification on biscuit is much easier. The major raw material is wheat, which is nowadays becoming expensive to be purchased by the low-income people. Because of this, the replacement of wheat flour with other raw material is necessary. Among these good starch sources are potato, cassava, Kocho, and other cereals. Kocho is one of the products prepared from Enset also called ‘false banana tree’.

Among the bakery products, cookies are most significant. These are an important food product used as snacks by children and adults. These products are mostly cherished by school going children, who need more protein per unit body weight than adults. Cookies hold an important position in snack foods due to variety in taste, crispiness and digestibility. These are popular among all age groups especially in children. Commercially available cookies are prepared from white wheat flour that is nutritionally inferior to whole wheat flour (Shahzad et al., 2006).

2.2. Nutritional requirements and sources of balanced diet

The basic nutrients that a human being needs to have to be a healthy person are carbohydrate, protein, fat, vitamins, minerals and water. Depending on the sex, age, work, and basal metabolic rate the energy required for an individual can be grouped in to different categories but when we see the energy required depending upon age a man of weight of 60 kg who is heavy worker requires 3800 Kcal and above, but for office worker only requires 2425 Kcal. For a woman who is a sedentary worker requires 1875 Kcal, for moderate worker reaches to 2225 Kcal, and for heavy worker goes up to 2900 Kcal. Keeping all these, for pregnant women requires additional 300 Kcal more and for lactating women requires additional 500 Kcal more (Swaminathan, 1989).

The energy requirement of an individual, in a state of desirable equilibrium, is equal to the energy expenditure. In some clinical situations, where an improvement in nutritional status may be advisable, the energy requirement may be set at a higher level than the energy expenditure in order to produce, temporarily, a positive energy balance. In certain physiological states, such as during growth in children, or in pregnancy and lactation, the energy requirement may also be higher than the energy expenditure.

The energy requirement of an individual is the level of energy intake from food that will balance energy expenditure when the individual has body size and body composition, and level of physical activity, consistent with long-term good health; and that will allow for the maintenance of economically necessary and socially desirable physical activity. In children, the energy requirement includes the energy associated with the deposition of tissues at rates consistent with good health.

Table-2.2. Energy Requirements of Infants from Birth to One Year

	Total requirement		
Age (months)	(Kcal/kg/day)	Boys (Kcal/day)	Girls (Kcal/day)
0.5	124	470	445
1-2	116	550	505
2-3	109	610	545
3-4	103	655	590
4-5	99	695	630
5-6	96.5	730	670
6-7	95	765	720
7-8	94.5	810	750
8-9	95	855	800
9-10	99	925	865
10-11	100	970	905
11-12	104.5	1050	975

Source: European Journal of Clinical Nutrition, 1996

For children of age between zeros to six month it is required about 118 Kcal/ body weight of energy. If the child is at the age of 6 to 12 month, the energy required is about 108 Kcal/body weight for detailed data see Table-2.2 and Table-2.3. Children are growing fast and need body building nutrients, which are mainly carbohydrate, protein and fat. Children require a protein content of 1.25 g/kg body weight to 2 g/ Kg body weight depending on the health and body composition. The conversion factor for of energy from carbohydrate is four Kcal per one gram of carbohydrate, for proteins it is also the same, but for fat, the conversion factor is nine Kcal per one gram of fat.

Table-2.3. Amino Acid Requirement of Humans (Mg/Kg Body Weight)

Amino acid	Infant	Children (10-22 month)	Children 2 years and above	Adults
Histidine	28	-	-	8-12
Isolusine	70	28	31	10
Leucine	161	42	73	14
Lysine	103	44	64	12
Methionine	58	22	27	13
Phenylalanine	125	22	69	14
Threonine	87	28	37	7
Thryptophane	17	3.3	12.5	3.5
Valine	93	25	38	10

Source: Swaminathan, 1989.

The need for balanced diet is essential for any human being and, to fulfill this, people have to eat different kinds of foods, each food has its own nutritional value and Table-2.4 shows the nutritional content of each food and the required nutrition for a specific group of age and gender. The nutritional requirement of different groups is also shown in Table2.5 and this shows the daily requirement of a person. In this Table it shows that children require high amount of protein and as they grow to adult stage the need for protein increases but this is due to the continued movement and work of that group. To see the details see Table-2.5. Table-2.4 food items for different population groups

Food	Adults (sedentary)		Adolescent (16-18 year)		Children (years)	
	Male (g/d)	Female(g/d)	Boys (g/d)	Girls (g/d)	7-9 (g/d)	1-3 (g/d)
Cereals	400	300	450	300	250	150
Pulses	50	40	60	50	40	35
Green leafy veg.	75	100	100	150	75	50
Other vegetable	75	50	50	100	50	20
Roots and tubers	75	50	75	50	50	10
Fruits	100	100	100	100	100	100
Milk	200	200	200	200	250	300
Sugar	20	20	20	20	20	15

Fat and oil	20	15	20	20	20	20

Source: M. Swaminathan, 1989

2.3. Enset cultivation and contribution to food security in Ethiopia

Enset ventricosum varies within the species to altitude, soil and climate. This allowed widespread cultivation in the mid to highlands of western Arsi-Bale, the Southern Nations and Nationalities People Regional State (SNNPRS), and western Oromia including West Shewa, Jima, Ilubabor and Welega (Robert, 1996). The consumption of this product is also widely practiced around these areas.

In December 1993, the FAO/WFP Crop and Food Supply Assessment document provided estimates of Enset and root crop production for the past seven years amounting to about 10% of the net cereal and pulse production. According to the report, although its (i.e. Enset and root crops) contribution to nutrition is considerable; a formula for its inclusion in the food balances needs to be determined (Yemane, 2006). Enset yield reports of 4 tons per hectare (in cereal equivalent) compared to Ministry of Agriculture estimates of 5 tons per hectare. Moreover, in the SNNPRS, 1994 estimates show that 300,000 hectares of *Enset* is projected to yield almost 10 tons per hectare.

Table-2.5. Nutrients for Different Population Groups

Nutrients	Adults (sedentary)		Adolescent (16-18 years)		Children	
	Male	Female	Boy	Girl	7-9 years	1-3 years
Protein (g)	67	53	76	61	51	39
Fat (g)	46	41	49	48	46	39
Energy (Kcal)	2402	1890	2660	2085	1943	1384
Calcium (mg)	1242	1175	1490	1421	1208	1054
Iron (mg)	31	25	30	32	20	12
Vit.A (m gm)	821	1025	1048	1470	835	626
Thiamine (mg)	1.88	1.5	2.19	1.63	1.35	0.91
Riboflavin (mg)	1.23	1.11	1.41	1.29	1.04	0.82
Niacin (mg)	17	12	18	14	11	7
Ascorbic acid(mg)	93	99	106	148	82	55
Pyridoxine (mg)	1.9	1.30	1.9	1.3	1.1	0.7

Folic acid (*m* gm)	247	249	310	333	210	159
Vit. B12 (*m* gm)	0.28	0.28	0.28	0.28	0.35	0.42

Source: Swaminathan, 1989

Inclusion of *Enset* production from Oromia Region (Oromia) and the national root crop production would have placed estimated '*Enset* and root crop production' at more than 1/4 of the total cereal and pulse production of Ethiopia (Robert, 1996).

The average number of plants harvested per household per year varied from below 12 plants in a few Woreda to more than 100 in several. If 50-60 plants are needed to fulfill a major staple food requirement, then obviously those harvesting the lower number must be supplementing the Enset foods and those harvesting the higher number are either surplus producers or could be utilizing smaller plants. Woreda per plant yields averaged 19.7 to 84.6 kg with an overall average of 44.2 kg at 50% moisture. This compares to farmers opinion that average yields are 25 kg and researchers reports of 12 to 42 kg at unspecified moisture levels.

Annual household production of Kocho varied from around 1 quintal in low producing areas to more than 90 quintals in three Woreda. Average annual household production varied from 5-15 quintals in subsistence producing Woredas to 35-70 quintals in surplus producing Woredas (Admasu, 2001).

The assessed total annual Kocho production from 80 Weredas and 7 special Weredas amounted to 4,381,903mt (metric tons) of which 3,704,698mt is from the Southern Region and 667,205mt is from the Oromia Region. This compares to 5,422,935 mt reported by the Ministries of Agriculture of which 5,008,515mt was estimated to be produced in the Southern Region and 414,420 in the Oromia Region. The previous production Figure accepted by the FAO-MoA for crop assessment in 1995 was 2,482,574mt but was derived by deduction and did not include production in Oromia Region (Brandt et al., 1997).

∨ ***Enset Ventricosum* varieties and their differences**

Enset ventricosum is the edible species of the separate genus of the banana family, but the Enset fruit is not edible. The Enset plant is growing at an altitude of 1500 to 3000 meter above sea level. The height of the plant can reach 6 to 8 meter when the plant is harvested 6 to 8 year after planting (Edward, 2003) shown in Figure-2.1.

Enset ventricosum is one of the plants, which have not yet fully investigated and still now there are about 29 verities of Enset and among these some of them are described in Table-2.6 bellow. The cause of their variation is due to the type of cultivation, the altitude of their growing area and other variables.

Enset ventricosum is a highly polymorphic species as may perhaps be deduced from the variety of names under which it has been described from sites throughout its large African range.

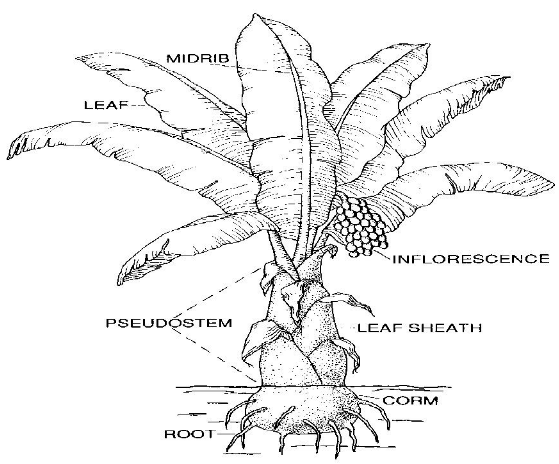


Figure-2.1 the Enset plant (*Enset ventricosum)*

Variations within *E. ventricosum* are found in:

- The colour of the midribs (red or green)
- The colour of the leaves (from green to heavily stained with red-brown)
- The colour of the bracts (red, purple or green)
- Waxiness
- Bract persistence

- Certain floral details, even in different parts of the same inflorescence, e.g.
    - The basal flowers are commonly hermaphrodite but rarely found to be functionally female
    - The outer tepal is very variable, normally with 3 lobes but sometimes with 1 - 2 smaller, acicular and internally attached extra lobes
    - There are 1 - 3 variably-shaped inner tepals
    - The number of stamens varies between 0 - 5
    - The number of staminodes is variable, depending on the number of stamens, and their size is also variable
    - The male flowers vary greatly in size (partly correlated with age) and in the form of the perianth parts
- Seed varies as follows:
    - Seed numbers vary from 0 - 40 seeds per fruit (mainly due to differences in pollination or fertilisation)
    - Seed varies in shape, from nearly spherical (if few seeds per fruit) to flattened-irregular (if many seeds per fruit); in surface characters, from smooth to deeply striate; and in decoration, with or without a lump of callus opposite the hilum sometimes with a shallow depression in its centre
    - Seed varies in size, e.g.
        - Ethiopia 3.33 cc.
        - Northern Kenya and Uganda 1.64 - 2.90 cc.
        - Democratic Republic of Congo 1.83 - 3.24 cc.
        - Angola to Transvaal, Malawi to Tanzania and southern Kenya 2.64 to 5.67 cc.
        - Northeastern Tanzania and southern Kenya 4.83 - 5.67 cc.

The most common varieties of *Enset ventricosum* are described bellow and among these varieties some of them are largely cultivated in our country and planted for the purpose of human consumption as food and for animals feed. Among these common varieties, some of them are named bellow for detailed information see Table-2.6.

- *Enset ventricosum* 'Atropurpureum'
- *Enset ventricosum* 'Green Stripe'
- *Enset ventricosum* 'Maurelii'

- *Enset ventricosum* 'Montbeliardii'
- *Ensete ventricosum* 'Tandarra Red'
- *Ensete ventricosum* 'Red Stripe'
- *Ensete ventricosum* 'Rubra'
- Musa maurelii
- Musa 'Santa Morellii'
- Musa ‘Tandarra Red’
- Musa ensete 'rubra'

2.4. Microbiology and physical and biochemical change of Kocho

Lactobacillus plantarum frequently occurs spontaneously in high numbers in most lactic acid fermented foods, especially when the food is based on plant material; for example, in brined olives, sauerkraut, salted gherkins, sourdough, Nigerian ogi (made from maize or sorghum), Ethiopian Kocho (made from starch of *Enset ventricosum*), Ethiopian sourdough made from tef (*Eragrostis tef*) and cassava. Thus, it is obvious that individuals consuming lactic acid fermented products of plant origin also consume large amount of *Lactobacillus planetarium* (Edward, 2003).

Leuconostoc mesenteroides is responsible for initiating fermentation (Gashe, 1987). Because of the activities of this species and to some extent, *S. faecalis*, the pH of the fermented Kocho is decreased from 6.5 to 5.6. Then these bacteria are succeeded by homo-fermentative lactics including *Lactobacillus coryneformis* subsp. *Coryneformis* and *L. plantarum*. The lactobacilli reduce the pH to about 4.2. *P. cerevisiae* although present, does not exert much effect because of the relatively low temperature (14 to 18^0C). Spore forming bacteria and yeast also present during the fermentation and a butyrous odor present in the first 2 weeks may be due to clostridia.

Table-2.6. Some of the *Enset Ventricosum* Varieties and Their Founders

No	Enset Ventricosum varieties	Founder	Year of discovery
1	Musa ensete	J. F. Gmelin	1791
2	Musa ventricosa	F. M. J. Welwitsch	1859
3	Ensete edule	P. F. Horaninow	1862
4	Musa kaguna	Hort.	1871
5	Musa buchananii	J. G. Baker	1893
6	Musa schweinfurthii	K.M.Schumann&O.Warburg	1900
7	Musa arnoldiana	E. A. J. De Wildeman	1901
8	Musa holstii	K. M. Schumann	1904
9	Musa ulugurensis	O. Warburg & O. Moritz	1904
10	Musa fecunda	O. Stapf	1906
11	Musa laurentii	E. A. J. De Wildeman	1907
12	Musa bagshawei	A. B. Rendle & S. Greves	1910
13	Musa davyae	O. Stapf	1913
14	Musa ruandensis	E. A. J. De Wildeman	1923
15	Musa rubronervata	E. A. J. De Wildeman	1923
16	Musa africana	E. Chiovenda	1935
17	Ensete buchanani	J. G. Baker	1947
18	Ensete schweinfurthii	K. M.Schumann&O. Warburg	1947
19	Ensete arnoldianum	E. A. J. De Wildeman	1947
20	Ensete holstii	K. M. Schumann	1947
21	Ensete ulugurense	O. Warburg	1947
22	Ensete fecundum	O. Stapf	1947

23	Ensete laurentii	E. A. J. De Wildeman	1947
24	Ensete bagshawei	A. B. Rendle & S. Greves	1947
25	Ensete davyae	O. Stapf	1947
26	Ensete ruandense	E. A. J. De Wildeman	1947
27	Ensete rubronervatum	E. A. J. De Wildeman	1947

Source: http://www.users.globalnet.co.uk/~drc/ensete_ventricosum.htm

As long as the Kocho fermentation remains strictly anaerobic, there is no problem with spoilage; but, if there are packets of air, or the Kocho is exposed to air, molds and other spoilage organisms can grow. Genera *Erwinia, Bacillus, Pseudomonas,* and *Leuconostoc* cause softness and sliminess in the Kocho. Yeasts also cause softness and sliminess. Various molds, particularly *Penicillium, Botrytis, Trichoderma, Chaetomium, Alternaria, Cladosporium, Aspergillus, Rhizopus,* and *Fusarium* causes softness and discoloration (Gashe, 1987). Aflatoxines B-1 and G-1 have been found in the product. The dominating LAB in Kocho bought in the market are lactobacillus, planetarium, *weissellaminer*, and Pediococcus *pentosaceus*, *ghashe* also found that *Lactobacillus planetarium* was one of the dominating species of lactobacilli (Edward, 2003).

The pH value of Kocho and bulla bought in the Addis Ababa market is 4.9 and 4.7, respectively. While fermenting, the flavor becomes slightly acid. The color should be light beige immediately after removing the Kocho from the fermenting pit but it will deteriorate rapidly to a dark brown or gray on exposure to air. Therefore, the Kocho is sold in tightly wrapped leaf packets. The flavor will also become sourer, and thus less desirable, if exposed to air. After fermentation, the smaller fibers incorporated in the original mass have been broken down to a powdery starch. The total weight loss, from harvest to hand pressing (wringing) to remove excess liquid, accounts for 60 to 70% of the original raw weight (IAR, 1974).

The protein content varied significantly with in the 29 Enset verities analyzed. While the percentage protein decreased with fermentation, the percent of essential amino acids (expressed as a percentage of the total protein after fermentation) slightly increased. Kocho was highest in lysine and lowest in methionine (Keith, 1996).

While fermentation enhances the nutritive value of foods, a similar result was not observed in the case of Kocho, possibly due to a leaching of the water-soluble nutrients during the long incubation. This could occur because the pits are no nether air or water tight. Thus, during the rainy season many nutrients could be washed away in to the soil. Lining the hole with plastic and the fermenting the Kocho might enhance the nutritive value (Keith, 1996). The nutritive value of unfermented Kocho and bulla is presented on Table-2.7.

Misikir, (2009) reported on the enrichment of Kocho with haricot bean, shows that the main nutritional compositions of Kocho are carbohydrate between 46.1 to 48 g per 100 g of Kocho; protein of 0.94 to 0.97 g/100g; fat of 0.12-0.13 g/100g; moisture of 49.7-51.7 g/100g; vitamin-C of 1.9- 9.2 mg/100g; cupper of 0.14- 0.18 mg/100g; zinc of 0.71-1.44 mg/100g; and iron of 7.5-14.44 mg/100g.

Table-2.7. Analytical Data on Unfermented Kocho and Bulla

Food item	Water (%)	CHO (%)	Protein (%)	Calcium(mg/100g)	Iron (mg/100g)	Fat (%)
Kocho	56.3	41.3	1.2	120	5.3	0.2
Bulla	43.7	55.4	0.25	44	7.7	0.1

Source: Keith, 1996

- **Kocho Fermentation and Preparation**

Kocho is the name of the chopped, grated, fermented, and steam beaked bread of pulp and corm of the Enset plant. The fermented Kocho should be a light tan color, and depending on how it is baked, may be dry and biscuit like or moist and gummy (Steinkrous, 1996).

The Kocho plant is prepared as follows; the pseudo-stem and corm are pulverized with a long wooden pestle and pound into a pulp from which the fibers are removed. The remaining scrapings, the pulp, and the inner core are kneaded together, rolled in to balls, and wrapped in a fresh Enset leaves. The leaf packages with fresh Enset mash are packed into a pit in the ground that has been completely lined with leaves and left for pre-fermentation for two to five days. After this pre-fermentation the package are opened and the mash is once again mixed and thoroughly kneaded, rolled into ball and wrapped in new fresh Enset leaves. The packages are pressed by hand and feet into the pit. Some of the waste mash and cellulosic material from the production are put on top to create a cover, and heavy stones are put on the top of this cover. The aim is to limit the access of air into the pit. The major fermentation takes two weeks at a temperature of 15 to 18 ^{0}C (the same temperature range used for fermentation of sauerkraut) but the Kocho can be left in the closed pit for periods of time from 6 months up to years in the cold region (Farnworth, 2003).

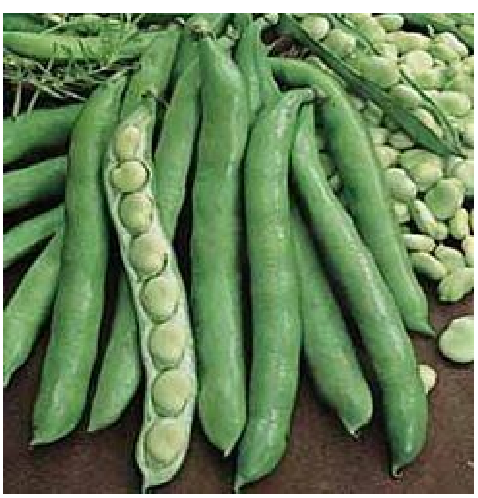
The bread is usually unleavened and flat, approximately 1 to 1.5 cm thick (as the cook desires) and of varying diameter. One hundred percent Kocho flour or a mixture of Kocho and other cereals flours may be used. A type of yeast bread is made with part Kocho and part wheat flour and is baked in the ground with a fire above providing the necessary heat. It takes at least 12 h to bake and is used for weddings or special holidays (Steinkrous, 1996).

The preparation of the flour to make Kocho is done using first by the separation of long fibers and further cutting of the Kocho-mass repeatedly in a series of diagonal lines with a sharp Knife to remove any remaining small fibers and to yield a uniform texture.

Finally, the flour is mixed with water, kneaded well, shaped on a mat to form a thin, circular layer, and baked. Cereal flour may be added when mixing to give a more bread like dough. This type of unleavened Kocho bread is baked in three ways. It may be (1) placed directly on a metal griddle, (2) wrapped in a leaf then cooked on both side, or (3) it may be wrapped in leaves and baked with steam by repeatedly sprinkling water on the metal griddle throughout the baking process. This last method produces a gummy, moist, gray paste.

2.5. The faba bean production and its nutritional composition

Faba beans (*Vicia faba*) are a relative of vetch, a determinate type with erect, coarse stems and large leaves without climbing tendrils. It grows to be a bushy plant, two to seven feet tall. The white or purplish flowers are born in clusters on short stalks in the axils of the leaves. The large-seeded varieties bear 1 or 2 pods at each node while the small-seeded types produce from 2-5 pods. The pods produced are up to 18 inches long and contain from 3-12 large beans. There are about 15 pods per stalk on the large types and 60 pods on plants of the small-seeded varieties. When stored under favorable conditions, most bean seeds have a life expectancy of 3 years. It is similar in size to the lima bean and is native to the Mediterranean region, especially Italy and Iran. It is one of the oldest cultivated plants known, with its culture extending back to prehistoric times. The faba bean is shown diagrammatically in Figure-2.2 bellow.



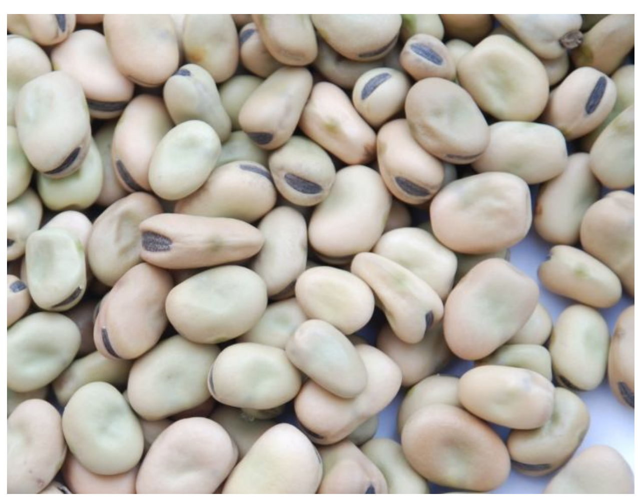


Figure-2.2. a: faba bean pods, b: dried faba bean

Faba bean has many other names among these are Horse bean, Broad bean, Windsor bean, English Dwarf Bean, Tick bean, Pigeon bean, Bell bean, Haba bean, Feve bean and Silkworm beans.

The faba bean is a cool-season annual legume. Optimum growing temperatures are 70-80° F. The plant is resistant to frost damage to at least 21° F., but does not do well under summer heat of the interior valleys, especially during flower/pod set (www.great-workout.com).

If the faba bean is grown for seed production, the crop takes 4-5 months to mature, depending upon the planting date. The seeds should be planted about one to two inches deep (large varieties) into well-prepared soil, three to five inches apart. Germination takes place in 7 to 14 days. Since they will grow into small bushes, the sprouted seeds should be thinned to 8 to 10 inches apart (this may not be practical), allowing two to three feet between rows for seed production. The released varieties of faba bean and their agronomic performance and area of adaptation in Ethiopia are shown in Table-2.8.

The ecological requirements of faba bean in Ethiopia shows that it grows on a wide range of soil types with moderate fertility levels, well drained and with a pH range of 6-7. This crop require an altitude range of 1800-3000 meters above sea level, annual rainfall of 700-1000mm and frost-free growing period with maximum temperature of 20-25^{0}C and minimum of 5-15^{0}C.

Comparison of the chemical composition of the legume flours with that reported for hard red spring wheat flour showed that legume flours have less starch, starch damage and pentosan content but more protein, fat, ash, and acid-detergent fiber. The various legume flours have similar starch and moisture content. Faba bean, lentil, and mung bean flours contain approximately the same amount of damaged starch, which is more than that in the navy and pinto bean flours. Faba bean flour has the highest protein content amongst Navy bean, Pinto bean, Lentil, Mung bean (Naivikul and D. Appolonia, 1978).

Faba beans are a good source of protein of adequate nutritional quality. They provide sufficient quantities of essential amino acids, except for cysteine and methionine, to ensure normal development in growing rats, according to values recommended by the NRC, 1978; Concepcion and vidal Valverde, 1997). Levels of trypsin inhibitors in faba bean seeds seem to be lower than in other legumes such as soybeans (Valdebouze et al., 1980), chickpeas (Soni et al., 1978; Diaz-Pollan et al., 1997), and lentils (Vidal et al., 1994). Simple and inexpensive methods have been suggested to remove trypsin inhibitors totally or partially from legume seeds (Antunes and Sgarbieri, 1980; Weder and Link, 1993; Vidal et al., 1994).

For cover crops, one plant per square foot is recommended. This is equal to 195 pounds of seed per acre for large varieties and 79 pounds of seed per acre for the small varieties. Plants do best on well drained heavy silt or clay loams but will also do well on adequately moistened sandy soils. Faba beans are relatively tolerant to boron up to 10ppm in irrigation water. Because they are of the legume family, faba beans do not need nitrogen fertilizer if the plants are properly modulated. Inoculation with legume-type bacteria, commercially available, is recommended. Yields of one to two tons of cleaned seed per acre may be expected.

Faba bean can also produce large amounts of biomass making them quite attractive as a green manure crop. 20 to 40 tons per acre of green forage worked back into the soil as organic matter shows promise in enhancing the tilt of many clay and sandy type soils.

Table-2.8. Released varieties of faba bean and their agronomic performance

Variety	Year of release	Area of adaptation		Maturity days	Seed size	Seed color	Seed shape	Yield (Kg/ha)	
		Altitude (m)	Rainfall(mm)					On-station	On-farm
CS-20-DK	1977	2300-3000	800-1100	145-160	400-500	Light green	Round	20-40	15-30
Kuse2-27-33	1979	2300-3000	800-1100	135-150	300-400	Light green	Round	20-35	15-25
Bulga-70	1994	2300-3000	800-1100	143-150	400-450	Light green	Round	20-45	15-35
NC-58	1978	1900-2300	700-900	118-132	400-450	Light brown	Round	20-40	15-35
Kassa	1980	1900-2300	700-900	120-135	400-450	Light brown	Round	20-45	15-30
Tesfa	1995	1800-2400	700-900	125-135	400-450	Light brown	Round	20-40	15-35
Mesay	1995	1800-2400	700-900	120-130	400-450	Brown	Round	25-50	20-45
Degaga	2002	1800-3000		116-135	450-550	Light green	Round	25-50	20-45
Lallo	2002	2600-3000		900-1000	158			36	32
Dagem	2002	2600-3000		900-1000	152			35	25

Source: EARO, 2004

In addition to the organic matter benefit, the leguminous nature of faba beans can provide large amounts of nitrogen to the soil benefiting existing perennial crops such as orchards or subsequent high nitrogen consuming annual crops. Green manure yields have been determined in several research trials throughout the world.

The dry beans are about 24% protein, 2% fat, and 50% carbohydrate, and have 700 calories per cup. This plant is used as livestock and poultry feed, for a cover crop, and as either a green or dry vegetable. It is also used as a coffee extender when roasted and ground. The detailed nutritional composition is shown in the Table-2.9.

For preparation to cook, remove beans from the pods and then hull the beans. The hull is the thin outer coat (pericarp) around each seed. Beans can then be cooked in boiling salted water for 20-25 minutes in a covered saucepan. Savory herb also makes a good addition. Other methods of preparation similar to lima beans are satisfactory. In addition, young, fresh faba beans can be cooked without hulling (Smith, 1957).

Table-2.9. The Nutritional Composition of faba Bean Boiled, 1 cup (170g):

Nutritional value	Amount per 170 g
Calories	187 Kcal
Protein	12.9g
Carbohydrate	33.4g
Total Fat	0.68g
Fiber	9.2g
Folate	177mcg
Thiamine	0.165mg
Zinc	1.77mg

Source: Smith, 1957

2.6. Process description for biscuit production

Biscuits are eaten by all sections of people across the board round the year. They are, thus, mass consumption items with number of varieties and shapes. The market is scattered. There are some dominant national and regional brands. In the developed nations, biscuit making is a conventional activity in many parts of the country. Despite the advent of modern, large capacity and automatic biscuit making plants, large section of people especially in semi-urban and rural areas still prefer fresh biscuits from local bakery, as they are cheap and offer many varieties. In our country locally prepared biscuit is not, much practiced instead the baking of bread and Kocho is mostly accustomed. These products are similar preparation with that of biscuit and make the people to have interest of doing it at household level.

Biscuits fit in the Bread, Cereal, Rice, and Pasta Group of the Food Guide Pyramid. They give you nutrients that are important to your health and provide energy for work and play. The most important nutrients they provide are carbohydrates, fat, and B vitamins for energy; calcium for strong bones and teeth; and protein for growth and repair. They also provide minerals, including iron. Enrichment of Kocho, which is low protein product, with flour results in the improvement of nutritional value.

Biscuits are made with four raw materials, which are, leavening agents, milk, fat or shortening, salt, and sometimes sugar and eggs. In this paper, the major raw material is replaced with Kocho which is a good source of starch and minerals. The rest of the raw materials will be the same.

Flour made from wheat is the main ingredient for making biscuit nowadays. All-purpose flour is white flour made from a blend of different types of wheat. This type of flour produces the best results for many products made in the home, including quick breads, such as biscuits. Whole wheat (also called stone-ground and graham) flour is made from the entire wheat kernel. Self-rising flour is all-purpose flour with the salt and leavening agent already added for convenience. One cup of self-rising flour contains 11/2 teaspoons baking powder and 1/2 teaspoon salt. This type of flour works well for biscuits but is not recommended for yeast breads (Sue Burrier, 2003).

Starch production from wheat is still applying the milling procedure. However, from a point of view of starch manufacture, this process is still far from satisfactory. Firstly, because the flour extraction in the mill does not exceed 75-80%, not more than 85-90% of the starch originally present in the wheat is available for starch production. Secondly, in the process of flour milling, part of the starch granules is damaged. Together with the smallest granules and fine gluten particles, damaged granules contribute to the low-grade B-starch, thereby reducing the yield of prime A-starch. Damaged granules remaining with the A-starch fraction may restrict the use of wheat starch in certain applications. Starch damage is aggravated by increased kernel hardness. Thirdly, the process itself is very sensitive to flour quality. For a successful separation of starch and gluten it is essential that the protein coagulates well before the vibrating screen; otherwise starch purification will be difficult and protein loss will occur (Kema et al., 1996).

Common wheat (*Triticum vulgare* or *T. aestivum*) is the most important cereal grown for milling into flour. Hard wheat is used for making bread. However, soft wheat is used to make cakes and biscuits. The very hard wheat called durum wheat is used to make pasta macaroni and noodles (Pavel, 1985).

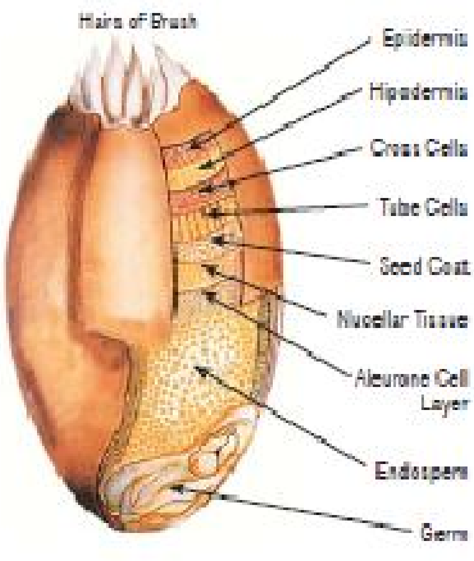


Figure-2.3. the Cross Sectional View of Wheat Kernel

The structure and composition of the dehulled kernel of the oat grain as shown in the Figure-2.3 bellow consists of hull, endosperm, bran, and embryo. The same is true for wheat. In the milling of wheat the bran is removed since it has no positive effect on the dough making property of the flours and also during the milling process the germ is removed this also has a negative impact on the nutritional value of the flour together with the loss of vitamins (Pavel, 1985). This results in the low level of fiber and vitamin content of the flour. The lack of this nutrient results in colon cancer, diverticulosis, cardiovascular diseases, and vitamin deficiency diseases especially B-complex vitamins.

Wheat flour contains two main proteins which are chemically distinct components: glutenin and gliadin. When the wheat flour is mixed with water the hydrated wheat protein complex (called gluten) gives the dough its elasticity, stickiness, and pliability; this is essential in the fermentation, loaf making, and bread structure development upon baking (Pavel, 1985).

Leavening agents, which are substances that help bread dough rise, are also another supplementary raw material. Biscuits are quick breads made with leavening agents that react quickly. These breads can be baked at once and do not require a rising period before baking. The leavening agent most often used for biscuits is baking soda plus an acid or baking powder. If a recipe calls for soda, it also calls for an acid, such as buttermilk (Burrier, 2003).

Most of the time milk is needed to moisten the flour, dissolve the salt, and permit the leavening agents to release gas (carbon dioxide, CO_2) that helps the bread to rise. Milk also contributes nutrients and helps the bread to brown. Different types of milk products are successfully used in baking, among these, Whole, reduced-fat, low fat, fat-free, reconstituted dry powder milk, and buttermilk can all be used in making biscuits.

Shortening helps make biscuits tender and gives them a flaky crumb. Fats, such as butter and margarine, also add flavor and color. Solid fat is a better choice for a quality biscuit. Biscuits made with oil are not as light and flaky as those made with shortening or solid fat.

In some recipes, salt is added for its own flavor. In other recipes, salt is used to bring out the flavor of other ingredients. Salt contains sodium, which some people are advised to limit in their diet. The addition of salt in Kocho results in good preservation action. Reduction of salt intolerant microorganisms and improvement of the taste can also be achieved by addition of salt. When you cut back on salt, the product will at first seem bland (Burrier, 2003).

Biscuit production is easy and it can be done at home and industrial level, but the main thing is to know the recipes and the quality. The UNIDO technology manual of small scale cereal milling and bakery products shows that to make 500 pieces of biscuit at 100g each and total weight of 50 kg. The loss during production and baking is equals to 10 % of the total raw material required. The detailed calculation is shown in the Table-2.10.

The freshly milled flour is not used directly to prepare biscuit. Therefore the flour should be stored for three to four weeks or be chemically treated to impart artificial maturing. The keeping quality of flour during lengthy storage is largely determined by its moisture content and the effect of varying atmospheric influences like temperature of storage should be in the range of 24 to 27 ^{0}C and the relative humidity bellow 60%.

Table-2.10. The Amount of Ingredients to Be Used to Make 50 Kg Mango Cake

Raw materials and processing conditions	Amount required (g)	Calculation	Amount needed to make 50 kg
Flour	168.00 g	(168/620) ´ 50kg	14 kg
Baking powder	2.60 g	(2.5/620) ´ 50 kg	0.217 kg
VegeTable shortening	84.50 g	(84.5/620) ´ 50 kg	7 kg
Mango (pulped)	122.00 g	(122/620) ´ 50 kg	10.2 kg
Sugar	98.00 g	(98/620) ´ 50 kg	8.2 kg
Egg	40.00 g	(40/620) ´ 50 kg	3.3 kg
Water	85.00 g	(85/620) ´ 50 kg	7 kg
Total	600.00 g		50 kg

Source: UNIDO, (2004)

The wheat flour used for biscuit production has different granular size. The finer the flour the lesser the capacity of holding water this is because of the starch granules are broken down to the simpler starch form and this smaller size of starch granules has low water holding capacity. If the granule size of the flour is high the water holding capacity of the flour is large together with the large size the proper removal of the moisture during heating becomes very difficult. The optimum granule size of flour for the production of biscuit is 140 micron when it is measured with the Granulo meter.

The flour of the given granule size will be mixed with the rest of the ingredients and knead to make dough. During kneading it will require a water of good quality and the temperature of the water for the kneading should be at a temperature of 20 to 25 ^{0}C. This is because of the formation of smear on the biscuit due to the low melting point of the margarine. In the case making hard biscuit the temperature of the water reaches up to 45^{0}C in order to melt the sugar completely.

The kneading time of the dough makes a lot of difference on the quality of the final biscuit. The more time it takes the better the mixing and also dough quality. Most of the time the mixing or kneading time is about 20 to 30 minutes. Depending on the type of biscuit the kneading time can be varied the data for the Deredawa Food Complex plc. shows that the time required for kneading is 30 minutes for hard biscuit and 20 minutes for soft biscuit.

The dough prepared for hard biscuit is squeezed by rolling cylinders, laminated in to sheets by various laminators the thickness of this fermented dough reaches to 1.5mm. This can be achieved through consecutive laminations of different gap size between the rollers. Then it is formed into different moulds by stamping (forming) cylinders and finally passes to the oven. In the oven, the biscuit stay for 5 to 6 minutes depending on the length of the heating chamber. For a batch process, it takes 6 minutes at a temperature of 180^{0}C. Generally, the temperature of the heating chamber for a contentious production is about 280 to 180^{0}C respectively for the given time above.

The scraps, which are returned from the stamping and laminating returned and laminated in the same way as the fresh dough. The biscuit after treated with heat it go to the packaging, storage, and distribution.

2.7. Farinograph parameters and their meaning

The farinograph determines dough and gluten properties of a flour sample by measuring the resistance of dough against the mixing action of paddles (blades). Farinograph results include absorption, arrival time, stability time, peak time, departure time, and mixing tolerance index.

The farinograph test is one of the most commonly used flour quality tests in the world. The results are used as parameters in formulation to estimate the amount of water required to make dough, to evaluate the effects of ingredients on mixing properties, to evaluate flour blending requirements, and to check flour uniformity for the detailed extension of the parameters see Figure-2.4. The results are also used to predict processing effects, including mixing requirements for dough development, tolerance to over-mixing, and dough consistency during production. Farinograph results are also useful for predicting finished product texture characteristics. For example, strong dough mixing properties are related to firm product texture.

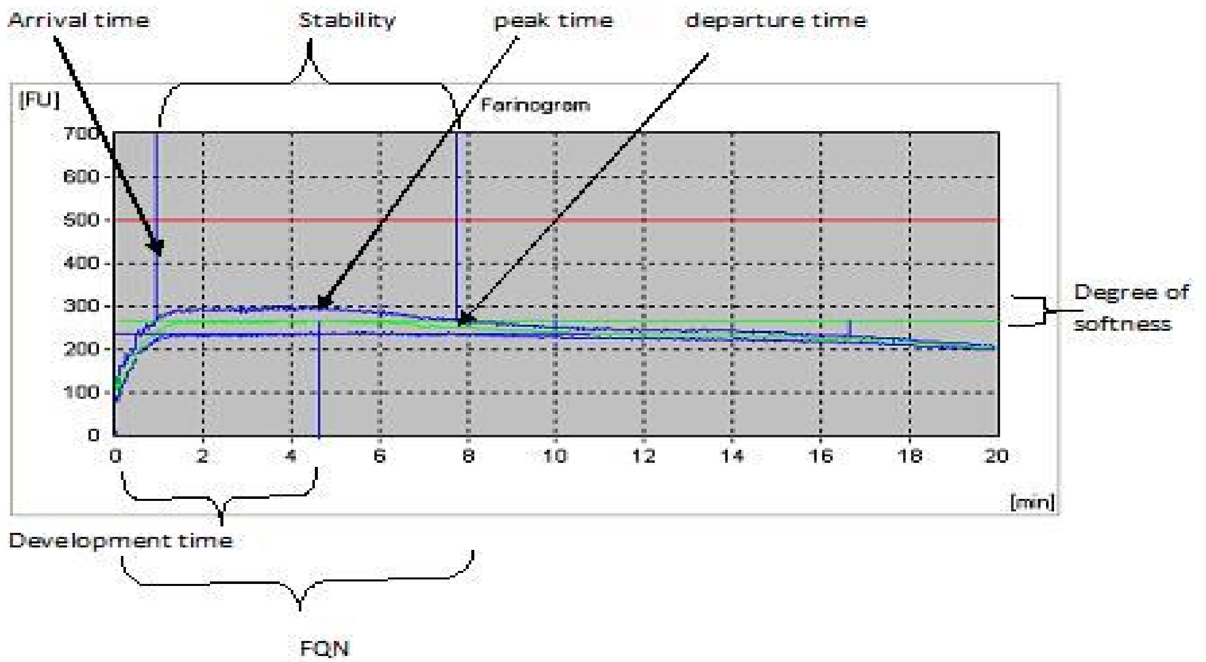


Figure-2.4. the graphical representation of the farinograph

The farinograph test measures and records the resistance of dough to mixing with paddles.

- Absorption is the amount of water required to center the farinograph curve on the 500-Brabender unit (BU) line. This relates to the amount of water needed for a flour to be optimally processed into end products. Absorption is expressed as a percentage.
- Peak Time indicates dough development time, beginning at the moment water is added until the dough reaches maximum consistency. This gives an indication of optimum mixing time under standardized conditions. Peak time is expressed in minutes.
- Arrival Time is the time when the top of the curve touches the 500-BU line. This indicates the rate of flour hydration (the rate at which the water is taken up by the flour). Arrival time is expressed in minutes.

- Departure Time is the time when the top of the curve leaves the 500-BU line. This indicates the time when the dough is beginning to break down and is an indication of dough consistency during processing. Departure time is expressed in minutes.
- Stability Time is the difference in time between arrival time and departure time. This indicates the time the dough maintains maximum consistency and is a good indication of dough strength. Stability time is expressed in minutes.
- Mixing Tolerance Index (MTI) is the difference in BU value at the top of the curve at peak time and the value at the top of the curve 5 minutes after the peak. This indicates the degree of softening during mixing. Mixing tolerance index is expressed in Brabender units (BU). Weak gluten flour has a lower water absorption and shorter stability time than strong gluten flour adapted from AACC, 2000.
- Farinograph quality number (FQN) is the point of the curve in which the curve has decreased by 30 FU after the maximum (based on the line of the diagram). Thus weak flour weakens early and quickly giving low quality number. Strong flour weakens late and slowly indicting a high quality number.
- Degree of softening is the difference between consistence line and medium line of the torque curve.

Sensory attributes such as color, appearance, taste, flavor, texture and overall acceptability are the major parameters in the acceptability of a food product. Color is the property possessed by the biscuit of different sensation on the eye (acceptable color). Appearance is the quality of the biscuit in terms of shape, size, form, and thickness. Taste is the sensation perceived when a small portion of biscuit is taken by mouth in terms of saltiness, sweetness, bitterness, and soreness. Flavor is the distinctive taste of the biscuit perceived by mouth and nose in terms of its acceptability. Texture is the mouth feelings of the biscuit in terms of hardness, softness, chew ability, and stickiness with respect to its acceptability. Overall acceptability is the sum of all the quality parameters and liking of the biscuit.

2.8. Water Activity in Foods

Water Activity (a_w) is a measurement of water energy. It indicates the amount of “free water” in a sample. “Free water” refers to the water molecules in a sample that are not chemically or physically bound. Water activity is equivalent to Equilibrium Relative Humidity (ERH), which is the ratio of water vapor pressure above any sample to the water vapor pressure of pure water at the same temperature.

Samples with no "free" water will have a_w of 0.000, while a sample such as pure water will have a_w of 1.000.

The a_w of a food or solution is the ratio of the water vapor pressure of the food or solution (P) to that of pure water (Po) at the same temperature (Paul and Vassilis, 2000).

$$a_w = \frac{P}{Po}$$

There are two basic types of water analysis. The first is a quantitative or volumetric analysis to determine the water content of a sample. Typically the sample is first weighed, and then oven dried and reweighed to measure its total water content. But merely knowing the water content of a sample does not give an indication of the physical properties of that water. The question is not how much water is in a sample, but how much of that water is available to be used by microorganisms or other destructive agents. The second type of water analysis, the measurement of water activity, answers this question. Water activity is an energy measurement which defines the amount of unbound water in a sample. Because microorganisms require water for survival, too much "free water" in a sample can serve as a medium for microbial reproduction, travel, and contamination. If water within a sample is held with enough force, microorganisms will not be able to exert the energy required to obtain water necessary for their subsistence. Because of this, a_w is commonly used in the evaluation of quality and safety of foods, drugs, and cosmetics (Paul and Vassilis, 2000).

Water activity is one of the most important properties of food governing microbial growth. The water activity can be defined as the free or available water in a food product. The requirements for moisture by microorganisms are expressed in terms of a_w. Therefore, a_w will determine what the lower limit for microbial growth will be in a food product.

Food products can be broadly classified into:

1. High a_w (≤ 0.92)
2. Intermediate a_w (0.85 to 0.92)
3. Low a_w (< 0.85).

Ingredients, e.g. salt and sugars and processing techniques, e.g. drying, curing, cooking etc. used in the production of food products, will influence the a_w and therefore the safety and shelf-life of the product. As with pH, the growth range for microorganisms is defined by the minimum, maximum and optimum values of a_w. Most microorganisms cannot grow below a_w of 0.60 (i.e. no microbial growth occurs below a_w of 0.50) with the majority growing at $a_w \leq 0.90$.

Table-2.11. The Minimum Water Activity Required by Some Pathogenic Microbes

Food poisoning organisms		Food-borne infectious organisms	
Name	Min a_w for growth	Name	Min a_w for growth
Bacillus cereus	0.95	*Clostridium perfringens*	0.95
Campylobacter coli	0.97	*Escherichia coli*	0.95
C. jejuni	0.98	*Salmonella spp.*	0.95
Clostridium botulinum:		*Vibrio parahaemolyticus*	0.94
Type A	0.95	*Yersinia enterocolitica*	0.96
Type B	0.94		
Type C	0.97		
Listeria monocytogenes	0.92		
Staphylococcus aureus	0.86		

Source: Paul and Vassilis, 2000

Typically, bacteria require a higher a_w to grow than moulds or yeasts. Most food borne pathogenic bacteria require $a_w \leq 0.91$ to grow. However, *Staphylococcus aureus* can grow at a_w of 0.83 (Table 2). Most spoilage bacteria do not grow below a_w of 0.91, while spoilage moulds can grow as low as a_w 0.80. Some halophilic (i.e. salt-loving) spoilage bacteria can grow as low as a_w 0.75. However, xerophilic (i.e. dry-loving) moulds and osmophilic (i.e. microorganisms which live in high osmotic pressures) yeasts can grow at a_w between 0.65 and 0.61, respectively. Biscuits, dry noodles, pasta and crisps are safe in the range of 0.3 and 0.6 of water activity.

- **Factors in determining Water activity**

The water potential of the water in a system is influenced by factors that affect the binding of water. They include osmotic, matrix, and pressure effects. Typically water activity is measured at atmospheric pressure, so only the osmotic and matrix effects are important.

Osmotic effects

Osmotic effects are well known from biology and physical chemistry. Water is diluted when a solute is added. If this diluted water is separated from pure water by a semi-permeable membrane, water tends to move from the pure water side through the membrane to the side with the added solute. If sufficient pressure is applied to the solute-water mixture to just stop the flow, this pressure is a measure of the osmotic potential of the solution. Addition of one mole of an ideal solute to a kilogram of water produces an osmotic pressure of 22.4 atm. This lowers the water activity of the solution from 1.0 to 0.98

a_w. For a given amount of solute, increasing the water content of the systems dilutes the solute, decreasing the osmotic pressure, and increasing the water activity. Since microbial cells are high concentrations of solute surrounded by semi-permeable membranes, the osmotic effect on the free energy of the water is important for determining microbial water relations and therefore their activity.

Matrix effects

The sample matrix affects a_w by physically binding water within its structure through adhesive and cohesive forces that hold water in pores and capillaries, and to particle surfaces. If cellulose or protein were added to water, the energy status of the water would be reduced. Work would need to be done to extract the water from this matrix. This reduction in energy status of the water is not osmotic, because the cellulose or protein concentrations are far too low to produce any significant dilution of water. The reduction in energy is the result of direct physical binding of water to the cellulose or protein matrix by hydrogen bonding and vander Waal forces. At higher water activity levels, capillary forces and surface tension can play a role.

Chapter Three

3. Material and Methods

3.1. Materials

The basic raw materials for the production of Kocho based biscuit were Kocho, faba bean and wheat flour. Additional ingredients include shortenings, sugar, salt, leavening agents, powder milk, and water. This Kocho biscuit supplemented with faba bean production involves the application of many processing and unit operations like milling of wheat to get flour, preparation of pseudo stem of Enset tree for the production of Kocho, preparing and processing of faba bean to make a faba bean flour and finally oven is used for cooking or baking purpose.

3.1.1. Sample collection and preparation of Kocho flour

The Enset plant was harvested from Areka Agricultural Research Center. The Kocho was prepared from the Enset plant of variety name called green *Ensete ventricosum* or its local name “Hale” which was planted at 28,04,1999 E.C. Then after two years at 23, 03, 2001 E.C. the Enset corm plant flowered this shows the maturity of the plant and harvested on Thursday 25,03,2001 E.C. The plant was 6.50m long, pseudo-stem height of 2 m and pseudo-stem circumference of 1.45 m. After the separation of the pseudo-stem as it can be seen in fig.-3.1a the corm was dogged out from the ground and the outer part is scrapped off this can be seen in fig.3.1b. The height and circumference of the corm was 0.67m and 1.7m respectively.

a. b.

Figure-3.1 Enset harvesting; a- pseudo-stem separation b- corm preparation

Enset plant

↓

Cutting and shaping

↓

Chopping and grounding

↓

Squeezing and separation of water (called Bulla)

↓

Fermentation for 10 day

↓

Further squeezing to let off water and acid

↓

Mashing and further chopping of squeezed Kocho

↓

Figure-3.2 Kocho flour preparation from Enset plant

Kocho preparation is simple and easy to prepare. The Kocho was first harvested from the plant of “Enset” (*Enset ventricosum*), which is like banana plant. From this plant root and the lower part of the stem, the starch was separated. The separation involved first chopping the parts and then squeezing to separate the water, which allows to settle the starch at the bottom called bulla, and then the squeezed product had gone through anaerobic fermentation for 10 days at a temperature of about 15 to 18 ^{0}C. Then fermented Kocho was taken out and gone for further size reduction of the fiber and well mashing of the Kocho. The simple flow diagram is shown in Figure-3.2.

a b

Figure-3.3 a-140 micron sieve b-miller

3.1.2. Sample Collection and Preparation of faba bean

The faba bean for the Kocho biscuit preparation was collected from Areka Agricultural Research Center. The faba bean or its local name “Kassa bean” was first planted at 08, 07,2000E.C and harvested at 23, 11, 2000E.C. The faba bean was kept dried during its storage time and till collection for the biscuit production.

The preparation of the faba bean into flour was done by first sieving to separate sand and other impurities. Then the faba bean was washed by tap water and then cleaning for large impurities then after the beans were soaked in water for overnight in tap water with bean to water ratio of 1 to 10 (w/v). After soaking excess water was drained off and the beans were dried at 60^{0}C using Magdi A. Osman oven.

This process makes the bean to be soft and make easier during milling and also the socking makes the anti-nutritional components to be reduced at some level. After the socking of the bean the water was drained off, the swollen bean was dried and then milled using a miller in Figure-3.3b. The milled powder of the faba bean was sieved to make the fine flour out of it as can be shown in Figure-3.3a. The schematic representation for faba bean processing is shown in the Figure-3.4 bellow.

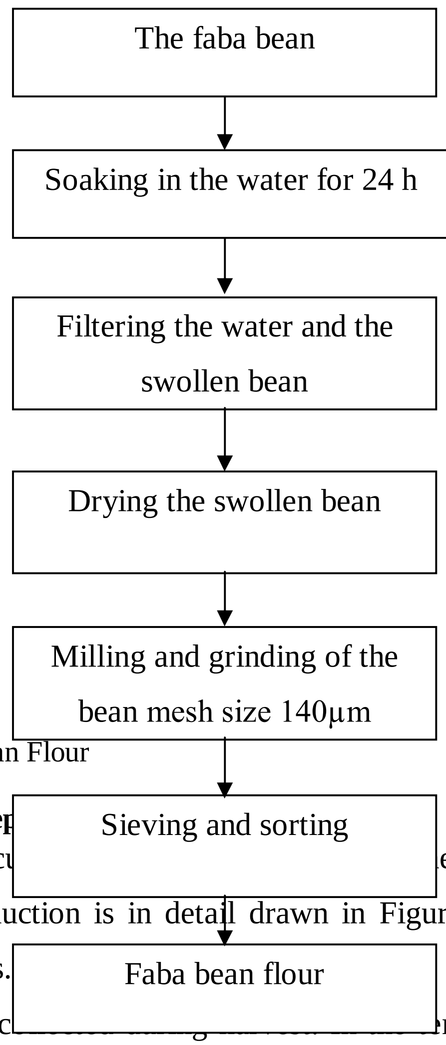


Figure-3.4. Preparation of faba Bean Flour

3.1.3. Sample Collection, and Prep

The wheat for the Kocho bisc e Kality Food Share Company. The processing of wheat flour production is in detail drawn in Figure-3.5. The industrial milling process consists of a series of operations. started by first cleaning and removing impurities that may have been c mpering (conditioning) operation, the moisture content of the kernels is adjusted to 15 to 16 percent H_2O by adding a limited amount of water this will easily make the separation of endosperm from the germ during the crushing of the wheat by the breaking roll. These breaking rollers are attached to sieves which further leads the large granules for extra milling operation using the milling rollers.

3.1.4. Enriched Kocho biscuit Preparation and Baking

After preparing all the flours the second stage was making the mix and third stage was baking biscuit. The process of biscuit making was conventional and easy. Kocho together with wheat flour and faba bean flour along with other ingredients was mixed with water.

a b

Figure-3.6. a- mixer b- oven

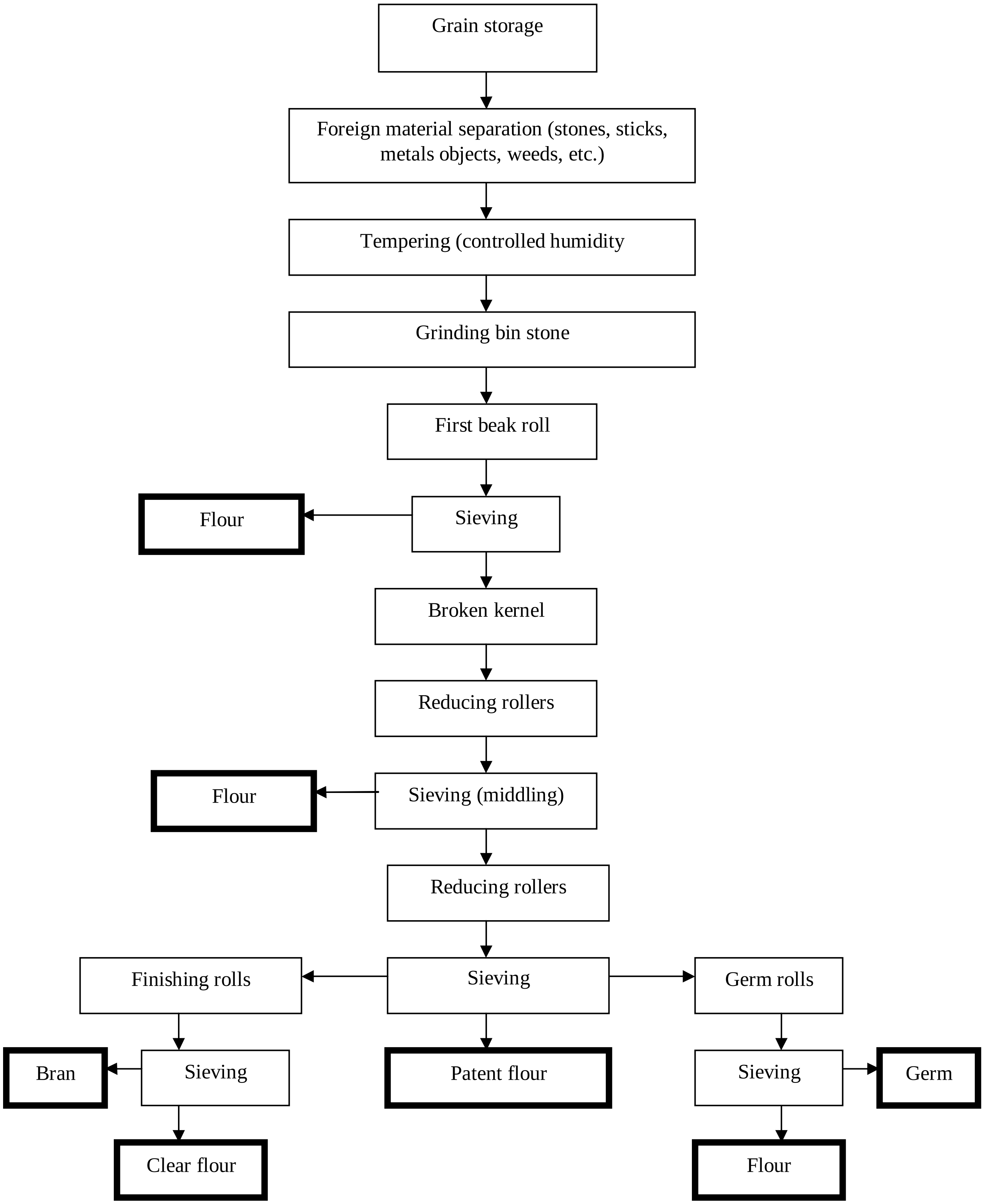


Figure-3.5. Wheat Flour Production

Then the dough was kept at a normal room temperature for about 5-10 minutes to allow proper fermentation. In the food industry, bubble formation is used to create structure and texture which is primarily responsible for the product attributes (Aguilera and Germain, 2007).

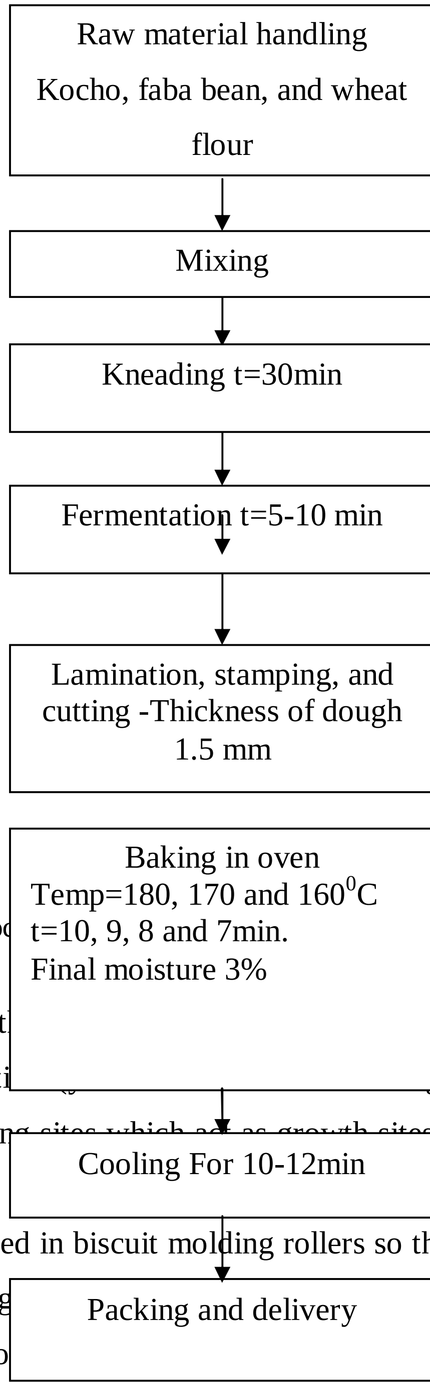


Figure-3.7 The Preparation and Proc

Bubbles are generated through t as, either through phase change (flash evaporation), or chemical reacti g). Gas that does not escape into the atmosphere is bound in nucleatin for bubbles in the expanding material (Baker and Mize, 1941).

Then fermented dough was placed in biscuit molding rollers so that it attains the proper thickness. Then this thin dough was shaped using ndi SPA Verona, Italia. After that, the biscuit was passed through the o moisture content to the minimum. The Kocho biscuits were taken and cooled and taken to EHNRI for the remaining tests. The preparation and processing flow diagram is shown in Figure-3.7.

3.2. Methods

3.2.1. Formulation of flour and time-temperature combination

The raw materials (Kocho and faba bean) for the production of enriched Kocho biscuit was brought from Areka Agricultural Research Center. The wheat flour and the rest of the recipes were purchased from Kality Food Share Company.

This enriched Kocho biscuit production underwent through different steps. And it is broadly divided in to five major methodological parts. These parts contain extra methodologies under each stage and the mechanism of how to work out those steps. The four groups are discussed bellow.

Group-I Raw material preparation

1. the preparation of Kocho flour
2. the preparation of faba bean flour
3. the preparation of wheat flour

Group-II The combination of the raw materials in the ratio pointed out in the Table-3.1. The ratios of the combination of the major raw materials are based on the fulfillment of the daily protein requirement of 39 g/day of a child of age one to seven. To fulfill this requirement, assuming that a child eats's four biscuit of each having 10g/biscuit. Based on the formulation by Youssef and Bushuk, 1998 in the production of bread from faba bean and wheat flour the percentage for faba bean incorporation with 20% and goes up with interval of 5%. Therefore the enriched Kocho biscuit was formulated as follow here under.

1. 50% Kocho flour, 25% wheat flour, and 25% faba bean flour, (KFW_F1)
2. 50% Kocho flour, 20% wheat flour, and 30% faba bean flour, (KFW_F2)
3. 50% Kocho flour, 15% wheat flour, and 35% faba bean flour, (KFW_F3)
4. A whole Kocho flour biscuit, (K_F)
5. Whole wheat flour biscuit (control), (W_F)

Group-III The baking of biscuit of the given ratio as shown in the Group-II. Depending on the ratio given in the Group-II the temperature of the baking varied by 180^0C, 170^0C, and 160^0C. And each of them is treated at four different times of heating 10min, 9min, 8min, and 7min.

1. KFW1 is further treated at three different temperature ranges 180^0C, 170^0C, 160^0C. And each treated at four different times 10min, 9min, 8min, and 7min. The same was true for the rest of the other mixing ratios listed from 2-5 here under.
2. 50% Kocho flour, 20% wheat flour, and 30% faba bean flour.
3. 50% Kocho flour, 15% wheat flour, and 35% faba bean flour.

4. A whole Kocho flour biscuit.
5. Whole wheat flour biscuit.

Group-IV The determination of proximate analysis was done at EHNRI. This was done using two steps

1. First the proximate analysis for the major raw materials (Kocho flour, wheat flour, and faba bean flour) was determined.
2. Next the proximate analysis for the final biscuit made from the given ratios above in Group-II was determined

Group-V In this stage the organoleptic test was conducted for all the five biscuit types by selected panelists.

According to different types and quantity of ingredients, different quality of biscuits was obtained. Table 3.1 shows the amount of ingredients to make 50 kg of biscuit based on the production procedure for Deredaw Food Processing manual for biscuit production.

The value of Kocho added in the first three ratios was the same and equals to be 50 % of the total of 16.8 kg of the major raw materials, but for the standard and whole Kocho flour biscuit it was used all the 16.8 kg of wheat flour and Kocho flour respectively. The quantities that will be used to vary the nutritional composition are in the case one 25% (4.2 kg of the major raw materials) wheat and 25% (4.2 kg of the major raw materials) faba bean flour; at the second ratio 20% (3.36 kg of the major raw materials) wheat and 30% (5.02 kg of the major raw materials) faba bean flour, for the third ratio 15% (2.52 kg of the major raw materials) wheat and 35% (5.88 kg of the major raw materials) of faba bean flour and finally a whole 100% (16.8 kg of the major raw materials) Kocho biscuit and whole wheat flour biscuit were made for standard. The rest of the product recipes were the same for all the five types of ratios. After this each of the different products were further treated at three different temperatures and four different heating times these are 180^0C, 170^0C, and 160^0C; and 10min, 9min, 8min, and 7 min respectively. The amount of each of the ingredients added is shown in Table-3.1 bellow. This data is to make 500 pieces of biscuit at 100g each and total weight of 50 kg.

Table-3.1. Amount of recipe to mix with 168 g of flour (major raw materials)

Raw materials and processing conditions	Amount required (g)	Calculation	Amount needed to make 50 kg
Flour	168.00 g	(168/500) ´ 50 kg	16.80 kg
Baking powder	2.50 g	(2.5/500) ´ 50 kg	0.25 kg
Vegetable shortening	84.50 g	(84.5/500) ´ 50 kg	8.45 kg

Sugar	100.00 g	(100/500) ´ 50 kg	10.00 kg
Milk products	40.00 g	(40/500) ´ 50 kg	4.00 kg
Water	85.00 g	(85/500) ´ 50 kg	8.50 kg
Salt	20.00 g	(20/500) ´ 50 kg	2.00 kg
Total	500.00 g		50 kg

The total amount of major raw materials required is the sum of each, and for Kocho it is 42 kg when we include the 10% loss during processing it will become 46.2 kg, and the rest including the loss are 16.632 kg for faba bean flour and for the wheat flour 11.088 kg. For the purpose of analysis, 500g is added in each of the major raw materials.

After the biscuit was baked the fourth stage followed which was the analysis of the flours and the final product biscuit. The products were analyzed for their nutritional quality at EHNRI. The analysis was done by following the AOAC, 2003 method to analyze the physicochemical property of the flour and biscuit. In addition, the organoleptic quality is done using 5 scale hedonic scales. The hedonic test method was used to analyze the taste, texture, appearance, flavor, color, and general acceptability of the final product.

3.2.2. Determination of flour property

1. Falling number calculation of flours

1. The properly prepared flour of 10gm was weighted and put on aluminum cups
2. The sample on the aluminum cup was put in the moisture analyzer of the type “rapid moisture tester Buher model AMB 310, Sweden ”
3. The rapid moisture analyzer was adjusted to a temperature of 130^{0}C for 9 minutes and the moisture analyzer was closed
4. When the time reached moisture content was taken from the screen
5. Corresponding to the moisture content a specified amount of flour was measured using weighting balance
6. The weighted sample was put in the measuring cylinder which is attached to the falling number tester of the type “perten falling number 1500, Sweden”
7. The sample was shake by hand till it fully dissolve then it was put in its position and the instrument starts to shake it for one minute then the falling number result was taken from the instrument screen.

2. Color analysis of flour

The color analyzer (model Stake Color Grader Series IV, Germany) uses ultra violet light to determine the absorbance of emitted lights. The detailed procedure for color analysis is shown here under.

1. Weight 30 gm of the flour
2. Put the flour in a beaker and add 50 ml of distilled water
3. Shake it for 45 seconds and pour it in the cubet
4. Take the measure at the 99 second

3. Functional property of the flour

The functional property of flour is calculated using MININFRA 2000 T grain analyzer Infacont kft Hungary.

1. First the sample holder was filled with flour
2. Then the holder was inserted in the instrument and the result was taken from the screen

4. Water and oil absorption capacity

1. One gram of the grounded flour (Kocho, faba bean, and wheat) was mixed with 10ml of distilled water or oil in a centrifuge tube of model Andreas Hettich Universal II D72, Germany.
2. And allowed to stand at room temperature (30 ± 2^0c) for one hour.
3. Then it was centrifuged for 30 min at 2000 revolution per min.
4. The supernatant was noted in a 10ml graduated cylinder. Water and oil absorption capacity was calculated as ml of water or oil absorbed per gram of the grounded flour

3.2.3. The determination of softness of the dough using farinograph

1. 300g of flour of each five mixing ratio flours were prepared and placed into the corresponding farinograph mixing bowl
2. Water from a burette was added to the flour and mixed to form a dough
3. As the dough was mixed, the farinograph recorded a curve on graph
4. The amount of water added (absorption) affects the position of the curve on the graph paper. Less water increases dough consistency and moves the curve upward.
5. The curve is centered on the 500-Brabender unit (BU) line ±20 BU by adding the appropriate amount of water and is run until the curve leaves the 500-BU line.

3.2.4. Proximate composition of enriched Kocho biscuit

The physicochemical analysis for the final product was done using the AOAC, 2003 method. The determination method of the moisture, carbohydrate, protein, fat, fiber, and ash is shown in detail in Appendix-VI.

3.2.5. Textural, water activity and sensory characteristics of biscuit

Textural characteristics of biscuit

The textural characteristics of biscuits were carried out using a texture analyzer (Model TA-Hdi, STable Microsystems, UK). Three Point Bend Jig was used for determining the breaking strength of the biscuit. Breaking strength of biscuit was measured using the HDP/BS blade. The preload stress is 5.6N and the initial grip separation is 10mm.

1. The top part of the jig fixes to the Load Cell Eye End
2. The bottom part attaches to the TA Base Table
3. Then the biscuits was put between the two jig and then lower the upper part with a speed of 2mm/s of preload speed then raised to 3mm/s during test.
4. The absolute peak force from the resulting curve was considered the breaking strength of the biscuit.
5. Return the probe at a speed of 10cm/s.

The determination water activity of flour and biscuit

1. A homogenous flour and grounded biscuit flour was prepared
2. Place the prepared sample in a sample cup, completely covering the bottom of the cup
3. The sample of flour was half filled in the cup. Overfilled cups will contaminate the sensors in the sensor chamber
4. The sample drawer knob turned to the OPEN/LOAD position and pull the drawer open.
5. The prepared sample was placed in the drawer.
6. Carefully slide the drawer closed
7. Turn the sample drawer knob to the READ position to seal the sample cup with the chamber, this start the read cycle. In about 10 minutes, the first aw measurement was displayed on the LCD. Length of read times may vary depending on how dry flour sample is.

Determination of Sensory evaluation

Sensory attributes such as color, appearance, taste, flavor, texture and overall acceptability of all the five biscuits including the control were evaluated by method using a Hedonic Rating test. Analysis of variance (ANOVA) was performed on the data gathered to determine differences, while the least significant test was used to detect significant differences among the means (Ihekoronye and Ngoddy, 1985).

A semi trained 10 panelists were selected to evaluate the total biscuits and select the preferable biscuit product. After determining the three mostly preferable biscuits from each mixing ratios, the final sensory evaluation for the 15 biscuits were done at EHNRI by the trained panelist. Samples were served to the panelists and they were asked to rate the acceptability of the product on hedonic scale, ranging from the extreme like (9) to dislike extremely (1). Their results were recorded and appropriately analyzed to determine the significance of variations of average score and the contribution of individual parameter.

3.3. Data analysis

The data obtained from the experiment were subjected to analysis using statistical software, SPSS (Statistical Package for Social Sciences) version 15.0. Whole wheat flour and its product, biscuit, are used as a control. Accordingly, ANOVA, mean comparison and significance were set at 5% level. The process parameters for Kocho biscuit were evaluated from the standard biscuit made at Kality Food Share Company. The suggested design was done using superpro version 4.7.

Chapter Four

4. Result and Discussion

4.1. Proximate composition of flours

The protein value for different flours is shown in Table-4.1 from this experiment it can be seen that faba bean flour (F_F) contributes high amount of protein and that of Kocho flour (K_F) show the lowest. Fortification of the Kocho flour with faba bean shows upgrading of the protein content from 1.78 of K_F

to 15.11 of KFW_F2, 14.22 of KFW_F1 and 13.69 of KFW_F3 in g/100g of flour at significant difference of $P \leq 0.05$.

The water activity of the flours shown in Table-4.1 that in the range of 0.47 to 0.5485 which was suitable and in a good condition of storage by restricting the access to water and reducing the chemical change inside the flour. The actual water activity of flours during storage depends on the type of the flour ranging from 0.3 to 0.6 as suggested by (Bolandi, et al., 2008).

Table-4.1. Proximate Composition of Flours

Flour type	**Type of test**			
	Protein of flour	**Ash of Flour**	**Moisture of Flour**	**Water activity**
KFW_F1	$14.22 \pm .03^{c}$	$1.05 \pm .01^{bc}$	$14.01 \pm .01^{d}$	$0.531 \pm .00^{a}$
KFW_F2	$15.11 \pm .02^{b}$	$1.08 \pm .01^{b}$	$14.28 \pm .03^{b}$	$0.537 \pm .00^{a}$
KFW_F3	$13.69 \pm .02^{d}$	$1.01 \pm .01^{c}$	$14.10 \pm .01^{c}$	$0.531 \pm .00^{a}$
K_F	$1.78 \pm .01^{f}$	$0.92 \pm .02^{d}$	$18.69 \pm .02^{a}$	$0.549 \pm .00^{a}$
W_F	$10.95 \pm .08^{e}$	$0.79 \pm .01^{e}$	$12.89 \pm .02^{e}$	$0.530 \pm .00^{a}$
F_F	$49.70 \pm .14^{a}$	$1.20 \pm .01^{a}$	$7.46 \pm .00^{f}$	$0.470 \pm .00^{b}$

$^{a-f}$ Means with the same superscript letters within a column are not significantly different ($p \leq 0.05$).

4.2. Flour Property

- **Oil and water holding capacity of the flours**

The water and oil holding capacity of each flour mixes are shown in the Table 4.2. From Table-4.2 the oil adsorption was higher in KFW_F3, which was 1.625ml per gm of the sample, where the proportion to faba bean increases to 35%and wheat of 15% and the percentage of Kocho was 50%. This shows that the hydrophobic protein in the faba bean was low and also results in an increase of the oil absorption together with increase in faba bean percentage. According to Adejuyitan, (2009) on some physicochemical properties of flour obtained from fermentation of tiger nut (*Cyperus esculentus*) shows that with increase of the nut the oil absorption also increase. This experiment shows the oil adsorption lowers in the sequence of F_F, W_F, KFW_F2, KFW_F1, and lastly K_F.

The water adsorption for the flours was higher in the faba bean flour this was because of the starch in the faba bean has hydrophilic ends so it attaches the water molecules to bind the starch molecules together. The F_F absorbs 2.975ml per gm of faba bean flour, and then followed by KFW_F1, W_F, KFW_F2, K_F and KFW_F3. As per Masakuni Tako experiment on, Rheological Properties of Wheat Amylopectin, the major binding point for water is hydrogen bonding end point also referred as polar end of the amylopectin in the starch molecule. The lower water and oil holding capacity of Kocho flour makes it viscous and difficult in making dough, however during the heat on mixing and oven treatment, the

Kocho flours in the presence of water and oil become less viscous and have better water and oil holding capacity than the other flours, this can be seen on the quality of biscuit on the texture analysis.

Table-4.2. Water and Oil Adsorption of Flour

Flour Blend	Tests			
	Oil adsorption (ml)	**Water adsorption (ml)**	**Falling Number**	**Color of Flour**
KFW_F1	1.10 ± 0.14^{d}	2.25 ± 0.14^{b}	$10.31\pm.01^{e}$	$10.42\pm.03^{d}$
KFW_F2	1.15 ± 0.00^{c}	2.05 ± 0.07^{c}	$10.41\pm.01^{d}$	$10.70\pm.01^{c}$
KFW_F3	1.63 ± 0.18^{b}	1.90 ± 0.07^{d}	$10.68\pm.01^{c}$	$10.29\pm.03^{e}$
K_F	0.50 ± 0.00^{e}	1.98 ± 0.04^{c}	$17.17\pm.08^{a}$	$16.98\pm.03^{a}$
W_F	1.18 ± 0.04^{c}	2.20 ± 0.07^{b}	$5.46\pm.21^{f}$	$5.08\pm.02^{f}$
F_F	1.93 ± 0.11^{a}	2.98 ± 0.04^{a}	$12.77\pm.14^{b}$	$12.58\pm.01^{b}$

$^{a–f}$ Means with the same superscript letters within a column are not significantly different ($p\leq0.05$).

- **Fouling number, color, and water analysis of flour**

The falling number determines whether the flour can be used for the biscuit production or for other processing by just determining the falling number. In wheat it used to determine the germination of the wheat. The lower the value of the falling number, the lower the quality of the wheat and if it is bellow the required value, it will not be used for the processing of biscuit or any other byproduct. Here in Table-4.2 the falling number for the whole Kocho flour is higher than the faba or the wheat flour. But this does not tell anything about the germination because the enzymatic activity was very low or does not exist in Kocho flour. While in faba flour the high amount tells the germination was very low. This result can also be used for other processing like pasta, macaroni, and spaghetti.

The color of the flour shows that K_F had higher intensity of 16.98. Which indicates that the darkness of the Kocho flour. This was because during the fermentation and milling the starch goes under discoloration and finally this gives a biscuit of darker color than the normal color of wheat flour of 5.08. The application of bleaching agent in wheat flour results in lower intensity of 5.08 interns gives lighter and creamy color of biscuit with the optimum time and temperature.

4.3. Farinograph analysis

The result from Table-4.3 shows that the consistency of the whole wheat flour was better than that of KFW_F3. The farinograph quality number shows that faba and KFW_F3 have the high score but the degree of softness of KFW_F3 was lower than the control wheat and results in the lower quality of the biscuit during baking. KFW_F2 shows 103 FQN which was almost closer to wheat FQN, but the DT (development time) and stability are very low which does not have very much effect on the quality of biscuit because it does not require dough development and stability like that of bread. In the Figure-4.1A the result for the KFW_F4 shows that a scattered and inconsistent graph this was because whole Kocho doesn't have gluten that makes the elasticity and stability of dough as in the case of whole wheat flour as can be seen in Figure-4.1E. The graph for KFW_F1 in Figure-4.1B shows that there was somehow better consistency than that of KFW_F4 this can be seen clearly from the graph that the gap between arrival time and the departure time was wider than that of whole Kocho. The gap tells that the stability of the dough and the stability are higher, if the gap is large. The result of KFW_F2 and KFW_F3 also showed in Figure-4.1C and Figure-4.1D respectively the stability of the dough increases while the faba bean content increases and the graph for KFW_F3 also show that which have good stability as compared to the other mixes. The dough development time for KFW_F4, KFW_F1, and KFW_F2 are difficult to differentiate from the graph, but for KFW_F3 and KFW_F5 it can be seen that the blue line from the X-axis to the high pick of the green line. In case of biscuit production the value given to dough development was less there for the dough development doesn't have major problem in the production of biscuit.

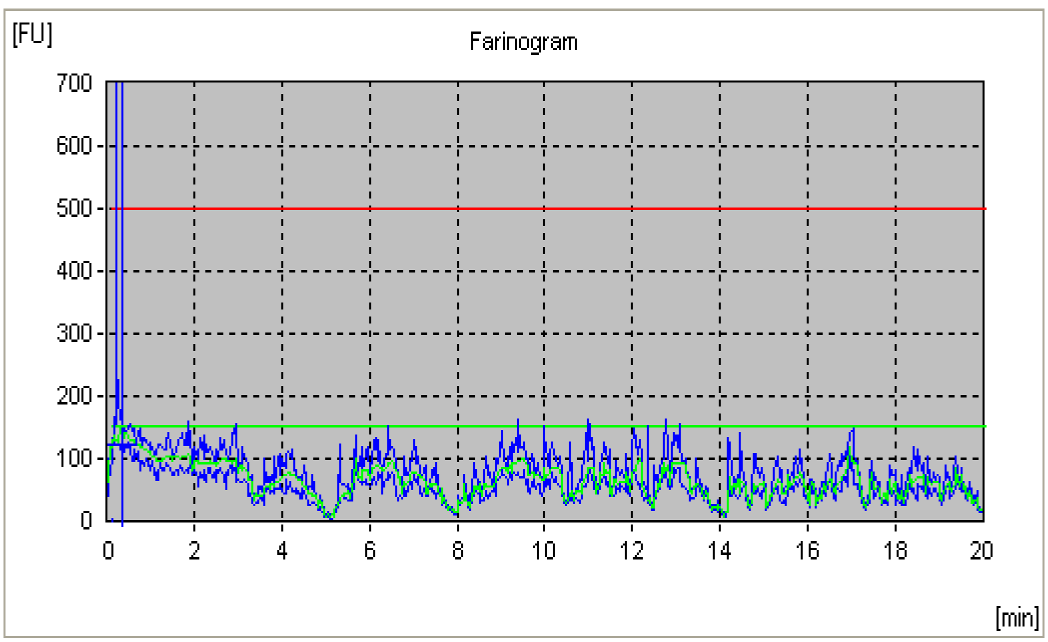


Figure-4.1A Farinograph Result of Whole Kocho Flour (KFW$_F$4)

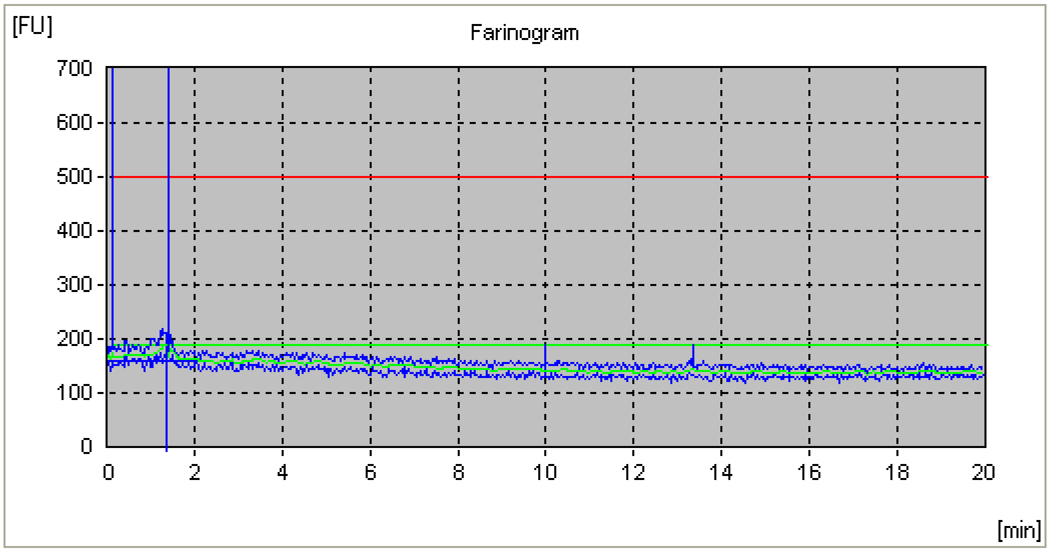


Figure-4.1B Farinograph Result of KFW$_F$1

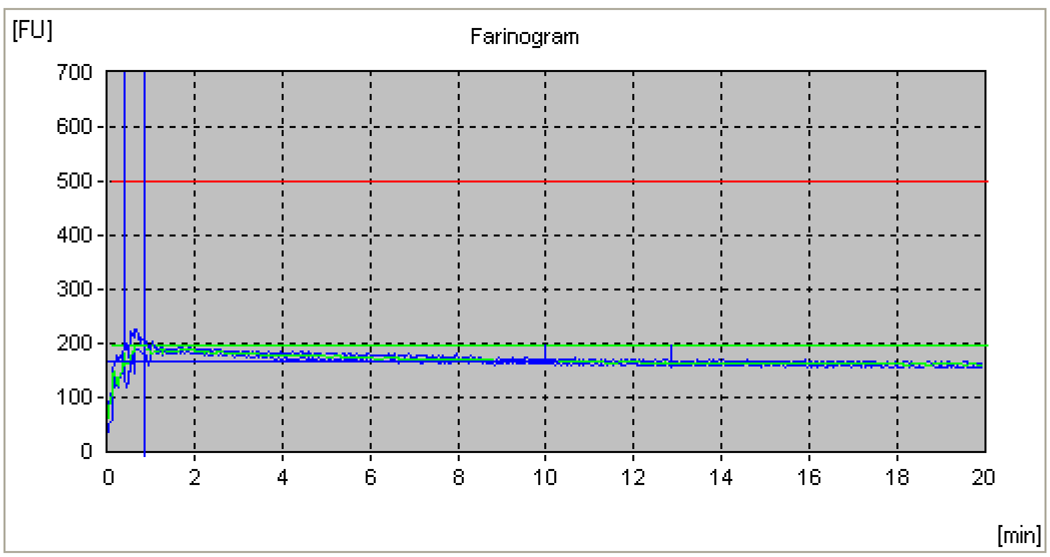


Figure-4.1C Farinograph Result of KFW$_F$2

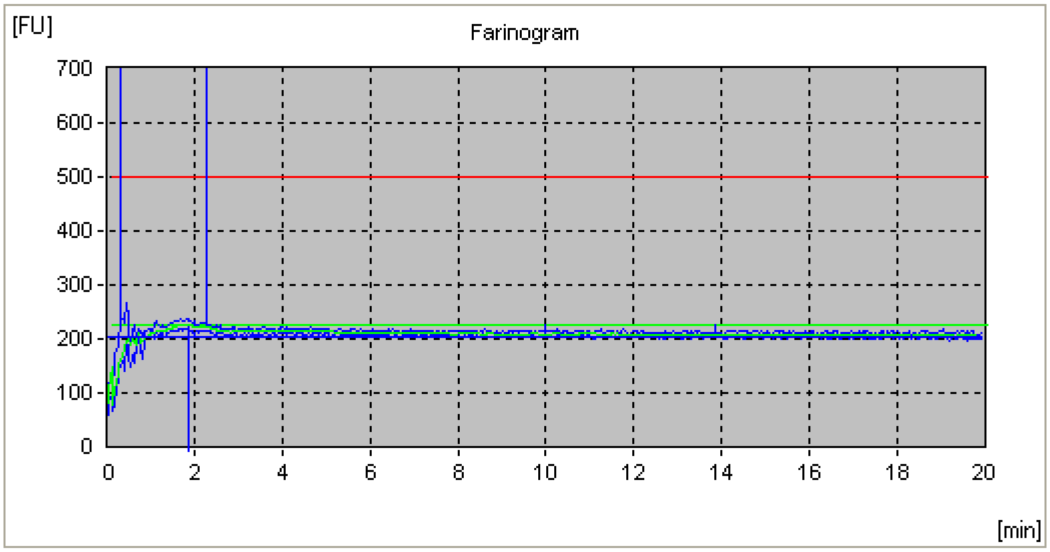


Figure-4.1D Farinograph Result of KFW$_F$3

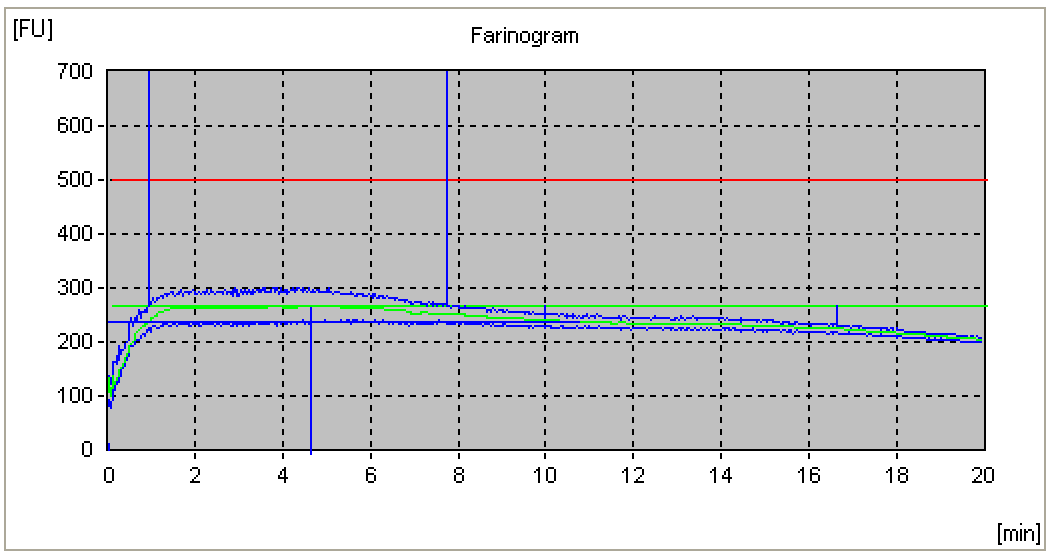


Figure-4.1E Farinograph Result of Whole Wheat (KFW$_F$5)

The higher the farinograph quality number (FQN) the better shape and large diameter of the biscuit was observed in the texture analysis of the biscuit. Both farinograph- and alveograph-strength were negatively correlated with biscuit diameter. The same results were reported by Bettge et al (1989).

Table-4.3. Farinograph Result for flour blends

Evaluation	**Moisture of flour (%)**	**Consistency (FU)**	**Water Absorption (%)**	**Devel-opment time (min)**	**Stability (min)**	**Degree of softening (FU)**	**Farinograph quality number:**

KFW_F1	15.90^{b}	192^{e}	54.50^{d}	1.4^{d}	1.3^{d}	49^{b}	21^{e}
KFW_F2	15.10^{d}	198^{d}	53.80^{e}	0.9^{e}	0.5^{e}	29^{d}	103^{d}
KFW_F3	15.30^{c}	228^{b}	54.70^{b}	1.9^{c}	2.0^{c}	18^{f}	200^{b}
K_F	20.70^{a}	155^{f}	59.80^{a}	0.4^{f}	0.1^{f}	67^{a}	7^{f}
W_F	13.40^{e}	269^{a}	53.50^{f}	4.7^{a}	6.8^{a}	27^{e}	108^{c}
F_F	14.34^{c}	205^{c}	54.60^{c}	2.6^{b}	4.9^{b}	32^{c}	206^{a}

$^{a\text{-}f}$ Means with the same superscript letters within a column are not significantly different ($p \leq 0.05$).

4.4. Effect of blend and baking time and temperature on the proximate analysis and mineral composition of enriched Kocho biscuits

- **Moisture content of the Kocho biscuit**

The moisture of biscuit is shown in Table-4.4. The moisture Content has a unit of g/100g. The difference in moisture content also shown by the subscripts it was given different letter for moisture content differencing at significance level (P) of greater than 0.05. The moisture can easily be seen from the Table for each of the mixing ratios at different time and temperature. With increasing temperature the moisture of biscuit becomes lesser and lesser infractions. This makes the biscuits to become harder and more hygroscopic. And also when the time for cooking increases the moisture value decreases. In Table-4.4 it can be easily seen that the moisture content for 160^{0}C and 7min is higher than the rest this explains the shelf life as well as the quality was low. The very low moisture content for 180^{0}Cfor 10min show that low quality due to burning and undesirable over browning reaction was occurred.

Quality biscuit should have optimum moisture content between 5-12g per 100g biscuit. So it should not be hard when chewing and should not be sticky due to high moisture content.

Table-4.4 Influence of time and temperature on moisture content of enriched Kocho biscuit (g/100g)

	160^{0}C				**170^{0}C**				**180^{0}C**			
	7min	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**
KFW_B1	1.63 ± 0.27^{ek}	2.26 ± 0.15^{df}	1.95 ± 0.07^{dh}	1.17 ± 0.01^{dl}	2.09 ± 0.03^{dg}	1.58 ± 0.00^{dk}	1.83 ± 0.12^{di}	1.73 ± 0.03^{bj}	1.82 ± 0.06^{di}	1.99 ± 0.02^{dh}	1.47 ± 0.06^{dg}	1.17 ± 0.26^{dl}
KFW_B2	3.14 ± 0.07^{bg}	3.17 ± 0.72^{ag}	3.49 ± 0.18^{af}	1.98 ± 0.01^{bk}	2.22 ± 0.02^{cj}	2.21 ± 0.02^{cj}	2.94 ± 0.09^{bh}	1.71 ± 0.01^{bm}	2.33 ± 0.04^{ci}	2.32 ± 0.11^{ci}	1.82 ± 0.12^{cl}	1.64 ± 0.14^{bn}
KFW_B3	3.67 ± 0.13^{ag}	2.77 ± 0.03^{bl}	2.99 ± 0.01^{bj}	2.84 ± 0.03^{ak}	3.80 ± 0.12^{af}	2.63 ± 0.03^{am}	3.25 ± 0.08^{ai}	2.75 ± 0.04^{al}	3.34 ± 0.14^{ah}	3.67 ± 0.02^{ag}	3.65 ± 0.10^{ag}	2.60 ± 0.07^{am}
KFW_B4	1.92 ± 0.07^{df}	1.44 ± 0.01^{ej}	1.58 ± 0.14^{ei}	1.06 ± 0.02^{em}	1.74 ± 0.01^{eh}	1.27 ± 0.04^{ek}	1.60 ± 0.03^{ei}	1.20 ± 0.10^{dl}	1.82 ± 0.03^{dg}	1.54 ± 0.03^{ei}	1.40 ± 0.08^{ej}	$.92 \pm 0.08^{en}$
KFW_B5	$2.95 \pm$	$2.37 \pm$	$2.29 \pm$	$1.69 \pm$	$2.70 \pm$	$2.39 \pm$	$2.02 \pm$	$1.45 \pm$	$2.71 \pm$	$2.42 \pm$	$1.96 \pm$	$1.42 \pm$

	0.09^{cf}	0.01^{ci}	0.04^{cj}	0.03^{cm}	0.07^{bg}	0.02^{bh}	0.01^{ck}	0.02^{cn}	0.05^{bg}	0.00^{bh}	0.02^{bl}	0.04^{cn}

$^{a-e}$ Means with the same superscript letters within a column are not significantly different ($p \leq 0.05$).

(Effect of blend on composition)

$^{f-n}$ Means with the same superscript letters within a row are not significantly different ($p \leq 0.05$). (Effect of time and temperature on same blend)

- **Crude Protein Content of Kocho biscuit**

Hereunder in Table 4.6 shows that with increasing the faba bean content the protein value increases. On the other hand the value of protein was higher in the KFW_B2 mix. The control wheat biscuit contains between 5-6% protein content. And the protein value of the whole Kocho biscuit was much lower than the required value for a normal person. Therefore improving the protein value of the Kocho was required and this can be achieved by adding faba bean.

The value of protein decreases in correspondence with time and temperature increases. KFW_B2 data shows high and somehow close to each other result. The change in protein content revealed that minimum change along time-temperature change. Even though the change is significant the protein denaturation by temperature results in reduction of the protein content of the biscuit. The change in protein value was large along the blend due to the high amount of protein in faba bean and lower amount of protein in Kocho flour results variation of the protein content in the blends.

Table-4.5. crude protein result for Kocho biscuit with varying blend and time-temperature (g/100g)

	160^{0}C				**170^{0}C**				**180^{0}C**			
	7min	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**
KFW_B1	8.11± 0.03^{cf}	7.79± 0.00^{ch}	7.80± 0.01^{ch}	7.93± 0.01^{cg}	7.59± 0.01^{ci}	7.61± 0.02^{ci}	7.13± 0.01^{cl}	7.49± 0.15^{cj}	7.65± 0.02^{ci}	7.17± 0.09^{cl}	7.05± 0.03^{cm}	7.40± 0.01^{ck}
KFW_B2	9.58± 0.02^{bj}	9.52± 0.02^{ak}	9.95± 0.39^{af}	9.18± 0.02^{am}	9.19± 0.02^{bm}	9.80± 0.01^{ahg}	9.69± 0.08^{ai}	9.75± 0.01^{ah}	9.26± 0.33^{bl}	9.74± 0.01^{ahi}	9.69± 0.03^{ai}	9.85± 0.07^{ag}
KFW_B3	9.96± 0.03^{af}	8.90± 0.02^{bl}	8.98± 0.01^{bl}	8.98± 0.03^{bl}	9.95± 0.00^{af}	9.51± 0.06^{bh}	8.99± 0.09^{bl}	9.08± 0.00^{bk}	9.86± 0.00^{ag}	9.31± 0.09^{bi}	9.23± 0.01^{bj}	9.56± 0.58^{bh}
KFW_B4	1.11± 0.01^{eg}	1.08± 0.01^{eg}	1.05± 0.01^{eh}	1.02± 0.02^{ehi}	1.09± 0.01^{eg}	1.01± 0.00^{ehi}	1.01± 0.00^{ehi}	.96± 0.01^{ei}	1.17± 0.02^{ef}	1.02± 0.02^{ei}	1.06± 0.01^{egh}	.98± 0.09^{ei}
KFW_B5	5.70± 0.05^{df}	5.66± 0.00^{dfg}	5.61± 0.01^{dg}	5.60± 0.02^{dg}	5.61± 0.01^{dg}	5.63± 0.01^{dg}	5.43± 0.01^{di}	5.42± 0.01^{di}	5.53± 0.02^{dh}	5.40± 0.08^{di}	5.41± 0.03^{di}	5.40± 0.03^{di}

$^{a-e}$ Means with the same superscript letters within a column are not significantly different ($p \leq 0.05$).

(Effect of blend on composition)

$^{f-m}$ Means with the same superscript letters within a row are not significantly different ($p \leq 0.05$). (Effect of time and temperature on same blend)

The most important documented forms of malnutrition reported by Ymer.G, (2000) and Kaluski et al., (2002) in the countrywide in Ethiopia were protein and energy malnutrition, and zinc deficiencies. To accommodate these faba beans fortified Kocho biscuit plays an important role as can be seen in the Table-4.5.

- **Fat Content of enriched Kocho biscuit**

The value of fat content varies along the different mixing ratios and time- temperature treatment. The difference along the different mixing ratios was due to the difference in the oil absorption during the mixing of the flour and the vegetable shortening. During mixing there was a development of heat and this allows the shortening to melt to some extent and absorbed by the flour. Heating in the oven even makes the shortening to melt and to be absorbed, but the high temperature and long time treatment can cause the fat to melt it out from the flour.

Table-4.6 Fat Result for Kocho biscuit and effect of baking time and temperature on the blend (g/100g)

	160^0C				170^0C				180^0C			
	7min	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**
KFW$_B$1	14.65 ±0.22^{ck}	14.95 ±0.17^{ci}	14.41 ±0.34^{cl}	15.07± 0.28^{bh}	16.42 ±0.05^{af}	14.91 ±0.06^{bi}	15.04 ±0.23^{ch}	14.69± 0.23^{bk}	15.15± 0.06^{cg}	14.77± 0.17^{bj}	15.04± 0.08^{ch}	14.76± 0.61^{bj}
KFW$_B$2	15.18 ±0.38^{bg}	14.96 ±0.01^{ch}	12.39 ±0.18^{dl}	14.50± 0.18^{ci}	15.20 ±0.30^{cg}	14.96 ±0.01^{bh}	12.40 ± 0.18^{el}	14.50± 0.18^{ci}	16.03± 0.37^{bf}	13.53± 0.37^{ej}	13.12± 0.10^{ek}	13.07± 0.26^{ek}
KFW$_B$3	13.23 ±0.06^{em}	15.59 ±0.05^{bi}	16.81 ±0.02^{bh}	12.64± 0.20^{eo}	14.37 ±0.11^{dk}	14.88 ± 0.14^{cj}	17.68 ±0.22^{ag}	13.72± 0.20^{dl}	13.00± 0.27^{en}	14.42± 0.07^{ck}	18.19± 0.19^{af}	13.74± 0.17^{cl}
KFW$_B$4	13.85 ±0.14^{di}	14.03 ±0.16^{dg}	12.46 ±0.09^{cm}	13.86± 0.15^{di}	13.49 ± 0.03^{ej}	13.44 ±0.45^{dj}	13.86 ±0.15^{di}	12.60± 0.21^{el}	14.40± 0.23^{df}	13.81± 0.03^{di}	13.94± 0.03^{dh}	13.33± 0.13^{dk}
KFW$_B$5	17.33 ± 0.08^{aj}	17.08 ±0.12^{ak}	17.55 ± 0.08^{ah}	16.90± 0.07^{al}	16.36 ±0.13^{bm}	17.46 ± 0.15^{ai}	17.57 ±0.23^{bh}	17.55± 0.10^{ah}	18.55± 0.21^{af}	18.20± 0.23^{ag}	17.12± 0.08^{bk}	15.56± 0.19^{ah}

$^{a-e}$ Means with the same superscript letters within a column are not significantly different ($p \leq 0.05$)

(Effect of blend on composition)

$^{f-o}$ Means with the same superscript letters within a row are not significantly different ($p \leq 0.05$) (Effect of time and temperature on same blend)

The fat content is mainly depends on the oil absorption of the flours from that result whole wheat flour has high oil absorption the same thing was also true on the result for the biscuit from whole wheat (KFW$_B$5). This can be shown in Table 4.7. The oil absorption was low in whole Kocho flour and this was also true for the biscuit (KFW$_B$4).

The data from Table-4.6 shows that the fat content was higher in wheat biscuit and lower in the whole Kocho biscuit. This indicates that the oil absorption was higher in wheat flour than Kocho or faba bean blended biscuit. The fat content of the biscuit results in cholesterol and other heart diseases therefore obtaining intermediate fat content in biscuit is necessary. Low fat biscuit should contain 7.5-15% and medium fat biscuit contain from 15-27% and high biscuit contains more than 27%.

The temperature and time of baking has lower significance on the fat content of the biscuit because the melting point of fat is lower than 150^{0}C for the vegetable shortening as well as the fat content of the Kocho, faba bean and wheat flours. The only thing that matters in the fat content of the biscuit is the oil binding property of the flours.

- **Crude Fiber Content of enriched Kocho biscuit**

The fiber content of the biscuits shows a wide range of difference between different blend and baking time and temperature combination. The data show that the fiber content was higher in wheat flour as it can be seen in Table-4.7. This was because the wheat flour contains fiber and the faba bean and the Kocho flour have been sieved with140micron sieve this results in separation of the fibers before processing. The high fiber content of Kocho makes it more advantageous for health by contributing to reduction of fat and reducing the risk of cancer and cholesterol. The main problem is that the Kocho has long fibers that can't pass through the 140 micron sieve. This makes full Kocho biscuit to have low amount of fiber therefore there should be another process to shred the fibers to finer form so that it can be applicable for incorporation in the formula.

With increase baking temperature and time the fiber content shows a reduction as can be seen in Table-4.7. The high amount of fiber content was observed in the blend KFW_B1 processed at 160^{0}C for 7min. and the low amount was recorded on blend KFW_B4 of full Kocho processed at 180^{0}C for 7min this shows that the temperature and time combination have greet effect on the fiber content of the biscuit.

A wide variety of fiber sources have been developed for use in various foods to provide more fiber. There are medical studies about the benefits of total dietary fibers consumption such as falling serum cholesterol concentration, lowering the risk of coronary heart disease, reducing blood pressure, aiding weight control, improving glycemic control, reducing the risk of certain types of cancer and improving gastrointestinal functions (Bonithonp et al., 2000; Terry, 2001; Bingham, 2003; Ferguson & Harris, 2003; Peters, 2003; Tames et al., 2003; Skeaff et al., 2005). As a result, fibers from different sources and compositions are being obtained, and the fortification of foods with dietary fibers is increasing (Manoela et al., 2008). Even though it is recommended that 25g/day of fiber, there is no limit of fiber incorporation in biscuit.

Table -4.8 Crude Fiber Result for Kocho biscuit with different blend and time-temperature (g/100g)

	160^{0}C				**170^{0}C**				**180^{0}C**			
	7min	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**

KFW$_B$1	4.76± 0.15^{bf}	2.95± 0.12^{dk}	1.45± 0.33^{cl}	.83± 0.01^{cn}	4.21± 0.21^{bg}	3.41± 0.07^{bi}	.90± 0.07^{cm}	.74± 0.03^{co}	3.48± 0.54^{bh}	3.15± 0.04^{bj}	.92± 0.06^{dm}	.67± 0.02^{bp}
KFW$_B$2	5.37± 0.08^{ag}	3.18± 0.01^{cj}	1.98± 0.05^{bl}	.975± 0.02^{bn}	5.27± 0.08^{ah}	2.81± 0.04^{ck}	1.32± 0.03^{bm}	.87± 0.01^{bo}	5.54± 0.07^{af}	3.44± 0.04^{ai}	1.03± 0.01^{bn}	.72± 0.01^{bp}
KFW$_B$3	2.39± 0.06^{ci}	4.25± 0.02^{bf}	2.44± 0.04^{ai}	1.36± 0.05^{am}	1.50± 0.06^{dl}	3.87± 0.16^{ag}	2.05± 0.13^{aj}	1.19± 0.03^{an}	.77± 0.12^{dp}	3.14± 0.01^{bh}	1.66± 0.03^{ak}	.96± 0.01^{ao}
KFW$_B$4	.55± 0.01^{egh}	.53± 0.02^{agh}	.56± 0.02^{egh}	.57± 0.02^{dg}	.50± 0.04^{eh}	.65± 0.01^{ef}	.47± 0.01^{dh}	.63± 0.02^{df}	.41± 0.01^{ei}	.48± 0.02^{dh}	.51± 0.03^{eh}	.61± 0.03^{cf}
KFW$_B$5	2.02± 0.08^{df}	1.64± 0.03^{ei}	1.03± 0.03^{dl}	.96± 0.02^{bm}	1.79± 0.07^{ch}	1.49± 0.03^{dj}	1.30± 0.03^{bk}	.84± 0.03^{bn}	1.90± 0.05^{cg}	1.25± 0.02^{ck}	.99± 0.01^{cm}	.96± 0.03^{am}

$^{a-e}$ Means with the same superscript letters within a column are not significantly different ($p \leq 0.05$).

(Effect of blend on composition)

$^{f-p}$ Means with the same superscript letters within a row are not significantly different ($p \leq 0.05$). (Effect of time and temperature on same blend)

- **Carbohydrate for the Kocho biscuit**

The result for the carbohydrate was calculated by subtracting the moisture, protein, fat, crude fiber and ash from the total weight on dry bases. It can be seen in Table-4.8 that the KFW$_B$4 (Kocho biscuit) shows high amount of carbohydrate than the control KFW$_B$5 (wheat biscuit). The mixes show a remarkable result of which between 70and 75%. Along time and temperature change the value of the CHO vary in small amount.

The high amount of CHO in KFW$_B$4 was due to Kocho flour was whole starch food and its result also shows high amount as can be seen in Table-4.8. For the rest of the blends the CHO was almost similar but significantly different at $p \leq 0.05$.

The time and temperature of baking biscuit has low significance because increase in time and temperature of baking results in the gelatinization of the starch in the biscuit and convert it in to simpler forms of CHO. Even though the dependence of the CHO on time and temperature is very low it does not mean CHO is not dependent on time and temperature rather high amount of temperature results in the complete burning of the carbon in the structure of the CHO in the presence of Oxygen.

Table-4.8 Carbohydrates Result for different blends and time temperature combinations (g/100g)

	160^{0}C				**170^{0}C**				**180^{0}C**			
	7min	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**
KFW$_B$1	71.85± 0.05^{ck}	71.94± 0.34^{cj}	72.75± 0.36^{bh}	72.83± 0.28^{dg}	69.69± 0.07^{em}	72.10± 0.12^{di}	72.15± 0.21^{ci}	72.66± 0.27^{ei}	71.26 ±0.14^{cl}	71.94 ±0.23^{dj}	74.20 ±0.00^{bf}	72.70± 0.27^{eh}
KFW$_B$2	70.18± 0.28^{eo}	70.15± 0.77^{eo}	72.19± 0.79^{cj}	72.45± 0.30^{ei}	71.51± 0.29^{dk}	71.15± 0.06^{el}	71.08± 0.21^{dm}	74.31± 0.29^{bf}	70.44 ±0.09^{en}	72.40 ±0.43^{ci}	73.39 ±0.18^{ch}	73.49± 0.32^{dg}
KFW$_B$3	72.83± 0.24^{bi}	71.50± 0.03^{dm}	70.23± 0.02^{dn}	74.28± 0.16^{bf}	72.13± 0.00^{cl}	72.66± 0.15^{bj}	69.76± 0.20^{eo}	73.85± 0.47^{ch}	74.00 ±0.14^{bg}	72.51 ±0.02^{bk}	69.05 ±0.03^{ep}	74.23± 0.26^{cf}
KFW$_B$4	80.47±	81.01±	82.27±	81.56±	80.94±	81.57±	80.75±	82.63±	80.12	81.07	80.98	82.24±

	0.04^{am}	0.02^{aj}	0.07^{ag}	0.12^{ah}	0.03^{ak}	0.41^{ah}	0.25^{al}	0.13^{af}	$\pm 0.24^{an}$	$\pm 0.07^{ai}$	$\pm 0.09^{ak}$	0.22^{ag}
KFW_B5	71.75 ± 0.23^{dm}	72.58 ± 0.14^{bk}	72.22 ± 0.08^{cl}	73.65 ± 0.14^{cg}	73.09 ± 0.27^{bi}	72.22 ± 0.11^{cl}	72.75 ± 0.25^{bj}	73.21 ± 0.04^{dh}	70.96 ± 0.10^{dn}	71.71 ± 0.11^{em}	73.22 ± 0.04^{dh}	75.42 ± 0.21^{bf}

$^{a-e}$ Means with the same superscript letters within a column are not significantly different ($p \leq 0.05$).

(Effect of blend on composition)

$^{f-o}$ Means with the same superscript letters within a row are not significantly different ($p \leq 0.05$). (Effect of time and temperature on same blend)

- **Ash Content for Kocho biscuit**

The ash content of the biscuits made from the whole Kocho showed high score this was due to the high amount of ash in Kocho. In wheat flour biscuit the ash content is lower than the KFW_B4 as shown in Table-4.9. The mixes show different value along the mix and a significance difference between time-temperature treatments. The more the ash content the more the mineral it contains. This makes Kocho flour to be more valuable to mineral supplement in the enrichment of the biscuit.

Even though blend has the higher effect on the ash content of the biscuit time and temperature has also significan effect as can be seen from the table 4.10. Since ashing takes place at higher temperature of 550^0C for 12h the effect of temperature and time on the ash content of the biscuit is low.

Table-4.9 Ash Content of Kocho biscuit with different blend and time-temperature (g/100g)

	160^0C				**170^0C**				**180^0C**			
	7min	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**
KFW_B1	1.91 ± 0.04^{dg}	1.95 ± 0.01^{ef}	1.90 ± 0.09^{eg}	1.96 ± 0.05^{df}	1.85 ± 0.01^{dh}	1.90 ± 0.01^{eg}	1.98 ± 0.04^{cf}	1.84 ± 0.01^{eh}	1.91 ± 0.02^{dg}	1.98 ± 0.02^{cf}	1.88 ± 0.01^{egh}	1.82 ± 0.01^{ei}
KFW_B2	1.92 ± 0.04^{dh}i	2.20 ± 0.02^{df}	1.97 ± 0.03^{dh}	1.88 ± 0.14^{ej}	1.88 ± 0.01^{dj}	2.11 ± 0.00^{dg}	1.99 ± 0.04^{ch}	1.99 ± 0.01^{dh}	1.95 ± 0.01^{cdhi}	2.01 ± 0.04^{ch}	1.98 ± 0.01^{dh}	1.94 ± 0.01^{di}
KFW_B3	2.17 ± 0.08^{ch}	2.35 ± 0.04^{bf}	2.16 ± 0.06^{ch}	2.30 ± 0.02^{bf}	2.11 ± 0.01^{ci}	2.22 ± 0.00^{cg}	2.18 ± 0.08^{bg}	2.19 ± 0.08^{cg}	2.00 ± 0.02^{cj}	2.23 ± 0.01^{bg}	2.06 ± 0.07^{ck}	2.03 ± 0.03^{cj}
KFW_B4	2.66 ± 0.02^{ah}	2.44 ± 0.14^{ak}	2.65 ± 0.02^{agh}	2.50 ± 0.03^{aj}	2.73 ± 0.06^{ag}	2.70 ± 0.08^{ag}	2.79 ± 0.07^{af}	2.60 ± 0.04^{ai}	2.49 ± 0.02^{aj}	2.55 ± 0.09^{ai}	2.62 ± 0.01^{ah}	2.52 ± 0.10^{aji}
KFW_B5	2.26 ± 0.02^{bg}	2.31 ± 0.02^{cg}	2.33 ± 0.02^{bf}	2.16 ± 0.06^{ci}	2.23 ± 0.06^{bh}	2.30 ± 0.01^{bg}	2.23 ± 0.04^{bh}	2.37 ± 0.03^{bf}	2.24 ± 0.03^{bh}	2.27 ± 0.03^{bg}	2.29 ± 0.02^{bg}	2.19 ± 0.04^{bhi}

$^{a-e}$ Means with the same superscript letters within a column are not significantly different ($p \leq 0.05$).

(Effect of blend on composition)

$^{f-k}$ Means with the same superscript letters within a row are not significantly different ($p \leq 0.05$). (Effect of time and temperature on same blend)

- **Mineral content of Kocho biscuit**

The mineral content for each mix of biscuit was made by taking the combination of time and temperature at 7min and 160 ^{0}C respectively for each of the biscuit blends because baking time and temperature doesn't have significant effect on the mineral composition rather it mainly depend on the blend. The results shown in Table-4.10 that the amount of Zn, Fe, and Ca are higher in KFW_B4 of the full Kocho biscuit than KFW_B5 of the full wheat biscuit. And a significant increase also can be seen Mg and Na. See Table-4.10 for more detailed result.

Studies by Tilahun et al., 2005 in Ethiopia showed that about 45% of the children were stunted and about 42% were underweight, in association with zinc, iron, and deficiencies. This makes the Kocho and faba bean application in the meal formula reduces the risk of mineral deficiency and malnutrition (under nutrition) problems in Ethiopia.

The amount of ash in the biscuit is directly proportional to the mineral composition of the biscuit. This means that the higher amount of ash in the full Kocho biscuit have the higher amount of the mineral this can be also be proven by seeing the Table-4.10. The combination of the full Kocho flour with faba bean and wheat results in the improvement of the mineral composition of the wheat as well as the faba bean.

Table-4.10 Mineral Content of Kocho biscuit with different blend (mg/100gm)

Biscuit Blend	Mineral					
	Mn	**Zn**	**Fe**	**Ca**	**Mg**	**Na**
KFW_B1	$0.18±0.01^{ab}$	$0.46±0.02^{b}$	$2.53±0.04^{c}$	$10.37±0.07^{d}$	$3.25±0.02^{a}$	$12.46±0.11^{d}$
KFW_B2	$0.22±0.02^{a}$	$0.54±0.03^{a}$	$3.40±0.32^{b}$	$12.07±0.45^{c}$	$3.30±0.02^{a}$	$13.67±0.40^{a}$
KFW_B3	$0.21±0.01^{a}$	$0.46±0.00^{b}$	$4.13±0.73^{a}$	$12.73±0.44^{b}$	$3.25±0.01^{a}$	$13.34±0.23^{b}$
KFW_B4	$0.09±0.00^{c}$	$0.35±0.00^{c}$	$2.07±0.01^{d}$	$17.58±0.01^{a}$	$2.71±0.00^{b}$	$12.67±0.03^{c}$
KFW_B5	$0.15±0.02^{b}$	$0.28±0.01^{d}$	$1.66±0.02^{e}$	$7.25±0.01^{e}$	$2.49±0.06^{c}$	$12.18±0.05^{e}$

$^{a-e}$ Means with the same superscript letters within a column are not significantly different ($p≤0.05$).

(Effect of blend on composition)

Zinc is an essential trace element as well as a micronutrient that is required for a broad range of biologic activities and is nontoxic with the exception of a very high dose (Anshoo et al., 2008). In Table-4.10the Zn value vary within 0.28 of whole wheat to 0.54 of KFW_B2 which was good source of Zn in KFW_B2. The results from BlazenkaS ebecic and Irena Vedrina-Dragojevic show that the Zn content in different kinds of biscuits ranges from 0.589 up to 1.764 mg/100g.

Iron is essential for cell maturation, protein formulation and as a carrier of oxygen throughout the bloodstream. Infants and women have the highest probability for iron deficiency. Iron is available in many forms in different foods. The Fe composition of KFW_B3 was 4.13 mg/100gm and this was the high because of the faba bean and Kocho presence. The Fe content of whole wheat biscuit was 1.66mg/100gm, which was very low.

4.5. Water activity of the biscuits

The water activity of the biscuit is mainly depends on the gravitational property, osmotic property, and matrix property of the biscuit. The result in KFW$_B$1, KFW$_B$2, KFW$_B$3 and KFW$_B$4 shows that almost bellow 0.6% as can be seen in Table-4.11 which results in a good preservative effect in preventing microbial growth. While in KFW$_B$5 the result goes up to 0.6 and above which gives more access to microbial growth than the rest of the biscuit samples. Water activity can be determined rapidly and accurately. Correlating water activity with shelf-life is of critical importance in work with bio-control formulations (Connick, 1996).

The graph in Figure-4.2 can be easily seen that the water activity for the whole wheat biscuit was higher than all, but the water activity for whole Kocho biscuit was very low. The result from M. Bolandi in Shelf-life Determination of Saffron Stigma Water Activity and Temperature Studies shows also that the water activity was higher in low temperature treated saffron. The shelf life of the biscuit is also influenced by the water activity in the product (Bolandi et al., 2008).

Table-4.11 Water Activity of Kocho biscuit with respect to blend and baking time and temperature

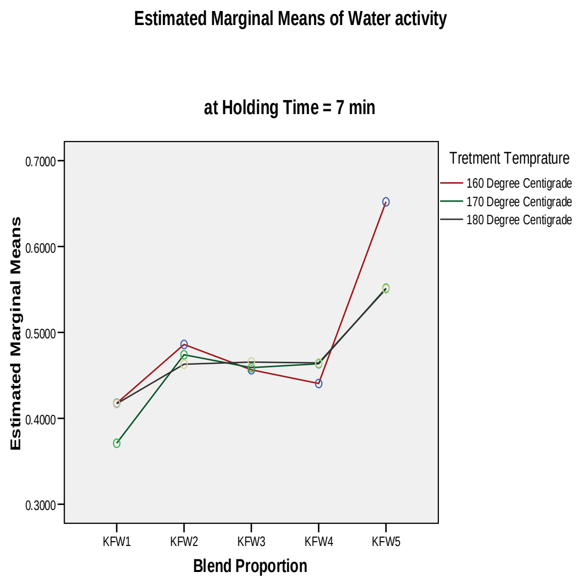
	160^{0}C				**170^{0}C**				**180^{0}C**			
	7min	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**
KFW$_B$1	0.417 $\pm0.00^{c}$	0.407 $\pm0.00^{c}$	0.426 $\pm0.00^{c}$	0.419 $\pm 0.00^{b}$	0.371 $\pm0.00^{c}$	0.402 $\pm0.00^{c}$	0.399 $\pm0.00^{cb}$	0.410 $\pm 0.00^{b}$	0.417 $\pm0.00^{b}$	0.412 $\pm0.00^{c}$	0.434 $\pm0.00^{b}$	0.409 $\pm0.0^{b}$
KFW$_B$2	0.486 $\pm0.00^{b}$	0.482 $\pm0.00^{b}$	0.482 $\pm0.00^{b}$	0.467 $\pm 0.00^{b}$	0.474 $\pm0.00^{b}$	0.463 $\pm0.00^{b}$	0.472 $\pm 0.00^{b}$	0.474 $\pm 0.00^{b}$	0.463 $\pm0.00^{b}$	0.474 $\pm0.00^{b}$	0.474 $\pm0.00^{b}$	0.476 $\pm0.0^{b}$
KFW$_B$3	0.456 $\pm0.00^{b}$	0.459 $\pm0.00^{b}$	0.451 $\pm0.00^{b}$	0.454 $\pm 0.00^{b}$	0.459 $\pm0.00^{b}$	0.460 $\pm0.00^{b}$	0.453 $\pm 0.00^{b}$	0.462 $\pm 0.00^{b}$	0.465 $\pm0.00^{b}$	0.473 $\pm0.00^{b}$	0.459 $\pm0.00^{b}$	0.452 $\pm0.0^{b}$
KFW$_B$4	0.440 $\pm0.00^{b}$	0.468 $\pm0.00^{b}$	0.462 $\pm0.00^{b}$	0.427 $\pm 0.00^{b}$	0.463 $\pm0.00^{b}$	0.464 $\pm0.00^{b}$	0.426 $\pm 0.00^{b}$	0.412 $\pm 0.00^{b}$	0.464 $\pm0.00^{b}$	0.443 $\pm0.00^{b}$	0.422 $\pm0.00^{b}$	0.398 $\pm0.0^{b}$
KFW$_B$5	0.652 $\pm0.0^{ad}$	0.626 $\pm0.00^{ad}$	0.623 $\pm0.00^{ad}$	0.601 $\pm 0.0^{ad}$	0.551 $\pm0.00^{ae}$	0.546 $\pm0.00^{ae}$	0.543 $\pm0.00^{ae}$	0.537 $\pm0.00^{ae}$	0.550 $\pm0.00^{ae}$	0.527 $\pm0.00^{ae}$	0.522 $\pm0.00^{ae}$	0.516 $\pm0.0^{ae}$

$^{a-c}$ Means with the same superscript letters within a column are not significantly different ($p \leq 0.05$).

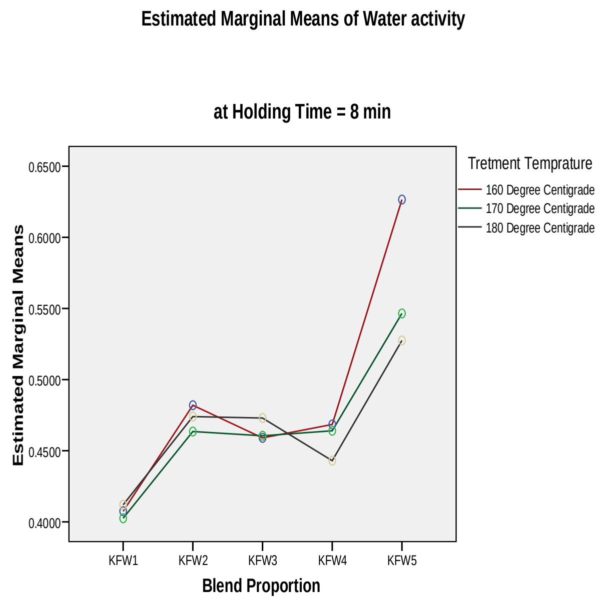
(Effect of blend on composition)

$^{d-e}$ Means with the same superscript letters within a row are not significantly different ($p \leq 0.05$). (Effect of time and temperature on same blend)

The water activity of the biscuit depends on both blend and baking time and temperature. The blend of the biscuit has a major factor respecting to the matrix and osmotic property formed between the blends and the ability to hold water molecules together so that it cannot be used by microorganisms. The osmotic property of the blend is the ability to let of the moisture pass



a



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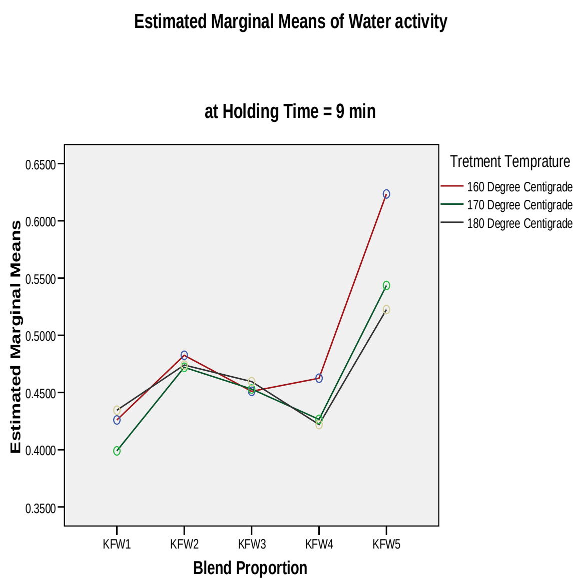

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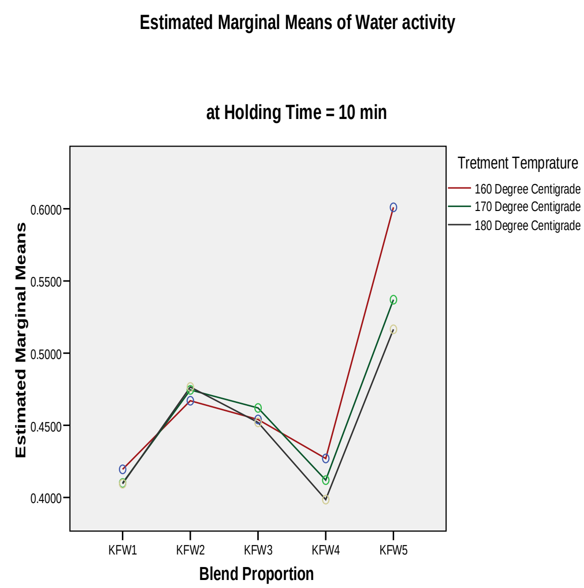


d

Figure-4.2 Water Activity for Kocho biscuit as function of time a: is for biscuit at 7min, b: is for biscuit at 8min, c: is for biscuit at 9min and d: is for biscuit at 10min.

through due to evaporation process. The gravitational properties of the blends have direct relation to the baking time and temperature of the biscuit. The application of heat results in the evaporation of the water molecules due to the deference in the gravitational force between the water molecule and the vapor form (steam). This results in the raising of the steam upward and detaches from the matrix bond giving low water activity in the biscuit.

4.6. Textural characteristics of Enriched Kocho biscuit

How crunchy are biscuits? For the consumer, a cookie's ideal texture is crunchiness (but not difficult to bite) and crumbliness (but not on the verge of disintegration). The application of three-point bend rig taste is the most convenient and accurate measurement method. A flexure unit is attached to the load cell. The unit is lowered centrally between the two supports on which the cookie rests, measuring the force needed to bend or snap the product. As the test progresses, the force imparted increases steadily as the cookie resists breaking.

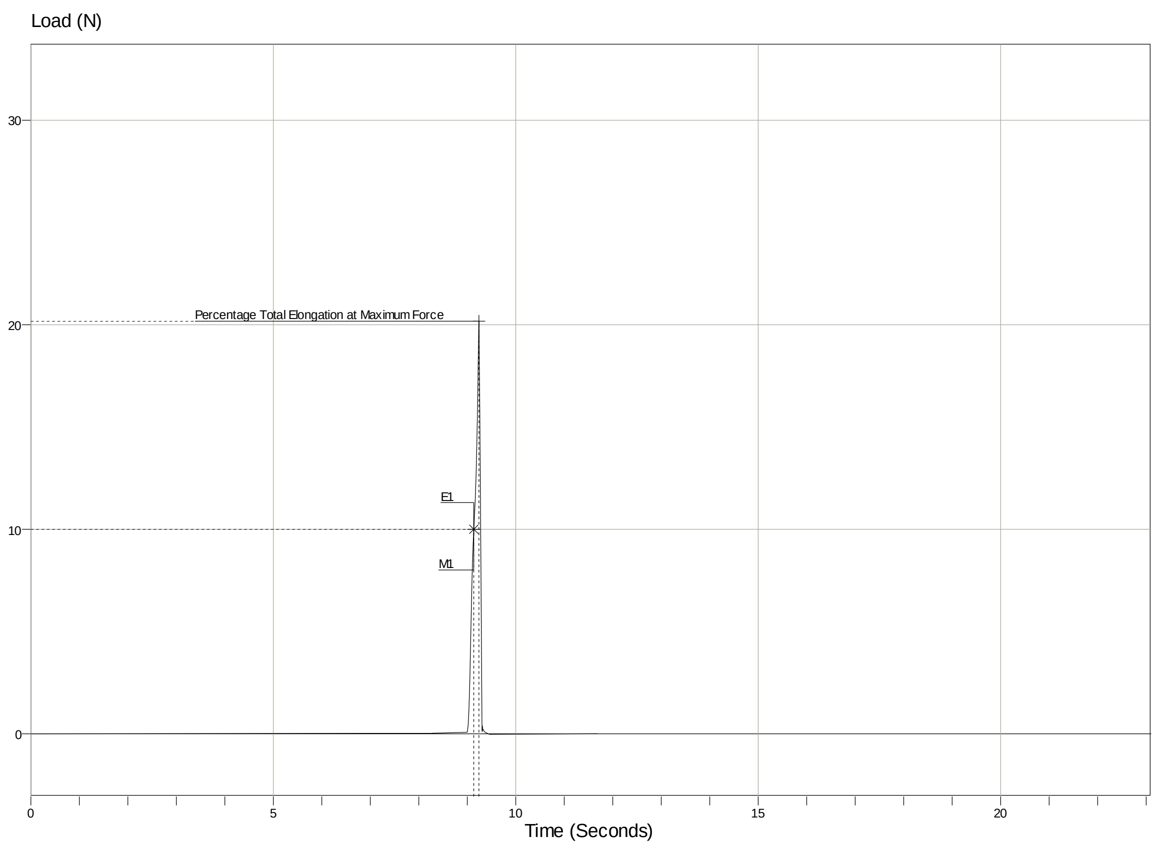


Figure-4.3 Load Verses Time Graph for the KFW_B2 baked at 170^0C for 10min

The strength of the Kocho biscuit was taken from the amount of force required to break the biscuit and it is called Load at maximum load and its unit is kilo Newton (kN). From Table-4.12 the force required to break the biscuit vary along the mixes and time-temperature, but the variation is not significant at $P \leq 0.05$. The highly dependence of the strength of the biscuit on the force applied to break it and the instrument that has been used for testing is also sensitive with the significance of 0.01 change in force applied on the biscuit.

Table-4.12 The Result for Strength of Kocho biscuit (Load at Maximum Load) in (kN)

	160^{0}C				170^{0}C				180^{0}C			
	7min	**8 min**	**9 min**	**10min**	**7 min**	**8 min**	**9 min**	**10min**	**7 min**	**8min**	**9min**	**10min**
KFW_B1	0.02±0.002	0.024±0.005	0.017±0.004	0.024±0.002	0.026±0.004	0.029±0.005	0.021±0.003	0.019±0.002	0.026±0.005	0.025±0.002	0.024±0.002	0.018±0.003
KFW_B2	0.038±0.006	0.031±0.006	0.027±0.003	0.029±0.010	0.026±0.005	0.031±0.006	0.025±0.003	0.026±0.005	0.031±0.006	0.026±0.003	0.025±0.008	0.036±0.009
KFW_B3	0.016±0.001	0.017±0.005	0.017±0.004	0.019±0.004	0.016±0.006	0.018±0.003	0.022±0.006	0.016±0.003	0.013±0.001	0.021±0.001	0.013±0.001	0.013±0.001
KFW_B4	0.010±0.001	0.009±0.002	0.005±0.002	0.010±0.001	0.007±0.002	0.007±0.001	0.008±0.001	0.008±0.001	0.011±0.001	0.011±0.001	0.013±0.001	0.011±0.001

The strength of the biscuit with the increase of faba bean flour shows that the strength to break the biscuit becomes higher. Along the same mix the strength to break the biscuit is increasing with increase of time and temperature. In KFW_B2 the increase in time and temperature doesn't have major difference while in Whole Kocho biscuit (KFW_B4) the increase in time and temperature increases the force required to break the biscuit. The result for the diameter and stress at a maximum load is shown in Appendix-II.

The result for strength at maximum load of KFW_B2 at 170^{0}C for 10min was 0.025kN and form the Table-4.12 the difference at p value of 0.05 shows the same result among the different tests of blend. In Figure-4.3 the pick shows that the maximum force applied on the biscuit to break it apart. In the graph E1 shows that the elongation of the breaker after cracking the biscuit to its final breakage. M1 in the graph represent that the minimum force applied to crack the biscuit.

From the appendix-II it can be seen that the diameter of the whole Kocho biscuit vary this was because of low binding property of Kocho flour due to the absence of gluten and gliadin which have the power to make the dough elastic during kneading and to easily detached from the roller shaper (cutter). For the rest of the biscuit the diameter is 4.5 which have good holding and consistency.

4.7. Sensory evaluation

The sensory evaluation was done first by screening out biscuits to be tasted and then the hedonic taste was performed. From this result the overall acceptability of Kocho biscuit KFW_B2 at 170^{0}C for 10 min shows a remarkable result of having 4.6% overall acceptance. For in KFW_B1 at 160^{0}C

Table - 4.14 Overall acceptance of Kocho biscuit dependence on the blend, baking time and temperature

	160^{0}C				170^{0}C				180^{0}C			
	7min	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**
KFW_B1	2.60±0.548	3.20±0.447	3.80±0.447	2.80±0.447^{di}	3.80±0.447	3.20±0.447^{dg}	2.60±0.548^{cj}	2.60±0.548^{dj}	3.00±0.707^{dh}	2.80±0.837^{ci}	2.20±0.837^{ek}	1.00±0.000^{el}

	^{dj}	^{dg}	^{af}		^{bf}							
KFW$_B$2	2.60±0.548^{dj}	2.60±0.548^{ej}	2.60±0.894^{ej}	2.00±0.707^{el}	2.60±0.548^{cj}	3.60±0.894^{ch}	3.40±0.894^{ai}	4.60±0.548^{af}	3.80±0.837^{bg}	3.40±0.548^{ai}	2.40±0.548^{dk}	1.20±0.447^{dm}
KFW$_B$3	2.80±0.837^{cj}	3.80±0.447^{ag}	2.80±0.447^{dj}	3.40±0.548^{ci}	2.60±0.548^{ck}	4.20±0.447^{af}	3.40±0.548^{ai}	2.80±0.447^{cj}	3.60±0.548^{ch}	2.60±0.548^{dk}	2.60±0.548^{ck}	1.80±0.837^{cl}
KFW$_B$4	3.80±0.447^{ag}	3.40±0.548^{ch}	3.40±0.548^{bh}	4.20±0.837^{af}	2.60±0.894^{ck}	3.00±1.000^{ej}	3.00±0.707^{bj}	3.20±1.095^{bi}	2.40±0.548^{el}	3.00±0.707^{bj}	3.20±0.447^{ai}	3.20±0.447^{ai}
KFW$_B$5	3.00±0.000^{bk}	3.60±0.548^{bi}	3.20±0.447^{cj}	4.00±0.707^{bg}	4.20±0.447^{af}	3.80±0.447^{bh}	2.60±0.548^{cm}	2.80±0.447^{cl}	4.00±0.707^{ag}	2.80±0.447^{cl}	2.80±0.447^{bl}	2.40±0.548^{bn}

$^{a-e}$ Means with the same superscript letters within a column are not significantly different ($p \leq 0.05$).

(Effect of blend on Overall acceptance)

$^{f-n}$ Means with the same superscript letters within a row are not significantly different ($p \leq 0.05$). (Effect of time and temperature on Overall acceptance within the same blend)

for 9min and 170^{0}C for 7min the overall acceptability was 3.8%. In Whole Kocho (KFW$_B$4 at 160^{0}C for 10 min) and Whole Wheat (KFW$_B$5 at 170^{0}C for 7 min) flours the overall acceptability of the biscuit for both was 4.2%. In Table – 4.14 the overall acceptance of the biscuits revealed that with increasing temperature to 180^{0}C its acceptability decreases. This shows that the temperatures as well as the baking time of the different blended biscuits have major effect on the sensory quality of the enriched Kocho biscuit. Even though there was no available data on the sensory evaluation of biscuit blended with Kocho flour and faba bean flour, the acceptability of the Kocho biscuit was better than the whole wheat flour biscuit overall acceptability this can be seen in Table- 4.14. This can be shown briefly in Appendix-III including the result for color, appearance, taste, flavor, and texture.

Chapter Five

5. Suggested technology for enriched Kocho biscuit manufacturing plant

5.1. Biscuit-making procedure

Biscuits were produced according to a commercial formulation and baking practice of Kality Food Share Company. The dough was prepared by blending Kocho flour, faba bean flour and wheat flour with other ingredients and mixing it in mixer (model G.P.A. Orlandi mixer, Italy). The dough was removed from the mixer and allowed to rest for 5-10 min. After that, the dough was sheeted using a sheeting machine (model G.P.A. Orlandi sheeter, Italy) and flattened using roller into a sheet of about 3.5 mm, and then cut into circular pieces measuring 4.5 cm in diameter. Samples were baked in an electric convection oven (model G.P.A. Orlandi oven, Italy) at 170 ^{0}C for 10 min, and were allowed to cool for about 15 min on a rack. Then the biscuits are ready for packaging and distribution.

The production capacity of the plant is determined by the speed of the packaging machine and it packs 60 packs per minute and a pack of biscuit weight 250 gm. From this the production capacity of the plant per day is 14.4 tons. For 300 days of working the yearly production capacity is 4320 ton per year.

5.2. Material and energy balance

- **Material balance to prepare Kocho flour**

The last stage was milling at this stage there was 3.49% loss of the total weight. Finally the Kocho flour obtained from 1000 kg of Enset was 404.065kg which is 61.96% of the total weight.

Over sieve size and fiber 34.9kg

Dried Kocho 654.465kg → **Milling and sieving** → 619.565 kg of Kocho flour

During the next unit operation, he form of water vapor accounts 12.94% of the initial weight.

129.40 kg of moisture

Chopped mass 783.865 kg → **Drying** → Dried Kocho 654.465 kg

During chopping of Enset Pseud as 6.31 % loss in the form of water and other. The fermentation process is assumed to be no losing in the weight and therefore the loss of water and other losses were due to chopping process.

Water and other solvents 63.135kg

Pseudo-stem and Corm 847 kg → **Chopping and fermentation** → chopped mass 783.865 kg

During cutting and forming of Enset plant 15.3% is removed in the form of scraps, leaves, roots, and water.

Scraps, leaves, roots, water 153 kg

1000kg of Enset → **Cutting and forming** → Pseudo-stem and Corm 847 kg

The suggested design for Kocho processing at a factory level is shown hereunder in Figure-5.1. From this design it can be seen that it involves different unit operations and application of different processing equipments.

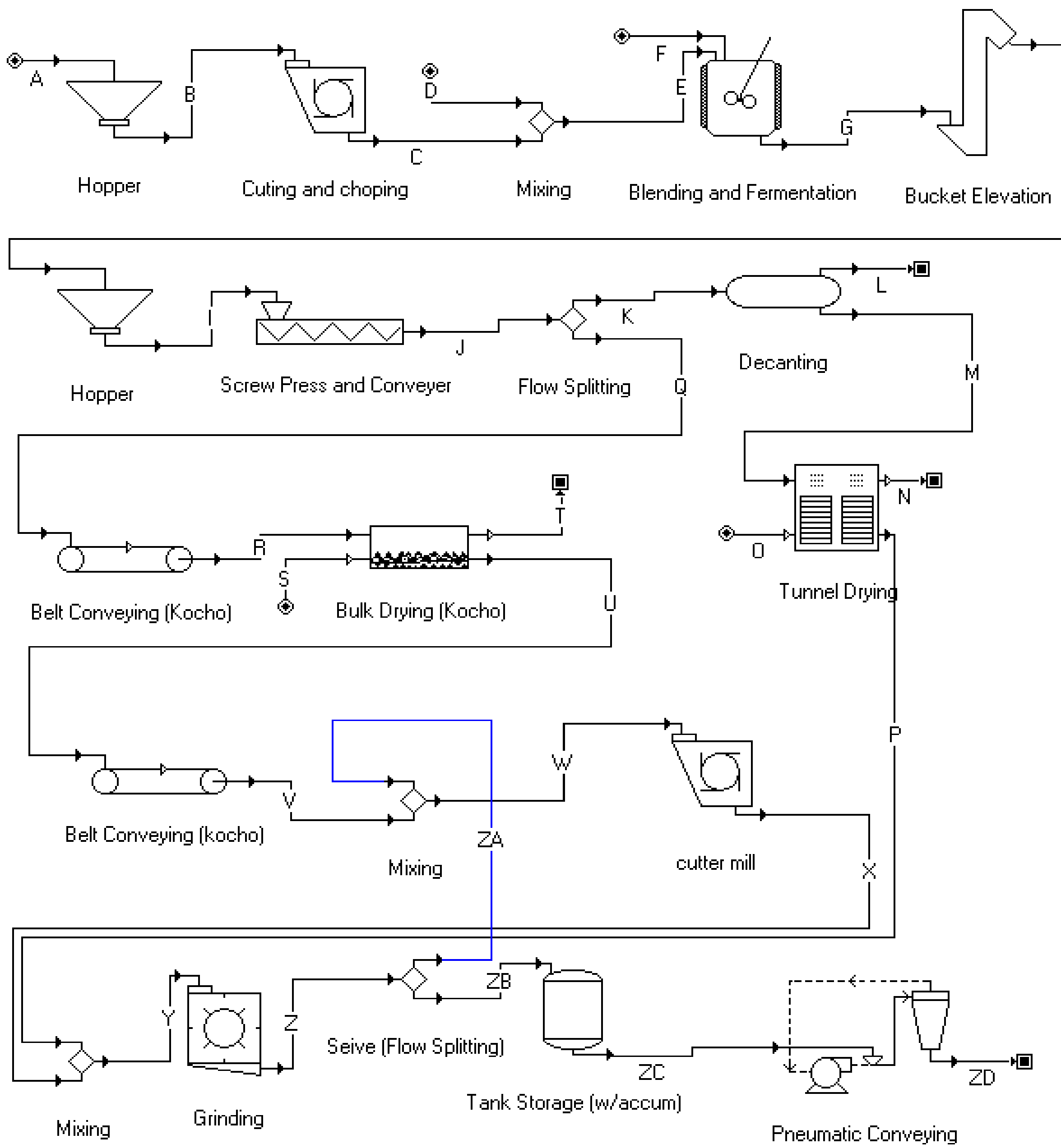


Figure-5.1schematic flow diagram for Kocho processing

Where: A and **B** – are shaped and reduced Enset corm and pseudostem, **C** – is the unfermented chopped mass of Corm and pseudostem, **D** – water, **E** –mix of C and D, **F** – is starter culture, **G**,**H** and **I** – are fermented Kocho mass, **J** – separation of the water by screw pressing, **K** – water and water soluble products, **L** – is water separated by decantation, **M** – is Bulla (the precipitated product of K), **N**–is the water vapor and other volatile components, **O** – is hot air, **P** –is dried Bulla, **Q** and **R** – are the squeezed Kocho mass, **S** –is the heat interring the Tunnel drier, **T** – is the heat and water leaving the tunnel, **U** and **V** – are the dried Kocho mass, **W** –is the oversize returned from Z and Kocho mass, **X** – is first milled Kocho mass, **Y** –is dried Bulla and the first milled Kocho mass, **Z** – is milled flour of Kocho and bulla, **ZA** – is the over sized from the secondary mill, **ZB** – is appropriate sieve size Kocho flour, **ZC** –is Kocho flour passing to final stage, and **ZD** – is packed Kocho flour.

- **Material balance for faba bean flour preparation**

The final stage for faba bean preparation was the milling and sieving process. At this stage the total loss from the 925.57 kg of dried faba bean was 4.02%.

Fiber and over sieve size 37.208kg

Dried faba bean of 925.57 kg → **Milling and Sieving** → faba bean flour of 888.362 kg

After decortications the drying proces is stage 18.4% of the 1290.35kg was lost through evaporation in the form of water.

237.424 kg of water

1162.992 kg of decorticated faba bean → **Drying** → dried faba bean of 925.57 kg

The next stage is the removal of the hull ons. At this stage 9.87% of the total 1251.05 kg of the swelled bean is lost in the form of husk, and water.

127.358kg of husk and water

Swelled faba bean of 1290.35kg → **Decortications** → 1162.992 kg of decorticated faba bean

The next stage is soaking. During this process the water increased the volume and swells the faba bean. It increased by 31%of the 955kg. Which means it absorbed 296.05 kg of water.

Water

985kg of faba bean → **Soaking** → Swelled faba bean of 1290.35kg

Water and impurities

The faba bean processing involves different unit operations like cleaning, soaking, decorticating, drying, and milling. The first unit operation is cleaning. During this stage there was 1.5% loss of the total weight of 1000kg of faba bean.

Impurities and welted seeds 15 kg

1000 kg of faba bean and impurities → **Cleaning** → 985kg of fines+ germ

The processing of faba bean also involves the application of different equipment and unit operations like that of Kocho. Faba bean processing is shown in Figure-5.2.

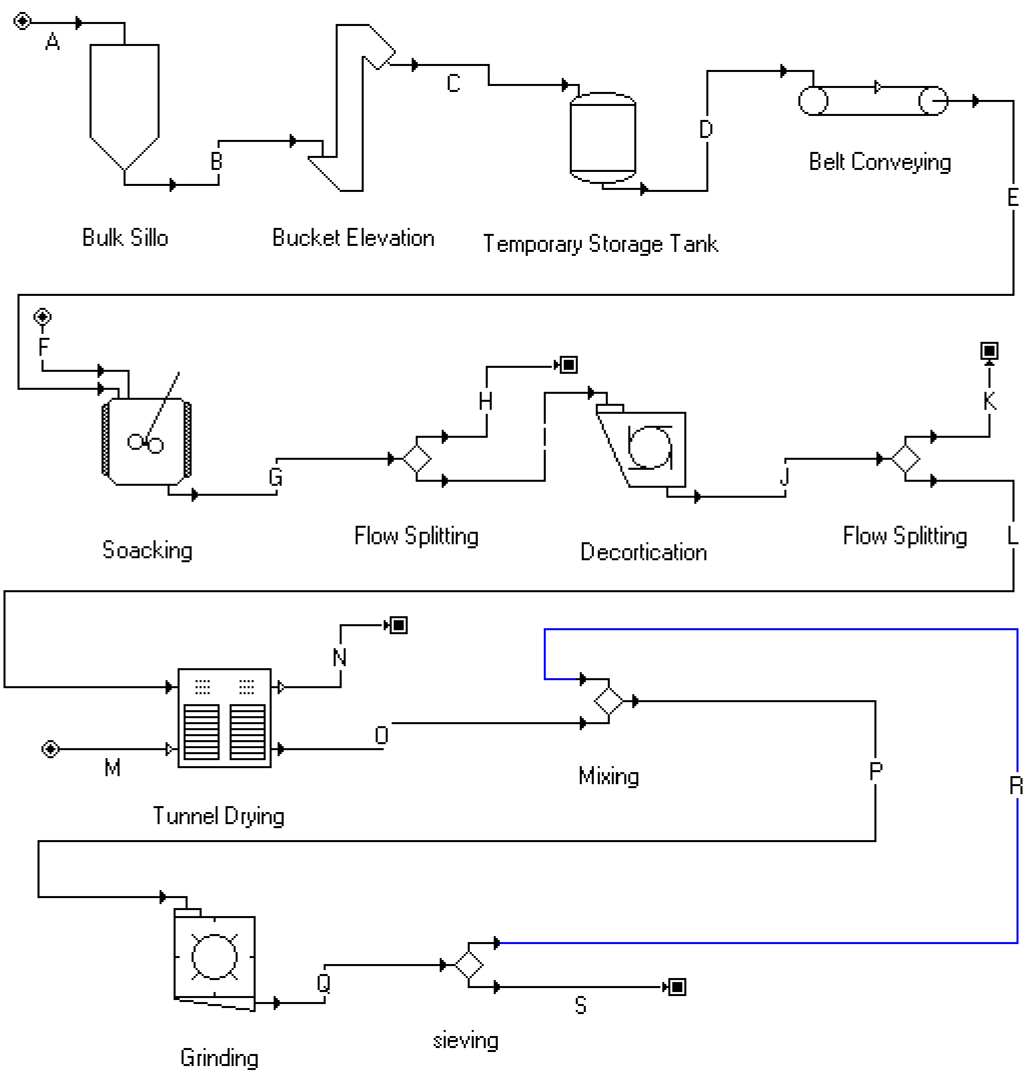


Figure-5.2 Schematic flow diagram for faba bean processing

Where: A – is the dried faba bean, **B** – is Faba bean leaving silo, **C** – through bucket elevator pass to temporary storage, **D** and **E** – are the transportation of the faba bean to the soaking tank, **F** – is the water added, **G** – is swelled faba bean and water, **H** – water, **I** – swelled faba bean, **J** – decorticated faba bean seed and hull, **K** – faba bean hull, **L** – swelled faba bean seed, **M** – heat interring the tunnel, **N** – heat and water vapor leaving the tunnel, **O** – is dried faba bean, **P** – is mix of O and R, **Q** – is the milled faba bean flour, **R** –is over size faba bean returning to the miller, **S** – is the final faba bean flour

The schematic flow diagram for the production of wheat flour is shown in Figure-5.3

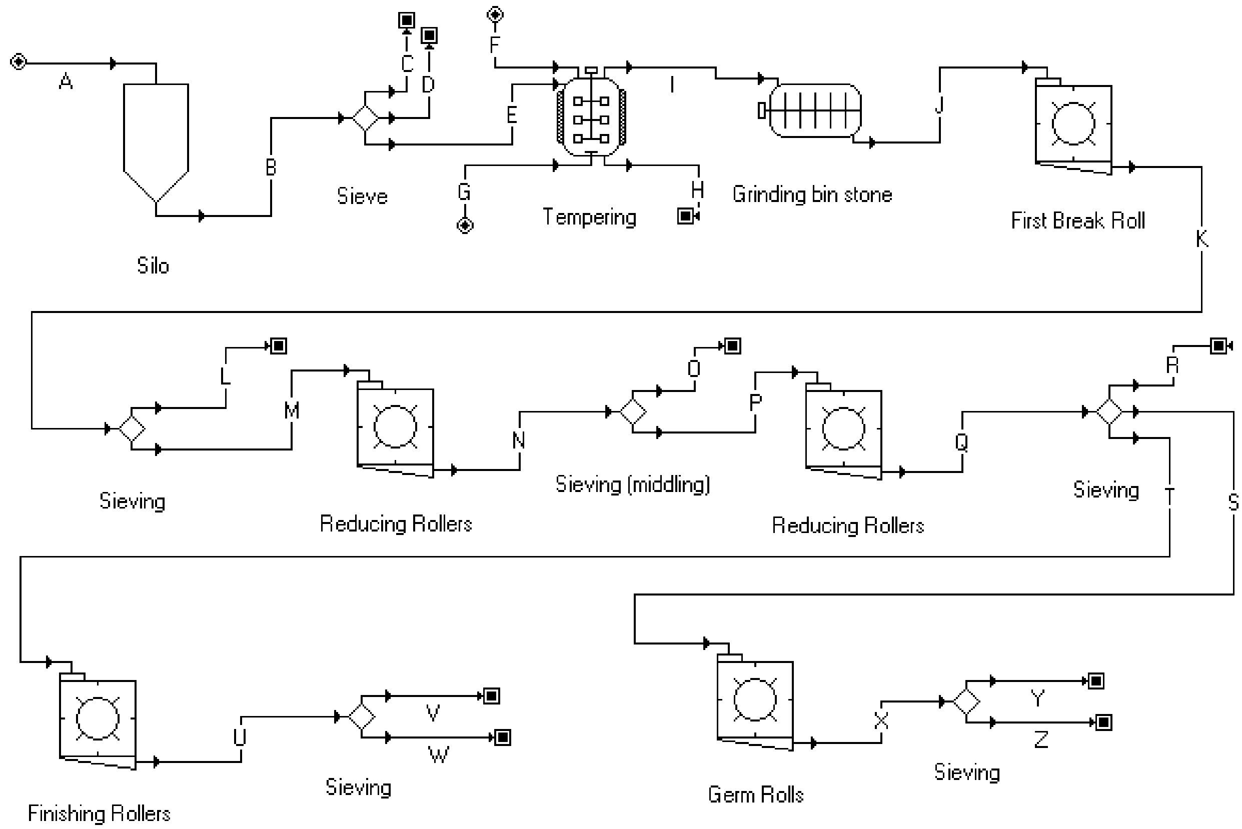


Figure-5.3. Schematic Flow diagram for wheat flour production

Where: A – wheat mass ,**B** – wheat passing for cleaning by sieve, **C** – over size impurities, **D** – undersized impurities, **E** – cleaned wheat kernel, **F** – water add, **G** – low temperature steam , **H** – water living the tempering process, **I** – tempered wheat passing to stone milling, **J** – crushed kernel, **K** – crushed kernel passing to primary mill, **L**, **O**, and **Z** – are wheat flours, **M** – oversized crushed wheat for primary mill, **N** – primary milled flour, **P** – over sized passing to the secondary miller, **Q** – secondary milled flour, **R** – patented flour, **S** – germ of the wheat kernel, **T** – wheat flour passing to final milling, **U** – final flour passing to sieve, **V** – Bran, **W** – clear flour, **X** – milled germ of wheat, **Y** – Germ

- **Material balance for Kocho biscuit**
  - **Assumptions for the production of biscuit**
    - The plant is working for 300 days per year and 16 h per day
    - Dough moisture content is 23%
    - Final biscuit moisture content = 3%
    - Dry matter content of biscuit = 97%
    - Production capacity of a machine is dependent on the packaging speed which is 60 packs per min. the daily production capacity is calculated hereunder.

Production capacity= $\frac{60pack}{min} \times \frac{250gm}{pack} \times \frac{60min}{h} \times \frac{16h}{day} = \frac{14{,}400{,}000gm}{day} = 14.4\ t/day$

Let assume that the production capacity of Kocho biscuit is at 85% of its whole capacity. Then production capacity of the Kocho biscuit per hour is equals to 765 kg/h

$$(60 pack/min \times 250 gm/pack \times 60 min/h) \div 1000 gm/kg = 900 kg/h$$

$$\frac{900kg}{h} \times 0.85 = 765 kg/h$$

The mixer has 890l/20min capacity and from these the loss from the mixing process is assumed to be 1.5% of the total flour and recipe added.

(B) Over left and other loss of

Flour and other recipes (X) → **Mixing** → B (A) Dough mass of 1055.031 kg/h

$$X \times 0.015 = B$$

By substituting equation 2 in equation one

$$X = \frac{1055.031kg}{h} + (X \times 0.015)$$

$$X = 1071.1\ kg/h$$

$$B = 1071.1\ kg/h - 1055.031 kg/h = 16.067 kg/h$$

Since the packaging speed per hour is 900kg/h and the output from the mixer is 890litter per20min. Hourly output of the mixer is 2670 l/h. Therefore the capacity of the mixer is well suited for 931kg/h mixing.

The amount of raw materials to make Kocho biscuit are calculated in terms of percentage of the total raw material required, and it shown below in Table-5.1. Therefore to make 1071.1 kg/h of raw material mix, just multiply by the corresponding percentage.

Table-5.1 raw material required to make Kocho biscuit kg/h

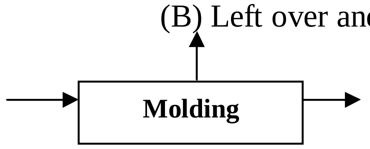
Raw materials		Percentage ratio (%)	Amount required to make 1000kg dough	Amount required in kg /h
Flour	Kocho flour	31.98	320.60kg	342.54 kg/h
	faba bean flour	19.19	192.36kg	205.54 kg/h
	Wheat flour	12.79	128.24kg	136.99 kg/h
Baking powder		0.2405	2.41kg	2.58 kg/h

Vegetable shortening	9.62	96.20kg	103.04 kg/h
Sugar	13.15	131.50kg	140.85 kg/h
Milk products	0.2405	2.41kg	2.58 kg/h
Water	12.4	124.00kg	132.82 kg/h
Salt	0.481	4.81kg	5.15 kg/h
Total	**100.092**		**1,071.99 kg/h**

The next stage is the lamination, molding, and shaping stage. At this stage it is assumed there is 3 % loss of the dough mass.

(B) Left over and unmolded

Dough mass of (X) Kocho biscuit



(A) 1023.38kg/h of molded and shaped

$$X \times 0.03 = B$$

$$X = B + A$$

By substituting Equation 1 to equation 2

$$X = 0.03X + 1023.38kg/h$$

$$X = 1055.031\ kg/h$$

$$B = X \times 0.03$$

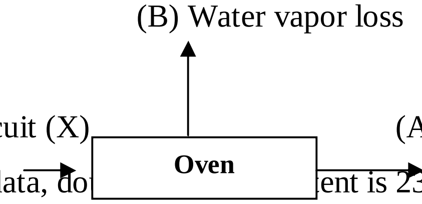
$$B = \frac{1055.031kg}{h} \times 0.03 = 31.651kg/h$$

After it had been molded the dough Kocho biscuit is heated. At this stage there was 20.62 % moisture loss.

(B) Water vapor loss

Molded Dough Kocho biscuit (X)

(A) Hot Kocho biscuit of 812.376 kg/h



Therefore from the given data, do ent is 23%; therefore the dry mater is 77%. And the final biscuit moisture content is 3% and this gives the dry mater to be 97%.

Moisture calculation

$$(X \times 0.23) = B + (A \times 0.03)$$

Dry mater calculation

$$(X \times 0.77) = (A \times 0.97)$$

$$X = \frac{812.376 kg/h \times 0.97}{0.77}$$

$$X = 1023.38 kg/h$$

By converting the output (A) in to percentage and subtracting from 100%: the water vapor loss becomes 20.62% of Dough Kocho biscuit(x)

$$B\% = 100 - \left(\frac{\frac{812.376kg}{h} \times 100}{\frac{1023.38kg}{h}}\right)$$

$$B\% = 20.62\%$$

$$B = 1023.38 kg/h \times 0.2062$$

$$B = 211.021 kg/h$$

The loss of moisture is not only in the oven (heating zone), but it also takes place at the cooling zone on the wire mesh while conveyed to the packaging line. At this stage the moisture loss is assumed to be reduced by 3%, therefore by adding 3% of 788.715kg/h on cooled Kocho biscuit the hot Kocho biscuit becomes 812.376 kg/h.

The last stage is packaging and at this stage it is assumed that there is 3.1% loss of the cooled packed Kocho biscuit in the form of broken, over burned, and left over Kocho biscuit.

(B) Broken, left over and burned biscuit

Cooled Kocho biscuit of (X) → **Packaging** → (A) Packed Kocho biscuit of 765 kg/h

Therefore

$$B = 3.1\% A$$

$$X = A + B$$

$$X = 765 kg/h + 23.715 kg/h$$

$$X = 788.715 kg/h$$

The suggested design of the Kocho biscuit processing line is similar except at the stage of mixing, And this can be shown in Figure-5.4.

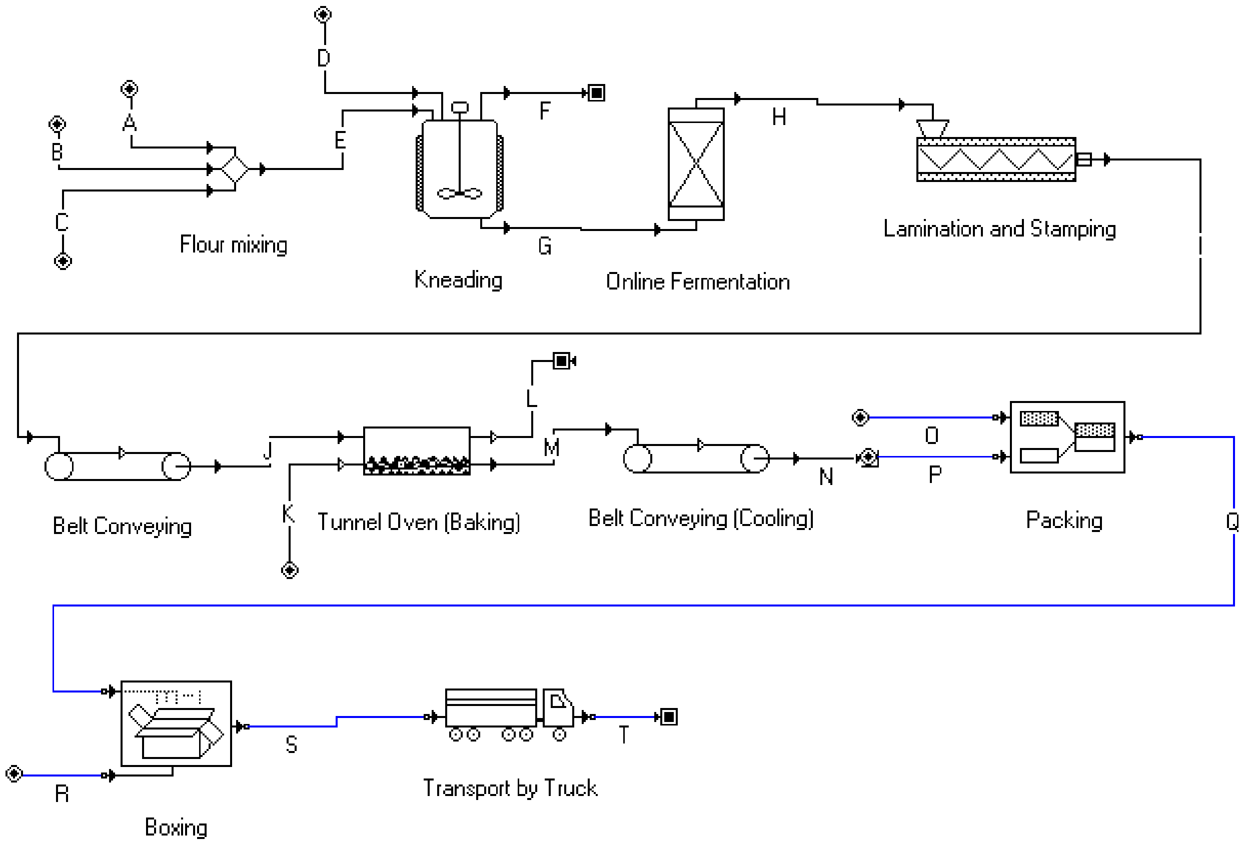


Figure-5.4 schematic flow diagram for biscuit production

Where: A – Kocho flour, **B** – faba bean flour, **C** – wheat flour, **D** – water, baking soda, sugar, salt, and vegetable shortening, **E** – blended flour, **F** – heat and lose of in the form of powder, **G** – dough mass, **H** – fermented dough, **I** – laminated, stamped and shaped dough biscuit, **J** – dough biscuit conveyed to tunnel oven, **K** – heat applied to the oven, **L** – heat and moisture leaving the oven, **M** – hot biscuit leaving the oven, **N** – cooled biscuit passing to the packaging, **O** – laminated poly propylene packing material, **P** – sorted biscuit for packaging, **Q** – packed biscuit passing to boxing, **R** – carton box, **S** – transportation of packed biscuit to vehicle, **T** – transportation to selling branches

- **Energy balance in oven for enriched Kocho biscuit production**

The energy balance for enriched Kocho biscuit of KFW2 at 170^{0}C for 10 min can be simply described the heat required to make the flour, dough, and biscuit. And the source of heat for the milling, mixing and baking is electricity. The major unit operation where heat and energy flow change in enriched Kocho biscuit production is in the Oven. The oven uses electrical energy as a source of heat. This electrical energy is converted to heat through the process of conduction, convection, and radiation in oven. The given parameters to calculate the energy balance are given bellow:

Total mass of dough (M_{dough}) = 1,023.38kg/h

Mass of biscuit out of oven ($M_{biscuit}$) = $812.376 kg/h$

Assume Temperature of dough after mixing (To) = 25^{0}C

Assume Temperature of dough before interring to oven (T_1) = 30^0C

Initial moisture of dough =14.28%

Assume Temperature of biscuit when it go out of oven (T_2) =170^0C

Final moisture content of biscuit = 1.705%

Latent heat of evaporation for water (λ)=800kcal/kg

Change in temperature(ΔT) = $T_1 - T_2$ -- (1)

$$= 170^0C\text{-}30^0C=140^0C = 413.15K$$

Composition of dough (M=14.28, P=15.11, F=8.72, CHO=60.81, and A=1.08)

Composition of biscuit (M=1.705, P=9.751, F=14.498, CHO=74.313, and A=1.991)

Cp1 of dough = 1.424Xc+1.549Xp+1.675Xf+0.837Xa+4.187Xw (J/kg.k) ---------------------- (2)

$$Cp1 = 1.424(0.6081) + 1.549(0.1511) + 1.675(0.0872) + 0.837(0.0108) + 4.187(0.1428)$$

$$Cp1 = 1.853\ \frac{J}{kgK}$$

Cp2 of biscuit = 1.424Xc+1.549Xp+1.675Xf+0.837Xa+4.187Xw (J/kg.k)

$$Cp2 = 1.424(0.7267) + 1.549(0.01515) + 1.675(0.1418) + 0.837(0.0195) + 4.187(0.0167)$$

$$Cp2 = 1.593\frac{J}{kgK}$$

Heat required by the product (sensible heat) = $mass\ of\ dough \times \Delta T \times Cp\ dough$ ----------- (3)

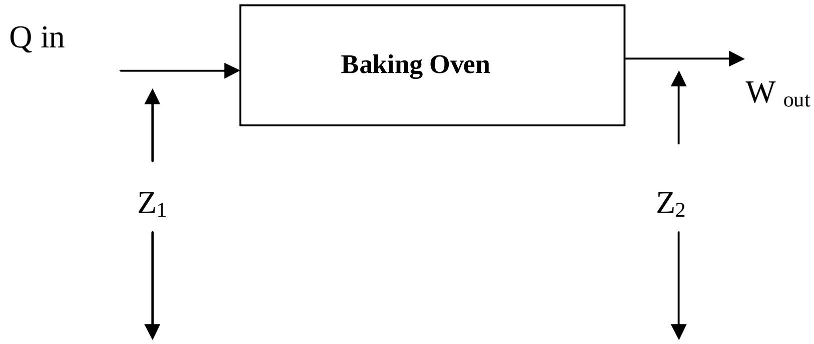
Sensible heat = 1,023.38kg/h×413.15K×1.853J/kgK = 783,466 J/h = 187.13Kcal/h

mass of water in dough evaporated = total mass of dough × (initial moisture of dough – Final moisture of biscuit) -- (4)

$$= \frac{1023.38kg}{h} \times (14.28\% - 1.705\%) = 12{,}869kg/h$$

$heat\ required\ for\ water = mass\ of\ water \times lathent\ heat\ of\ evaporation$ ----------- (5)

$$= \frac{12{,}869kg}{h} \times \frac{800Kcal}{kg} = 10{,}295{,}200.00Kcal/h = 4.31 \times 10^{10}J/h$$



$$U_1+P_1V_1+u_1^2/2+Z_1g+Q_{in}= U_2+P_2V_2+u_2^2/2+Z_2g+W_{out} \text{--} (6)$$

Where

U is the internal energy = f (T) (temperature of material)

Zg = potential energy (Z=height, g=9.81m/s^2)

$u^2/2$ = kinetic energy (u=velocity)

W = $\int_0^l Fdx$ (F in Newton (N), x and l in meter (m))

Assume that:

Work done by pressure and volume = 0

The internal energy (U) = is equal along the two end of the oven (U_1=U_2)

The speed of wire mesh intering and living the oven is at the same speed (u_1=u_2)

The height of the oven is equal along the two ends (Z_1=Z_2)

The final simplified form of the equation will be

$Q_{in}=W_{out}$

Over all energy balance

$Qin = Qout$ ---7

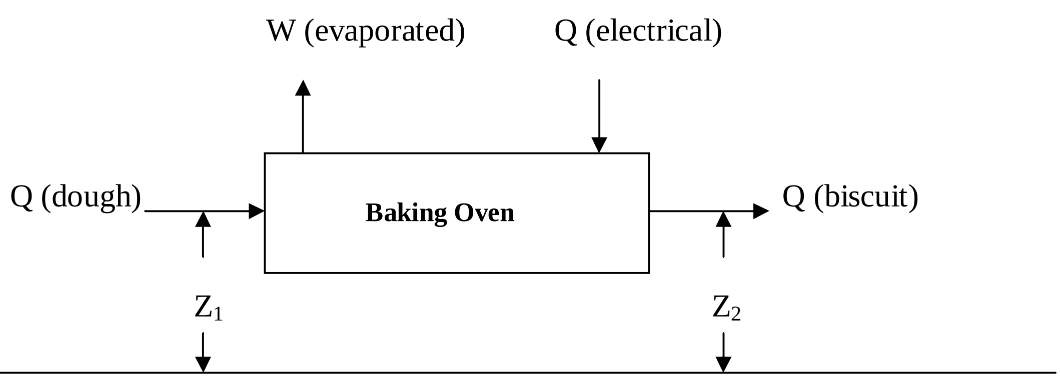
Energy in + Energy generated = Energy out + Consumption + Accumulation

Where:

Energy generated = is energy generated by dough

Consumption= is the energy taken by the biscuit

Accumulation= is the energy preserved by the oven



$$Q\ dough + Q\ electric = W\ evaporated + Q\ biscuit$$

$$Q\ dough = M\ dough \times Cp1 \times (T1 - T0)$$

$$Q\ dough = \frac{1023.38kg}{h} \times 1.853\ \frac{J}{kgK}(30-25)K = 9{,}481.6J/h$$

$$Qbiscuit = Mbiscuit \times Cp2 \times (T2 - T1)$$

$$Qbiscuit = \frac{812.376kg}{h} \times 1.593\frac{J}{kgK} \times (170-30)K = 181{,}176.1J/h$$

$$heat\ required\ for\ water = mass\ of\ water \times lathent\ heat\ of\ evaporation$$

$$W(evaporated) = \frac{12{,}869kg}{h} \times \frac{800Kcal}{kg} = 10{,}295{,}200.00Kcal/h = 4.31 \times 10^{10}J/h$$

$$Qdough + Qelectrical = Qbiscuit + Wevaporated$$

$$Qelectrical = Qbiscuit + Wevaporated - Qdough$$

$$Qelectrical = \frac{181{,}176.1J}{h} + 4.31 \times \frac{10^{10}J}{h} - \frac{9{,}481.6J}{h} = 4.3 \times 10^{10}J/h$$

Chapter Six

6. Economic analysis of the study / techno-economic feasibility

6.1. Building, equipment and manpower requirements

Given Plant parameters

- Capacity, tons per year — 4,320 ton per year
- Number of shifts /day — 2
- Working days/year — 300
- Land area/ covered, m^2 — 5000

The working days per year and number of shifts per day for the Kocho biscuit production is taken from the already processing work plan of the Kality Food Share Company. And the capacity of the plant was determined based on the capacity of the packaging machine and the tunnel oven used for the processing and other parameters like raw materials and working hours and days.

6.1.1. Machinery and equipment cost

If the cost of a piece of equipment or plant of size or capacity q_1 is C_1, then the cost of a similar piece of equipment or plant of size or capacity q_2 can be calculated from $C_2 = C_1 (q_2 / q_1)^n$ (Robert H. Perry, 2007) The value of *n* for different equipment is listed at the appendix-IV. The cost of equipment and *n* value is obtained from Appendix-III summarized in Table below.

Where the value of the exponent *n* depends on the type of equipment or plant

SN	Item	Quantity	Unit price (birr)	Total price (birr)	Capacity	Power intake
1	Universal mixer	1	65,000.00	65,000.00	2670 litters/h	7.50 KW
2	Laminator	1	247,000.00	247,000.00	1.5-3.8M/min	3.00KW
3	Rotary cutting machine	1	273,000.00	273,000.00	200kg	4.50KW
4	Rotary molder	1	78,000.00	78,000.00	250kg/h	2.20KW
5	Oven drive and oven tension	1	91,000.00	91,000.00	3300×680×880mm	1.50 KW
6	Electric band oven-size 25m	1	416,000.00	416,000.00	250kg/h	150.00 KW
7	Cooling conveyor-size 10m	1	32,500.00	32,500.00	8000×820×680mm	0.75KW
8	Packing conveyer	1	32,500.00	32,500.00	6000×820×680mm	0.37KW
9	Packing machine	1	130,000.00	130,000.00	25-180 packs/min	4.50KW
10	Delivery vehicle	2	500,000.00	1,000,000.00		
	Sub-Total			2,365,000.00		
	Contingencies on Equipment	15%		354,750.00		
	Total			**2,719,750.00**		**174.32KW**

6.1.2. Building requirement

It is assumed that the factory or plant is installed in the southern nation's nationalities people region where the production of Enset is high in Butajra area. And the whole area needed to cover the plant as well as other building and storage requirements is assumed to be 5,000m^2. There the cost of land is assumed to be 10Birr/m^2.

SN	Building	Total area (m^2)	Unit price Birr/m^2	Total price Birr/m^2
1	Raw material storage	500	20.00	10,000.00
2	Working space	2000	20.00	40,000.00
3	Spare part house	500	20.00	10,000.00
4	Office	500	20.00	10,000.00
5	Laboratory	200	20.00	4,000.00
7	Green area	500	20.00	10,000.00

8	Other common facilities like cafeteria, bath etc	300	20.00	6,000.00
9	Transportation (road facilities)	500	20.00	10,000.00
	Sub-Total	5,000		100,000.00
	Contingencies on Building (10%)			10,000.00
	Total	**5,000**		**110,000.00**

6.1.3. Manpower requirement

No	Work specification	Required No	Gross monthly salary (birr)	Total monthly salary (birr)	Yearly salary (birr)
	Skilled man power				
	Manager	1	4,000.00	4,000.00	48,000.00
	Production head	1	2,000.00	2,000.00	24,000.00
	Quality head	1	2,000.00	2,000.00	24,000.00
	Purchasing and sales head	1	2,000.00	2,000.00	24,000.00
	Accountant	2	1,068.00	2,136.00	25,632.00
	Secretary	1	900.00	900.00	10,800.00
	Laboratory technicians	3	1,068.00	3,204.00	38,448.00
	Mechanical Engineer	1	2,000.00	2,000.00	24,000.00
	Semi-skilled man power				
	Production supervisor	2	1,068.00	2,136.00	25,632.00
	Mechanics	3	500.00	1,500.00	18,000.00
	File directory	1	500.00	500.00	6,000.00
	Production line workers	22	500.00	11,000.00	132,000.00
	Raw material Storage area workers	20	500.00	10,000.00	120,000.00
	Final product storage area workers	10	500.00	5,000.00	60,000.00
	Unskilled workers				
	Security guard	14	700.00	9,800.00	117,600.00
	Cleaners	6	600.00	3,600.00	43,200.00
	Total	**99**			**741,312.00**

6.2. Cost estimation

6.2.1. Cost of raw materials

The cost of each raw material per annum is calculated by multiplying the raw material required per hour by 300 working days per year and 16hour per day, then multiply by their unit price. The unit price for water is 0.00315 Birr/liter.

Particulars	Quantity per hour (kg/h)	Quantity per day (kg/day)	Quantity per annum (kg/year)	Unit price (Birr/kg)	Total cost(birr)
Wheat flour	136.99	2,191.84	657,552.00	10.00	6,575,520.00
Kocho flour	342.54	5,480.64	1,644,192.00	7.00	11,509,344.00
faba bean flour	205.54	3,288.64	986,592.00	4.00	3,946,368.00
Shortening	103.04	1,648.64	494,592.00	15.00	7,418,880.00
Sugar	140.85	2,253.60	676,080.00	12.00	8,112,960.00
Salt	5.15	82.40	24,720.00	2.50	61,800.00
Yeast (baking powder)	2.58	41.28	12,384.00	18.00	222,912.00
Water	132.82	2,125.12	637,536.00	0.00315	2,008.24
Total					**37,849,792.24**

6.2.2. Cost of utility

The electricity for the production of Kocho biscuit includes the energy required for the equipments, light, fans and other equipments. The water required for the production of Kocho biscuit includes the water required for the main production line, for laboratory, for cleaning and others like for garage and for steam on process line. The yearly water consumption of Kality food Share Company is 510,000 litters and this is taken for Kocho production too. The packaging material for the biscuit has a capacity of 250gm per pack and equals to 4 packs per kilogram. The yearly production of 4,320,000 kilogram per year and it requires 17,280,000 packs per year.

Utilities	**Quantity per annum**	**Unit price (Birr)**	**Total cost (Birr)**
Electricity (Kwh)			
Equipment	174.32	0.4993	87.038
Others	130.00	0.4993	64.91
Water (L)	510,000.00	0.00315	1,606.50
Packing material (packs)	17,280,000.00	0.5	8,640,000.00
Total			**8,641,758.45**

6.2.3. Fixed capital cost estimation

The factors are based on the grass type processing industries and based on the data of H. C. Bauman, Fundamentals of Cost Engineering in the Chemical Industry, Van Nostr and Reinhold, New York, 1964, p. 295, for essentially carbon steel equipment. For, a given company's labor costs and material costs may inflate at different rates. To quite a large extent, inflation becomes repressed, or differentiated, in such fields as taxation, import control, and price restriction. The material and labor cost is estimated 5.27 times the sum of equipment, installation, instrumentation, piping, and electrical cost. See appendix-V.

Item		**Description/factor**	**Total cost in Birr**
I. Direct cost	A. Material + labor	Estimated	24,222,909.43
	a. Equipment	,, ,,	2,719,750.00
	b. Installation	0.09×TEC	244,777.50
	c. Instrumentation	0.13×TEC	353,567.50
	d. Piping	0.29×TEC	788,727.50
	e. Electrical	0.18×TEC	489,555.00
	B. Building + auxiliary	Direct estimated	110,000.00
	C. Service facilities	0.4×TEC	1,087,900.00
	D. Land	0.06×TEC	163,185.00
	Total direct cost	**A + B + C +D**	**25,583,994.43**
II. Indirect cost	A. Engineering &supervision	0.1×TDC	2,558,399.44
	B. Construction + Contractor fee	0.1×TDC	2,558,399.44
	C. Contingency	0.06×TDC	1,535,039.67
	Total indirect cost	**A + B + C**	**6,651,838.55**

III. Fixed capital investment	**Direct + Indirect cost**	**32,235,832.98**
IV. Working capital	**0.15×FCI**	**4,835,374.95**
V. Total capital investment	**III + IV**	**37,071,207.92**

6.2.4. Estimation of total product cost

Item		Description/factor	Total cost, birr
I. Manufacturing cost	A. Fixed Charges		
	a. Depreciation	0.1×instrumentation+ 0.02 ×building	37,556.75
	b. Local taxes	0.02×FCI	644,716.66
	c. Insurance	0.006×FCI	193,415.00
	Total of A		**875,688.41**
	B. Direct production cost		
	Total product cost (tpc)	Total fixed charg/0.15	5,837,922.72
	a. Raw material	Already estimated	37,849,792.24
	b. Utilities	,, ,,	8,641,758.45
	c. Operating labor (ol)	0.1×tpc	583,792.27
	d. Supervisory	0.1×ol	58,379.23
	e. Maintenance	0.05×FCI	1,611,791.65
	f. Lab charges	0.12×ol	70,055.07
	Total of B		**54,653,491.62**
	C. Plant overheads	**0.1×tpc**	**583,792.27**
	Total manufacturing cost	**A + B + C**	**56,112,972.30**
Π. General Expenses	a. Administrative cost	0.05×tpc	291,896.14
	b. Distribution	0.1×tpc	583,792.27
	c. R & D	0.05×tpc	291,896.14
	d. Interest	0.05×tpc	291,896.14
	Total general expenses		**1,459,480.68**
Total product cost		**I + Π**	**57,572,452.98**
Total product cost/kg of biscuit per year		$= \frac{\mathbf{57,572,452.98}}{\mathbf{4,320,000}}$	**13.32695671**

6.2.5. Gross earnings

Assuming that whole selling price of 1kg of Kocho biscuit =16 birr

Expecting all produced biscuit will be sold

Total income = 16.00×4,320,000 = 69,120,000.00

Gross income = total income – total product cost

= 69,120,000.00 – 57,752,452.98 = 11,547,547.02 birr

Let the tax rate be 35% (income tax of Ethiopia)

Vat is 10% of gross income

The taxable is 30% of yearly income (gross income)

Taxable money= 30% × 11,547,547.02 birr = 3,464,264.106 birr

Taxes = 0.35×3,464,264.106 birr = 1,212,492.437 birr

Vat= 10%×11,547,547.02=1,154,754.702

Net profit = gross income – (tax + vat)

=11,547,547.02 – (1,212,492.437 + 1,154,754.702) birr

= 9,180,299.88 birr/year

Rate of return

$$ROR = \frac{net\ profit}{total\ capital\ investment} \times 100 = 24.76\%$$

$$pay\ out\ period = \frac{FCI}{NP + Depre.} = 3.5\ years$$

Breakeven point

$$\boldsymbol{BEP = \frac{TPC - DPC}{Sup - Vcup}}$$

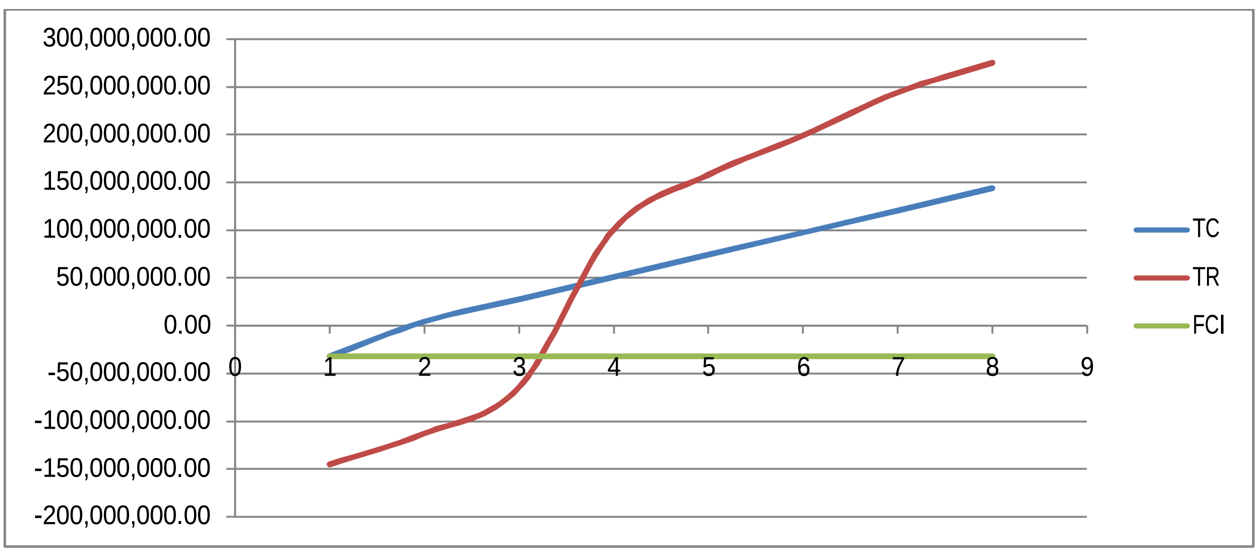
$$BEP = \frac{\mathbf{57,572,452.98 - 25,583,994.43}}{24 - \mathbf{13.32695671}}$$

$$BEP = 2997126.282 kg/year$$

$$\boldsymbol{BEP}(\%) = \frac{\boldsymbol{BEP}}{\boldsymbol{Total\ capacity\ of\ plant}} \times \mathbf{100\%}$$

$$\boldsymbol{BEP}(\%) = \frac{\frac{2997126.282 kg}{year}}{\boldsymbol{\frac{4320000 kg}{year}}} \times \mathbf{100\%}$$

BEP=69.38%



Chapter Seven

7. Conclusion and Recommendation

7.1. Conclusion

This study was primarily aimed to investigate production of enriched Kocho biscuit. Secondly it was attempted to determine suitable time-temperature combinations for the best formulated blend biscuit. Moreover to obtain a good quality, in terms of sensory evaluation and texture analysis, of the enriched Kocho biscuit. Furthermore to improve the nutritional composition of the whole wheat flour biscuit. It revealed that from the experiment KFW_B2 at 170^0C for 10min fulfilled the quality and quantity, in terms of nutritional composition, as well as the sensory quality of the enriched Kocho biscuit.

The result from the flour analysis shows that the protein value of whole Kocho flour was 1.78% on dry base and fortification of this flour by 35% faba bean flour and 15%wheat flour gave a protein value 13.68% in dry basis; the result for crude protein also revealed that for KFW_B2 was 15.12% in dry basis; for KFW_B1 was 14.22% dry basis; and for wheat flour was 10.96% db. By just seeing the result blend KFW_B2 gave better value for enriched biscuit production.

Kocho in the form of biscuit showed a remarkable result on the nutritional and sensory evaluation. The best temperature for production of enriched Kocho biscuit was 170^0C for the blend of KFW_B2. 10min was the beast backing time for the KFW_B2. KFW_B2 at 170^0C and 10min was better when compared in nutritional and sensory quality. The result for protein content of KFW_B2 baked at 170^0C for 10 min was 9.75±0.01 this was much higher than the control wheat flour biscuit of 5.71±0.01 for KFW_B5 baked at 160^0C for 7min.

The daily requirement of protein for children with the age of 1-3 and 4-10 was 39g/day and 50g/day respectively. If a child of age 1-10 eat biscuit of 515.46g which is equivalent to two packs of 250g each of enriched biscuit of KFW_B2 at 170^0C for 10min. Two pack of the enriched Kocho biscuit covers the daily requirement of protein and this shows that the protein malnutrition can be reduced by just giving the children the fortified Kocho biscuit.

Furthermore, from the result of the texture analysis it can be concluded that the maximum load to break whole Kocho biscuit was very low as compared to other blends of the biscuit formulations. The maximum load to break the enriched biscuit of blend KFW_B2 baking at temperature 170^0C for time 10min was 0.026kN. For KFW_B4 at the same time and temperature was 0.008kN which is much way below the finally selected quality enriched Kocho biscuit of KFW_B2 at 170^0C for 10min.

The sensory evaluation for KFW_B2 also revealed that it was acceptable even though whole wheat flour biscuit was the most preferable. The sensory evaluation for KFW_B2 at 170^0C for 10 min were 3.4%, 4.8%, 4.6%, 4.2%, 4.6%, and 3.6% for color, taste, over all acceptance, flavor, appearance, and texture respectively.

The following specific conclusions were drawn from result of this thesis study.

1. It can be concluded that Enset can be processed at industrial level for the production of biscuit.
2. The beast quality of the biscuit blend in this paper was KFW_B2 and correspondingly the appropriate temperature and time were 170^0C and 10min.
3. Nutritionally the selected enriched Kocho biscuit (KFW_B2) was also show a remarkable result of protein, fat, carbohydrate, fiber, ash and moisture of 9.7%, 14.5%, 74.31%, 0.87%, 1.99% and 1.71% respectively.
4. The mineral content of KFW_B2 at 170^0C for 10min was Mn of 0.22mg/100g Zn of 0.54mg/100g, Fe of 3.40mg/100g, Ca of 12.07mg/100g, and Mg of 3.30mg/100g, Na of 13.67mg/100g.
5. The texture result and sensory evaluation also implies that KFW_B2 at 170^0C and 10min enriched Kocho biscuit gives 0.026% and 4.6%
6. As overall production of enriched Kocho biscuit results in the value added biscuit when it is seen from the nutritional composition point
7. Gives benefit for the farmers by increasing the agro pricing and farm gate price
8. It contributes to the food security and whole optimum resource utilization in Ethiopia
9. The result from this study can be used for investigators and food companies (investors) for the production of Kocho based processed foods which intern lead to boosting up Enset production in similar agro ecological zone of the country.

7.2. Recommendation

This study shows that Kocho in the form of biscuit supplemented with faba bean and wheat is a good source of protein and mineral as compared to the whole wheat flour biscuit. The locally available and less utilized Enset plant for Kocho can also be processed to biscuit at an industrial level through the application of different processes. The time temperature combination for biscuit production was also within the range of 140^0C-200^0C which is common to wheat biscuit production. The time for biscuit production was adjusted by losing or tightening of the leaver which control the speed of the belt; therefore it is possible to change the time for the required period.

Enriched Kocho biscuits are nutritive snacks produced from dough that is transformed into appetizing product through the application of heat in an oven similar to wheat flour biscuit. They are ready-to-eat, convenient and inexpensive food product, containing digestive and dietary principles of vital importance. Kocho biscuit supplemented with faba bean should be produced and distributed for protein malnourished children as well as for young people too. It is recommend that the production of enriched Kocho biscuit is mostly preferred and less cost as compared to the imported enriched biscuit.

This project result can give opportunity for the investors to look after the valuable and untouched Enset plant as a source of biscuit production. It also gives the chance for entrepreneurs who have the capacity to produce enriched Kocho biscuit at small scale level.

The following recommendation are made based on a holistic view of the subject area:

1. The application of the flower of Enset plant as a source of food or as additive in the other foods.
2. The Kocho flour as a medicinal value in terms of high calcium, magnesium and zinc content. These minerals have healing power to bone breakage, cancer, and other heart related disorders.
3. The utilization of the leaves of Enset plant for the packaging material at large scale since traditionally it is applicable.
4. The possibility of extraction of starch from the stripe, which carry the leaves, of the Enset plant.

8. References

Adejuyitan, J. A., Otunola, E. T., Akande, E. A., Bolarinwa, I. F. and Oladokun, F. M. (2009). Some physicochemical properties of flour obtained from fermentation of tiger nut (*Cyperus esculentus*) sourced from a market in Ogbomoso. African Journal of Food Science. Vol 3(2), 051-055, Nigeria.

Admasu Tsegaye and P.C. Struik (2001). Enset (*Ensete ventricosum*), Kocho yield under different crop establishment methods as compared to yields of other carbohydrate food crops. Netherland journal of agricultural science 49, 81-94.

Aguilera J.M, and Germain J.C. (2007). Advances in image analysis for the study of food microstructure. Wood head Publishing Limited, Cambridge, 261–287.

Amy, Penner, Leaelaf Hailemariam, Martin Okos A, B, and Osvaldo Campanella (2009). Lateral growth of a wheat dough disk under various growth conditions. Journal of Cereal Science 49, 65–72.

Anshoo, Malhotra, Devinder K. and Dhawan (2008)Zinc improves antioxidative enzymes in red blood cells and hematology in lithium-treated rats. Journal of food technology, 28, 43-50.

AOAC (2003). Official Methods of the Association of Official Analytical Chemists, 14th ed. Washington DC.

Blazenka S. Ebecic and Irena Vedrina-Dragojevic (2004). Wheat flour confectionery products as a source of inorganic nutrients: Zinc and copper contents in hard biscuits. Journal of cereal chemist.

Baker, J.C., and Mize, M.D. (1941). The origin of the gas cell in bread dough. Journal of Cereal Chemistry 18, 19–34.

Bingham, S.A. (2003). Dietary fiber in food and protection against cholesterol cancer in the European prospective investigation into cancer and nutritional (EPIC): an observational study. The Lancet, 57, 9–14.

Bolandi, F. Shahidi, N. Sedaghat, R. Farhoush and H. Mousavi-Nik (2008). Shelf-life Determination of Saffron Stigma Water Activity and Temperature Studies. World Applied Sciences Journal 5 (2): 132-136, Damghan, Iran.

Bonithon-Kopp, C., Kronborg, O., Giacosa, A., Rath, U. & Faivre, J. (2000). Calcium and fibre supplementation in prevention of colorectal adenoma recurrence: a randomized intervention trial. The Lancet, 356, 1300–1306.

Burrier, Anna Lucas, Paula May, Sandra Bastin, Rosie Allen (2003). Bread and biscuit project, Gallatin County University of Kentucky College of Agriculture, Lexington, and Kentucky State University, Frankfort.

Brandt, Anita Spring, Clifton Hiebsch, J. Terrence mccabe, Endale Tabogie, Mulugeta Diro, Gizachew Wolde-Michael, Gebre Yntiso, Masayoshi Shigeta, and Shiferaw Tesfaye (1997). The Tree against Hunger Enset-Based Agricultural Systems in Ethiopia, American Association for the Advancement of Science with Awassa Agricultural Research Center.

Concepcion, Vidal-Valverde, Juana Frias, Concepcion Diaz-Pollan, Mar Fernandez, Maria Lopez-Jurado, and Gloria Urbano (1997). Influence of Processing on Trypsin Inhibitor Activity of faba Beans and Its Physiological Effect. Journal of agriculture and food Chemistry, 45, 3559-3564.

Connick JR, D. J. Daigle, C. D. Boyette, K. S. Williams, B. T. Vinyard and P. C. Quimby JR (1996). Water Activity and Other Factors that Affect the Viability of Colletotrichum truncatum Conidia in Wheat Flour Kaolin Granules (Pesta). Journal of Biocontrol Science and Technology 6, 277-284.

CSA (2007/08). Central Statistical Agency Report on area and crop production forecast for major grain crops for private peasant holdings for Meher season, Statistical bulletin 409, Addis Ababa.

CSA (2006). Central Statistical Agency Report on small scale manufacturing industries survey, Statistical bulletin 381, Addis Ababa.

Diaz-Pollan, C., Sotomayor, C., Frias, J., Vidal-Valverde, C.(1997) Available, non-available carbohydrates and trypsin inhibitor activity in processed chickpeas. Z. Lebensm. Unter. Forsch.

EARO (2004). Ethiopian Agricultural Research Organization Directory of released crop varieties & their recommended cultural practices, Addis Ababa Ethiopia.

European Journal of Clinical Nutrition (1996). Energy and Protein requirements, Proceedings of an IDECG workshop, volume 50, London School of Hygiene and Tropical Medicine, UK

Farnworth (2003). Hand Book of Fermented Functional Foods, CRC press Boca Raton Boston New York Washington DC.

Ferguson, L.R. & Harris, P.J. (2003). The dietary fiber debate: more food for thought. The Lancet, 361, 1487–1488.

H. C. Bauman (1964). Fundamentals of Cost Engineering in the Chemical Industry for essentially carbon steel equipment. Van Nostrand Reinhold, 295, New York.

Ihekoronye AI, Ngoddy PO (1985). Integrated food science and technology for the tropics. 1st ed. McMillan publishers, 261- 291.

Kaluski, Ophir E, Amede T. (2002). Food security and nutrition the Ethiopian case for action. Public Health Nutrition, 5, 373–81.

Kema, Harold J. Helmens, and Peter A. M. Steeneken, Groningen (1996). Wet-milling/Ammonia Process for the Manufacture of Wheat Starch and Gluten. The Nether lands.

Magdi, A. Osman (2007). Effect of Different Processing Methods, on Nutrient Composition, nutritional Factors, and in vitro Protein Digestibility of Dolichos Lablab Bean Pakistan. Journal of Nutrition 6, 299-303.

Maryke, Labuschagne, M.C. Brooks Coetzee and Char1 S van Deventer (1996). Biscuit-Making Quality Prediction Using Heritability Estimates and Correlations, 70, 25-28

Masakuni and Susumu Hizukuri (2003). Rheological Properties of Wheat (Halberd) Amylopectin, Department of Biochemical Science and Technology, Kagoshima University, Kagoshima, 55, 345–349, Japan.

Naivikul O., and D.Appolonia. (1978). Comparison of legume and wheat flour carbohydrates. The American Association of Cereal Chemists.

NRC (1978). National Research Council report on Nutrient requirements of domestic animals. 10. In Nutrient Requirements of Laboratory Animals, 3rd ed.; National Academy of Science: Washington, DC.

Olaoye O. A, Onilude A. A and Oladoye C. O. (2007). Breadfruit flour in biscuit making: effects on product Quality.

Paul Gibbs and Vassilis Gekas (2000). Water Activity and Microbiological Aspects of Foods. Journal of Leatherhead Food Research Association, UK.

Paul, MN. (2000). American Association of Cereal Chemists, 10th ed.

Pavel, (1985). Introduction to food processing, Engle wood Cliffs Ltd, New Jersey, USA.

Robert, H. Perry. (1997). Perry's chemical engineers' handbook 7th ed., printed by R. R. Donnelley & Sons Company in the United States of America.

Peters, U. (2003). Dietary fiber and colorectal adenoma in a colorectal cancer early detection programme. Journal of cereal science, 361, 1491–1495

Renata D. de M. C. Amboni & Edna R. Amante (2008). Physicochemical and sensory characteristics of cookies containing residue from king palm (Archontophoenix alexandrae) processing. International Journal of Food Science and Technology 43, 1534–1540.

Robert Shank and Chernet Ertiro (1996). A Linear Model for Predicting Enset Plant Yield and Assessment of Kocho Production in Ethiopia United Nations development programmed Emergencies Unit for Ethiopia Addis Ababa, Ethiopia.

Shahzad H., Faqir M. Anjum, Masood S., Butt, Muhammad I., Ali A. (2006). Physical and Sensory Attributes of Flaxseed Flour Supplemented Cookies. Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan 30, 87-92.

Smith, U.C. Coop. Ext. Leaflet (1957). Three New Varieties of Fava Beans, San Mateo County

Soni, G.L., Singh, T.P., Singh, (1978). Comparative studies on the effects of certain treatments on the antitryptic activity of the common Indian pulses. Indian Journal of Nutrition Dietary Requirements 15, 341-347.

Steinkrous (1996). Handbook of indigenous fermented foods, 2nd ed. CRC press Boca Raton Boston New York Washington DC.

Swaminathan (1989). Human Nutrition, Bangalore Ltd, India.

Taki, K., Nakayama, T., Yatsuzuka, T., Ohshima, M., (2003). Visual observations of batch and continuous foaming processes. Journal of Cellular Plastics 39, 155–169.

Tames, S.L., Muir, J.G., Curtis, S.L. & Gibson, P.R. (2003). Dietary fiber: a roughage guide. Journal International Medicine, 33, 291–296.

Terry, F.C. (2001). Fruit, vegetables dietary fiber, and risk of cholesterol cancer. Journal of National Cancer Institute, 93, 525–533.

Tilahun Amede, Ann Stroud, and Jens Aune (2005). Advancing human nutrition without degrading land resources through modeling cropping systems in the Ethiopian Highlands.

UNIDO Technology Manual, (2004). Small-scale Cereal Milling and Bakery Products, Production Methods, Equipment and Quality Assurance Practices,

Valdebouze, P.; Bergeron, E.; Gaborit, T.; Delort-Laval, J. (1980). Content and distribution of trypsin inhibitors and hemagglutinins in some legume seeds. Canadian Journal of Plant Science, Canada. 60, 695-701.

Vidal Valverde, C. Frias, J. Valverde, S. (1992). Effect of processing on the soluble carbohydrate content of lentils. Journal of food processing 55, 301-304.

Yemane Tsehaye and Fassil Kebebew (2006). Diversity and cultural use of Enset (*Enset ventricosum* (Welw Cheesman) in Bonga in situ Conservation Site, Ethiopia. Ethnobotany Research & Applications 4:147-157.

Yewelsew Abebe, Barbara J. Stoecker, Margaret J. Hinds, Gail E. Gates (2006). Nutritive value and sensory acceptability of corn- and Kocho-based foods supplemented with legumes for infant feeding in southern Ethiopia. African journal of food, agriculture, nutrition and development volume 6 No. 1.

Yimer G. (2000). Malnutrition among children in southern Ethiopia: levels and risk factors. Ethiopia Health Dev; 14:283–92

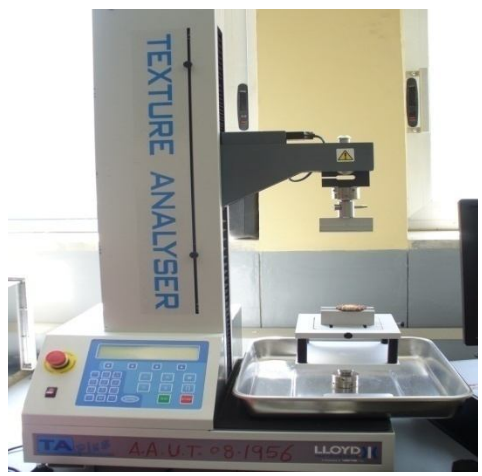
Youssef W.Bushuk (1998). Bread Making Properties of Composite Flours of Wheat and faba Bean Protein Preparation. American association of cereal chemist’s vol. 63.No4.

Appendices

Appendix-I Photo of Enset processing and laboratory equipments used

a-pseudo stem separation(detaching)   b. scraping pseudo stem with bamboo

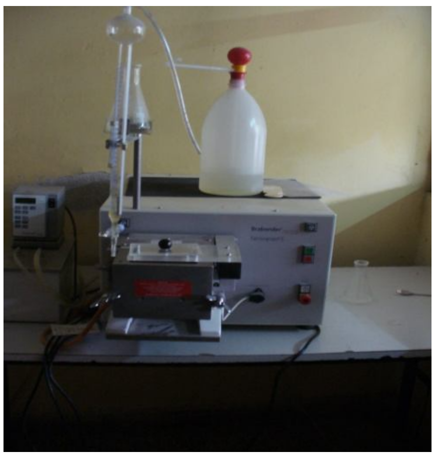
c. scrapping the outer part of Enset corm   d. chopping of Enset corm



e. retsch as 200 digital 2007   f. TA-Hdi, STable Microsystems texture analyzer

g. mixer B15

h. AMB310 Adam moisture taster



i. Brabender Farinograph E

j. mini infra 2000T grain analyzer

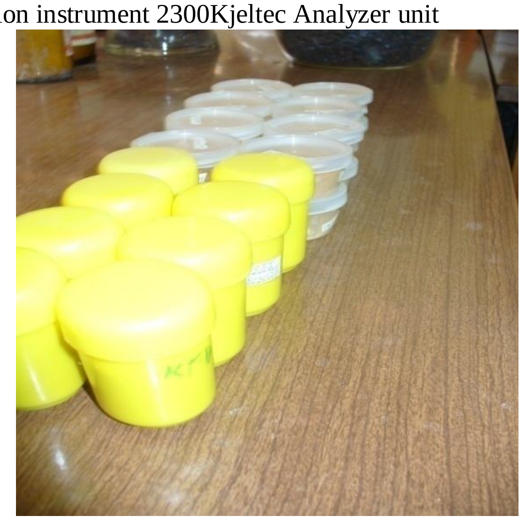
k. Perten falling number 1500

l. Stake colour grader series IV

m. external digital micrometer PM025D

n. titration instrument 2300Kjeltec Analyzer unit

o. SOXTEC 2055 manual control unit



p. grounded Kocho biscuit samples

q. Matured and dried faba bean

r. Biscuits made from Kocho, faba bean and wheat

Appendix-II Result for texture analysis

Table-A result for diameter of biscuit in cm

KFW1											
160^0C				170^0C				180^0C			
7min	**8 min**	**9 min**	**10min**	**7 min**	**8 min**	**9 min**	**10min**	**7 min**	**8 min**	**9 min**	**10min**
4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000

KFW2											
160^{0}C				**170^{0}C**				**180^{0}C**			
7min	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**
4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000
KFW3											
160^{0}C				**170^{0}C**				**180^{0}C**			
7min	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**
4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000
KFW4											
160^{0}C				**170^{0}C**				**180^{0}C**			
7min	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**
4.333± 0.0943	4.067± 0.3091	3.433± 0.7760	4.100± 0.2828	4.200± 0.1633	4.133± 0.1247	4.321± 0.4309	4.418± 0.3421	4.221± 0.1319	4.033± 0.0626	4.213± 0.4427	4.195± 0.0576
KFW5											
160^{0}C				**170^{0}C**				**180^{0}C**			
7min	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**
4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000	4.500± 0.0000

Table-B result for stress at maximum load in M Pa

KFW1											
160^{0}C				**170^{0}C**				**180^{0}C**			
7min	**8 min**	**9 min**	**10min**	**7 min**	**8 min**	**9 min**	**10min**	**7 min**	**8 min**	**9 min**	**10min**
0.013± 0.001	0.015± 0.003	0.011± 0.002	0.015± 0.002	0.017± 0.003	0.018± 0.004	0.013± 0.002	0.012± 0.001	0.016± 0.003	0.016± 0.001	0.015± 0.002	0.011± 0.002
KFW2											
160^{0}C				**170^{0}C**				**180^{0}C**			
7min	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**
0.0237 95± 0.0035 446	0.0195 17± 0.0036 514	0.0168 61± 0.0018 597	0.0183 61± 0.0063 708	0.0162 48± 0.0032 371	0.0192 74± 0.0039 983	0.0157 20± 0.0015 977	0.0162 48± 0.0032 371	0.0192 74± 0.0035 015	0.0162 14± 0.0021 034	0.0156 42± 0.0050 285	0.0225 43± 0.0054 714
KFW3											
160^{0}C				**170^{0}C**				**180^{0}C**			
7min	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**
0.0097 792± 0.0009 3300	1.0694 ± 0.3100 6	0.0104 97± 0.0026 997	1.2150 ± 0.2203 4	1.0340 ± 0.3926 0	0.0116 19± 0.0020 130	1.4061 ± 0.3767 8	1.0123 ± 0.1922 1	0.0081 959± 0.0007 8349	0.0133 86± 0.0003 6152	0.0080 007± 0.0008 4641	0.0080 344± 0.0005 4129
KFW4											
160^{0}C				**170^{0}C**				**180^{0}C**			
7min	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**	**7min**	**8min**	**9min**	**10min**
0.0069 605± 0.0008 3762	0.7453 3± 0.2274 2	0.0052 536± 0.0009 3457	0.0073 510± 0.0008 9545	0.0054 041± 0.0022 350	0.5508 7± 0.0887 17	0.0062 7± 0.0027 44	0.0075 036± 0.0171 933	0.0082 117± 0.0008 7265	0.0050 87± 0.0038 25	0.6550 81± 0.0085 12	0.4200 77± 0.0063 187

Appendix- III. Sensory evaluation result for different blend, time and temperature combination for the Kocho biscuit

Blend Proportion	Temperature (^0C)	Time (min)	Overall acceptance		Texture		Flavor		Taste		Appearance		Color	
			Mean	Std. D	Mean	Std. D	Mean	Std. D	Mean	Std. D	Mean	Std. D	Mean	Std. D
KFW1	160	7 min	2.60	±.548	2.20	±.447	2.60	±.894	2.40	±.548	3.80	±.447	4.20	±.447
		8	3.20	±.447	2.80	±.837	3.00	±.707	2.80	±.447	3.40	±.548	3.60	±.548
		9	3.80	±.447	4.00	±.000	3.60	±.548	2.80	±.837	4.00	±.707	3.80	±.447
		10	2.80	±.447	2.60	±.548	2.80	±.447	3.00	±.707	3.60	±.548	3.20	±.447
		Total	3.10	±.641	2.90	±.852	3.00	±.725	2.75	±.639	3.70	±.571	3.70	±.571
	170	7	3.80	±.447	3.80	±.447	3.80	±.447	3.60	±.894	4.20	±.837	3.60	±.548
		8	3.20	±.447	3.20	±.837	2.80	±.447	2.80	±.447	3.00	±.707	3.60	±.548
		9	2.60	±.548	2.40	±.548	2.40	±.548	2.40	±.548	3.40	±.548	3.20	±.837
		10	2.60	±.548	2.40	±.548	2.80	±.447	2.20	±.447	3.60	±.548	3.80	±.447
		Total	3.05	±.686	2.95	±.826	2.95	±.686	2.75	±.786	3.55	±.759	3.55	±.605
	180	7	3.00	±.707	3.40	±.548	2.80	±.447	2.80	±.837	3.60	±.894	2.40	±.548
		8	2.80	±.837	3.20	±.447	2.40	±.548	2.60	±.548	2.60	±.548	2.80	±.447
		9	2.20	±.837	2.40	±.548	2.20	±.447	2.40	±.548	3.20	±.447	2.40	±.548
		10	1.00	±.000	1.60	±.548	1.80	±1.304	1.80	±.447	3.60	±.548	3.20	±.447
		Total	2.25	±1.020	2.65	±.875	2.30	±.801	2.40	±.681	3.25	±.716	2.70	±.571
	Total	7	3.13	±.743	3.13	±.834	3.07	±.799	2.93	±.884	3.87	±.743	3.40	±.910
		8	3.07	±.594	3.07	±.704	2.73	±.594	2.73	±.458	3.00	±.655	3.33	±.617
		9	2.87	±.915	2.93	±.884	2.73	±.799	2.53	±.640	3.53	±.640	3.13	±.834
		10	2.13	±.915	2.20	±.676	2.47	±.915	2.33	±.724	3.60	±.507	3.40	±.507
		Total	2.80	±.879	2.83	±.847	2.75	±.795	2.63	±.712	3.50	±.701	3.32	±.725
KFW2	160	7	2.60	±.548	2.40	±.548	2.60	±.548	2.80	±.837	2.60	±.548	2.40	±.548
		8	2.60	±.548	2.80	±.447	2.60	±.548	3.20	±1.095	2.60	±.548	4.20	±.447
		9	2.60	±.894	2.20	±.447	2.60	±.894	3.20	±1.095	2.60	±.894	3.40	±.548
		10	2.00	±.707	3.00	±.707	2.00	±.707	3.60	±.894	2.00	±.707	3.80	±.447
		Total	2.45	±.686	2.60	±.598	2.45	±.686	3.20	±.951	2.45	±.686	3.45	±.826
	170	7	2.60	±.548	3.40	±.894	2.60	±.548	3.00	±.707	2.60	±.548	3.60	±.548
		8	3.60	±.894	2.80	±.447	3.60	±.894	3.60	±.894	3.60	±.894	4.20	±.447
		9	3.40	±.894	2.80	±1.304	3.20	±.447	3.60	±.894	3.20	±.447	4.40	±.548
		10	4.60	±.548	3.60	±.548	4.20	±.837	4.80	±.447	4.60	±.548	3.40	±.548
		Total	3.55	±.999	3.15	±.875	3.40	±.883	3.75	±.967	3.50	±.946	3.90	±.641
	180	7	3.80	±.837	4.00	±1.000	3.60	±1.140	3.80	±.837	4.00	±.000	3.60	±.548
		8	3.40	±.548	2.60	±.548	3.40	±.548	3.00	±1.225	3.40	±.548	3.00	±.000
		9	2.40	±.548	2.40	±.548	2.40	±.548	3.20	±1.095	2.40	±.548	3.40	±.548
		10	1.20	±.447	1.80	±.447	1.20	±.447	3.20	±.447	1.20	±.447	3.60	±.548
		Total	2.70	±1.174	2.70	±1.031	2.65	±1.182	3.30	±.923	2.75	±1.164	3.40	±.503

	Total	7	3.00	±.845	3.27	±1.033	2.93	±.884	3.20	±.862	3.07	±.799	3.20	±.775
		8	3.20	±.775	2.73	±.458	3.20	±.775	3.27	±1.033	3.20	±.775	3.80	±.676
		9	2.80	±.862	2.47	±.834	2.73	±.704	3.33	±.976	2.73	±.704	3.73	±.704
		10	2.60	±1.595	2.80	±.941	2.47	±1.457	3.87	±.915	2.60	±1.595	3.60	±.507
		Total	2.90	±1.069	2.82	±.873	2.83	±1.011	3.42	±.962	2.90	±1.037	3.58	±.696
KFW3	160	7	2.80	±.837	2.40	±.548	2.80	±.837	2.80	±.447	2.80	±.837	3.40	±.548
		8	3.80	±.447	3.60	±.548	3.40	±.548	3.40	±.548	3.60	±.548	3.60	±.548
		9	2.80	±.447	3.20	±.447	2.20	±.447	3.20	±.447	2.80	±.447	3.20	±.447
		10	3.40	±.548	2.60	±.548	2.60	±.548	3.20	±1.095	3.40	±.548	2.40	±.548
		Total	3.20	±.696	2.95	±.686	2.75	±.716	3.15	±.671	3.15	±.671	3.15	±.671
	170	7	2.60	±.548	3.60	±.894	3.20	±.837	4.20	±.837	2.60	±.548	3.80	±.837
		8	4.20	±.447	4.20	±.837	4.40	±.548	4.20	±.447	3.40	±.548	3.60	±.548
		9	3.40	±.548	3.80	±.447	3.80	±.447	3.40	±.548	2.40	±.548	3.60	±.548
		10	2.80	±.447	3.20	±.447	2.20	±.447	3.20	±.447	2.80	±.447	2.60	±.548
		Total	3.25	±.786	3.70	±.733	3.40	±.995	3.75	±.716	2.80	±.616	3.40	±.754
	180	7	3.60	±.548	3.40	±.894	2.60	±.548	3.60	±.894	3.60	±.548	4.00	±1.000
		8	2.60	±.548	3.20	±1.095	2.40	±.548	3.00	±.707	2.60	±.548	3.40	±.548
		9	2.60	±.548	3.40	±.548	2.80	±.837	4.20	±.837	2.60	±.548	2.60	±.548
		10	1.80	±.837	3.20	±.837	1.60	±.548	3.20	±.447	1.80	±.837	2.20	±.447
		Total	2.65	±.875	3.30	±.801	2.35	±.745	3.50	±.827	2.65	±.875	3.05	±.945
	Total	7	3.00	±.756	3.13	±.915	2.87	±.743	3.53	±.915	3.00	±.756	3.73	±.799
		8	3.53	±.834	3.67	±.900	3.40	±.986	3.53	±.743	3.20	±.676	3.53	±.516
		9	2.93	±.594	3.47	±.516	2.93	±.884	3.60	±.737	2.60	±.507	3.13	±.640
		10	2.67	±.900	3.00	±.655	2.13	±.640	3.20	±.676	2.67	±.900	2.40	±.507
		Total	3.03	±.823	3.32	±.792	2.83	±.924	3.47	±.769	2.87	±.747	3.20	±.798
KFW4	160	7	3.80	±.447	4.20	±.447	3.60	±1.342	3.40	±.548	3.00	±.707	3.80	±.447
		8	3.40	±.548	3.40	±.548	4.20	±.837	3.00	±.707	3.40	±.894	3.80	±.837
		9	3.40	±.548	2.80	±.447	3.00	±.707	2.60	±.548	2.40	±.548	2.60	±.548
		10	4.20	±.837	3.80	±1.095	3.20	±.447	3.80	±1.095	3.20	±1.095	1.80	±.837
		Total	3.70	±.657	3.55	±.826	3.50	±.946	3.20	±.834	3.00	±.858	3.00	±1.076
	170	7	2.60	±.894	2.20	±.837	2.60	±.894	2.40	±1.140	2.80	±.447	3.20	±.837
		8	3.00	±1.000	2.40	±.548	3.00	±.000	2.80	±.837	2.60	±.548	3.00	±.707
		9	3.00	±.707	2.80	±.837	4.00	±1.000	3.00	±.707	3.60	±.894	3.00	±1.000
		10	3.20	±1.095	3.00	±.707	2.80	±.837	3.00	±.707	3.40	±.548	1.40	±.548
		Total	2.95	±.887	2.60	±.754	3.10	±.912	2.80	±.834	3.10	±.718	2.65	±1.040
	180	7	2.40	±.548	2.20	±.837	2.40	±.548	2.00	±1.000	2.80	±.447	3.00	±.707
		8	3.00	±.707	2.80	±.447	2.60	±.548	3.00	±.000	3.00	±.000	2.80	±.837

		9	3.20	±.447	3.60	±.894	3.20	±1.095	3.60	±.894	3.00	±.707	2.40	±.548
		10	3.20	±.447	3.00	±.707	3.20	±1.095	2.80	±.837	2.40	±.548	1.80	±.837
		Total	2.95	±.605	2.90	±.852	2.85	±.875	2.85	±.933	2.80	±.523	2.50	±.827
	Total	7	2.93	±.884	2.87	±1.187	2.87	±1.060	2.60	±1.056	2.87	±.516	3.33	±.724
		8	3.13	±.743	2.87	±.640	3.27	±.884	2.93	±.594	3.00	±.655	3.20	±.862
		9	3.20	±.561	3.07	±.799	3.40	±.986	3.07	±.799	3.00	±.845	2.67	±.724
		10	3.53	±.915	3.27	±.884	3.07	±.799	3.20	±.941	3.00	±.845	1.67	±.724
		Total	3.20	±.798	3.02	±.892	3.15	±.936	2.95	±.872	2.97	±.712	2.72	±.993
KFW5	160	7	3.00	±.000	3.00	±.707	3.00	±.707	2.80	±.447	2.20	±.447	2.80	±.447
		8	3.60	±.548	3.40	±.548	3.80	±.447	3.40	±.548	3.60	±.548	2.80	±.447
		9	3.20	±.447	3.00	±.707	3.80	±.447	2.80	±.837	3.20	±.447	3.40	±.548
		10	4.00	±.707	4.00	±.707	4.00	±.707	3.60	±1.140	4.20	±.837	3.80	±.837
		Total	3.45	±.605	3.35	±.745	3.65	±.671	3.15	±.813	3.30	±.923	3.20	±.696
	170	7	4.20	±.447	4.00	±.707	4.00	±1.000	4.40	±.894	4.40	±.894	3.40	±.548
		8	3.80	±.447	3.80	±.837	3.60	±.548	4.00	±.707	4.00	±.707	3.60	±.548
		9	2.60	±.548	2.40	±.548	3.00	±.707	3.00	±.000	2.60	±.548	2.60	±.548
		10	2.80	±.447	3.20	±.837	2.60	±.548	3.00	±.707	2.40	±.548	2.60	±.548
		Total	3.35	±.813	3.35	±.933	3.30	±.865	3.60	±.883	3.35	±1.089	3.05	±.686
	180	7	4.00	±.707	3.60	±.548	3.60	±.548	3.00	±.000	3.80	±.447	2.60	±.548
		8	2.80	±.447	3.00	±.707	2.40	±.548	2.80	±.447	1.60	±.894	3.20	±.837
		9	2.80	±.447	2.80	±.447	1.80	±.837	3.00	±.707	2.60	±1.140	2.60	±.548
		10	2.40	±.548	2.40	±.548	1.60	±.894	2.80	±.837	1.80	±.837	2.80	±.447
		Total	3.00	±.795	2.95	±.686	2.35	±1.040	2.90	±.553	2.45	±1.191	2.80	±.616
	Total	7	3.73	±.704	3.53	±.743	3.53	±.834	3.40	±.910	3.47	±1.125	2.93	±.594
		8	3.40	±.632	3.40	±.737	3.27	±.799	3.40	±.737	3.07	±1.280	3.20	±.676
		9	2.87	±.516	2.73	±.594	2.87	±1.060	2.93	±.594	2.80	±.775	2.87	±.640
		10	3.07	±.884	3.20	±.941	2.73	±1.223	3.13	±.915	2.80	±1.265	3.07	±.799
		Total	3.27	±.756	3.22	±.804	3.10	±1.020	3.22	±.804	3.03	±1.134	3.02	±.676
Total	160	7	2.96	±.676	2.84	±.898	2.92	±.909	2.84	±.624	2.88	.781	3.32	±.802
		8	3.32	±.627	3.20	±.645	3.40	±.816	3.16	±.688	3.32	.690	3.60	±.707
		9	3.16	±.688	3.04	±.735	3.04	±.841	2.92	±.759	3.00	.816	3.28	±.614
		10	3.28	±1.021	3.20	±.913	2.92	±.862	3.44	±.961	3.28	1.021	3.00	±1.000
		Total	3.18	±.770	3.07	±.807	3.07	±.868	3.09	±.793	3.12	.844	3.30	±.810
	170	7	3.16	±.898	3.40	±.957	3.24	±.926	3.52	±1.122	3.32	±1.030	3.52	±.653
		8	3.56	±.768	3.28	±.936	3.48	±.770	3.48	±.872	3.32	±.802	3.60	±.645
		9	3.00	±.707	2.84	±.898	3.28	±.843	3.08	±.702	3.04	±.735	3.36	±.907
		10	3.20	±.957	3.08	±.702	2.92	±.909	3.24	±1.012	3.36	±.907	2.76	±.970

		Total	3.23	±.851	3.15	±.892	3.23	±.874	3.33	±.943	3.26	±.872	3.31	±.861
	180	7	3.36	±.860	3.32	±.945	3.00	±.816	3.04	±.978	3.56	±.651	3.12	±.881
		8	2.92	±.640	2.96	±.676	2.64	±.638	2.88	±.666	2.64	±.810	3.04	±.611
		9	2.64	±.638	2.92	±.759	2.48	±.872	3.28	±.980	2.76	±.723	2.68	±.627
		10	1.92	±.954	2.40	±.866	1.88	±1.092	2.76	±.779	2.16	±1.028	2.72	±.843
		Total	2.71	±.935	2.90	±.870	2.50	±.948	2.99	±.870	2.78	±.949	2.89	±.764
	Total	7	3.16	±.823	3.19	±.954	3.05	±.884	3.13	±.963	3.25	±.871	3.32	±.791
		8	3.27	±.723	3.15	±.766	3.17	±.828	3.17	±.778	3.09	±.825	3.41	±.699
		9	2.93	±.704	2.93	±.794	2.93	±.905	3.09	±.825	2.93	±.759	3.11	±.781
		10	2.80	±1.151	2.89	±.894	2.57	±1.068	3.15	±.954	2.93	±1.119	2.83	±.935
		Total	3.04	±.884	3.04	±.861	2.93	±.948	3.14	±.880	3.05	±.909	3.17	±.833

APPENDIX-IV The value of *n* for different equipments

Equipment	Size	Unit	Approximate cost, \$000	Size range	Exponent
Agitator, turbine, top entry, open, FOB	10 (7.5)	hp (kW)	7.0	2–30 (1.5–22.4)	0.45
Agitator, turbine, top entry, closed, FOB	10 (7.5)	hp (kW)	10.7	2–200 (1.5–150)	0.56
Blower, centrifugal, 4 lbf/in² (27.6 kN/m²), DEL, excluding motor	10 (4.72)	10^3 sft³/min (sm³/s)	67	0.5–150 (0.24–71)	0.60
Cone crusher, FOB, crusher only	100 (74.6)	hp (kW)	130	30–300 (22.4–224)	0.92
Jaw crusher, FOB, excluding motor	10 (7.5)	hp (kW)	34	1–60 (0.75–44.7)	0.65
Jaw crusher, FOB, excluding motor	100 (74.6)	hp (kW)	284	60–400 (44.7–300)	0.81
Centrifugal pump, C/S, FOB, excluding motor	10 (7.5)	hp (kW)	1.6	0.5–40 (0.37–30)	0.30
Centrifugal pump, C/S, FOB, excluding motor	100 (74.6)	hp (kW)	4.4	40–400 (30–300)	0.67
Conveyor, belt, C/S, FOB, excluding motor	100 (9.3)	ft² (m²)	6.7	60–200 (5.6–18.6)	0.50
Conveyor, screw, C/S, DEL, excluding motor	70 (540)	ft × in diameter (m × mm diameter)	10	50–100 (390–780)	0.46
Centrifuge, automatic batch, horizontal, C/S, FOB	20 (1.86)	Filter area, ft² (m²)	100	7–80 (0.65–7.43)	0.65
Compressor, reciprocating, <1000 lbf/in², FOB, including motor	300 (224)	hp (kW)	133	1–20000 (0.75–1490)	0.84
Crystallizer, forced circulation, C/S, FOB	100 (91)	ton/day (Mg/day)	283	10–1000 (9.1–970)	0.59
Dryer, drum, C/S, FOB, excluding motor	100 (9.3)	ft² (m²)	73	10–400 (0.9–37)	0.52
Dryer, vacuum, shelf, C/S, FOB, excluding trays, vacuum equipment	100 (9.3)	ft² (m²)	17	15–1000 (1.4–93)	0.56
Dust collector, cloth, shaker type, FOB, including motors	10^4 (4.7)	sft³/min (m³/s)	17	10^3–5×10^4 (0.47–23.6)	0.79
Dust collector, multicyclones, FOB	10^4 (4.7)	sft³/min (m³/s)	7	10^3–1.5×10^5 (0.47–70.8)	0.66
	10^4 (4.7)	ft³/min at 40°C	77	10^3–8×10^4 (0.47–73.8)	0.39
Electrostatic precipitator, FOB	2×10^5 (94)	(m³/s)	383	8×10^4–10^6 (37.8–472)	0.81
Ejector, single-stage, 100 psig, steam, FOB	3 (10^{-2})	lb/h (air/mmHg absolute)	2.7	0.2–30 (6.8×10^{-4}–0.1)	0.50
Ejector, two-stage, FOB, including condenser, piping	1 (3.4×10^{-3})	[kg/h/(N/m²)]	6.3	0.2–10 (6.8×10^{-4}–3.4×10^{-2})	0.43
Ejector, multistage, FOB, including condenser, piping	10 (3.4×10^{-2})	[kg/h/(N/m²)]	16.7	0.2–100 (6.8×10^{-4}–0.34)	0.26
Filter, vertical-pressure leaf, C/S, DEL	100 (9.3)	ft² (m²)	17	30–1500 (2.8–140)	0.57
Filter, plate and frame, C/S, DEL	100 (9.3)	ft² (m²)	5.7	10–1000 (0.9–93)	0.55
Filter, vacuum rotary drum, C/S, FOB, including motor	100 (9.3)	ft² (m²)	63.3	10–1500 (0.9–140)	0.48
Heat exchanger, shell-tube, floating head, C/S, DEL; fixed tube × 0.85; U tube × 0.87; kettle × 1.35	1000 (93)	ft² (m²)	21.7	20–20000 (1.9–1860)	0.59
Heat exchanger, thermal screw, C/S, FOB, excluding motor	100 (9.3)	ft² (m²)	33	10–400 (0.9–37)	0.78
Kettle, jacketed, glass-lined, FOB	100 (0.38)	U.S. gal (m³)	53	50–1000 (0.2–3.8)	0.48
Motors, ac induction, wound rotor, TEFC, FOB	10 (7.5)	hp (kW)	12.3	10–25 (7.5–18.6)	0.56
Motors, ac induction, wound rotor, TEFC, FOB	70 (52)	hp (kW)	19.3	25–200 (18.6–149)	0.77
Piping, typical straight run, C/S, FOB, \$/ft					
Installed: \$/ft × 6 to 7	6 (152)	Nominal diameter in (mm)	0.0093	1–24 (25–610)	1.33
Complex network: FOB \$/ft × 2 Installed: \$/ft × 13					
Pressure vessel horizontal drum (150 psig), C/S	1000 (3.8)	U.S. gal (m³)	6.3	100–80000 (0.4–302)	0.62
Jacketed reactors, including mixer, FOB	100 (0.38)	U.S. gal (m³)	9.3	10–4000 (0.04–15.1)	0.53
Refrigeration, packaged mechanical, INST	100 (351.7)	U.S. tons (kW)	133	10–1000 (35.2–3520)	0.73
Screen, vibrating, single-deck, DEL, including motor	500 (46)	ft² (m²)	10	150–700 (14–65)	0.62
Stack, carbon steel		ft (m)	—	20–150 (6.1–45.7)	1.00
Tanks: atm, horizontal cylinder, C/S, FOB	1000 (3.8)	U.S. gal (m³)	4.7	100–40000 (0.4–151)	0.57
Vertical cylinder, C/S, FOB	1000 (3.8)	U.S. gal (m³)	3.3	100–20000 (0.4–76)	0.30
Vertical jacketed, C/S, FOB	1000 (3.8)	U.S. gal (m³)	15	70–1500 (0.26–5.7)	0.57
Vertical agitated, C/S, FOB, including motor	1000 (3.8)	U.S. gal (m³)	12.3	100–20000 (0.4–76)	0.50
		$\left(\frac{\text{feed, lb/year}}{10^6}\right)^{0.65}$			
Towers, distillation including internals, INST	4000 (trays)		3300	300–30000	1.00

APPENDIX-V factors with separation of materials and labor

	Total factor	Materials factor	Labor factor
Equipment delivered	1.00		
Installation	0.09		0.09
Instruments installed	0.13	0.09	0.04
Piping	0.29	0.155	0.135
Foundations and steel	0.18	0.08	0.10
Insulation painting	0.11	0.025	0.085
Electrical	0.18	0.06	0.12
Battery-limit building	0.21	0.13	0.08
Site preparation	0.08		
Auxiliaries	0.55		
Physical-plant cost	2.82		
Engineering and home office	0.31	0.01	0.30
Field expense	0.43	0.30	0.13
Direct plant cost	3.56		
Contractor's fees	0.17		
Contingency	0.39		
Fixed-capital cost	4.12		

APPENDIX-VI AOAC 2003 General procedure for proximate analysis

Moisture determination using air oven method

The moisture determination was done using the drying process of the final product (biscuit) in an oven of temperature range of 100-120^{0}C. It involved the use of different equipments like oven, dishes, porcelain, desiccators, and other apparatuses. In addition, the final moisture content was determined using the following relation (AOAC, 2003).

$$\%Moisture = \frac{W_2}{W_1} \times 100$$

$$\%Totalsolids = \frac{W_3}{W_1} \times 100$$

Where W_1= weight of wet sample

W_2=loss of weight

W_3=weight of dry sample

Total and crude protein determination

The determination of crude protein passed through three steps these are digestion, distillation and titration. In the determination of total protein the Kocho biscuit was well prepared and grounded and then it passed through the Kjeldahl apparatus after treated with acid and base. The ammonia released after alkalization with sodium hydroxide was steam distilled into boric acid and titrated with sulfuric acid. The result obtained will be interpreted using the following equation (AOAC, 2003).

$$\text{Total Nitrogen Content (\% / Weight)} = \frac{(T - B) \times N \times 14.007 \times 100}{W}$$

Where:

T= Volume in ml the standard Sulphuric acid of used in the titration for the test material

B= Volume in ml the standard Sulphuric acid used in the titration for the blank determination

N= Normality of standard Sulphuric acid

W= Weight in g of the test material

Therefore, Crude Protein Content (% / Weight) = % Total Nitrogen Content × 6.25

Fat in the biscuit sample

The Fat was extracted with ether (peroxide free) from dried samples in a Soxhlet apparatus. The amount of fat was calculated from the difference in weight of the extraction flask before and after extraction. In this analysis different chemicals and equipments were used such as potassium iodide, ether, sodium bicarbonate and other chemicals. The equipments include Soxhlet extraction apparatus, extraction flask, extraction thimble, beaker, and other. The data obtained was interpreted using the fallowing relation (AOAC, 2003).

$$W = W_2 - W_1$$

$$\text{Fat g/ 100g fresh sample} = W \times ((100 - \%\ \text{moisture}) / W_D)$$

Where W = weight of fat

W_2 = weight of extracted fat and extraction flask after extraction

W_1 = weight of extracted fat and extraction flask before extraction

W_D = weight of dried sample

The determination of crude fiber

A fat-free or low fat content sample was treated with boiling sulfuric acid and subsequently with boiling potassium hydroxide or sodium hydroxide. The residue after subtraction of the ash is regarded as fiber. Some of the apparatuses used to determine the fiber content includes beaker, watch glass, stirrer, sintered glass crucible, oven, desiccators and others. The data was interpreted using the relation shown bellow (AOAC, 2003).

$$\text{Crude fiber g/100g} = (W_1 - W_2)(100 - M) / W_3$$

Where W_1 = crucible weight after treated with acid and base; and drying in an oven

W_2 = crucible weight after drying in muffle furnace (ash and crucible)

W_3 = sample dry weight

M = % moisture content of the sample

Carbohydrates determination of biscuit

The carbohydrate was determined by subtraction method. But the scientific procedure for carbohydrate determination is first digested with perchloric acid. Hydrolyzed starch together with soluble sugar are determined calorimetrically by the Clegg Anthrone method and expressed as glucose. Some of the reagents used include perchloric acid, sulfuric acid, anthrone reagent and glucose. The apparatuses include filter paper, spectrophotometer and others. And finally, the data will be interpreted by the relation as shown bellow (AOAC, 2003).

$$\text{Carbohydrate} = 100\ \text{g} - (\text{g protein} + \text{g fat} + \text{g alcohol} + \text{g ash} + \text{g water})$$

$$\text{Total available carbohydrate (as \% glucose)} = (25 \times b) / (a \times W)$$

Where:

W = Weight of the sample

a = Absorbance of dilute standard

b = Absorbance of dilute sample

Ash content determination of biscuit

Organic matter was burned off at low temperature then heat treated in muffle furnace and the inorganic materials remaining is cooled and weight. Heating is carried out in stages, first to derive the water, then to char the product thoroughly and finally to ash at 550^0C in a muffle furnace. Different apparatuses had been used including muffle furnace, electric hot plate, silica dishes, and desiccators. And finally it is determined by using the equation shown bellow (AOAC, 2003).

$$\% \text{ Ash} = (W_2 / W_1) \times 100$$

Where:

W_1 = weight of sample before ash

W_2 = weight sample after ash

Mineral analysis of biscuit

The crucibles used were thoroughly washed and dried in an air-circulating oven at 100°C for 15 minutes. They were removed into desiccators to cool. The crucibles later preheated in the carbolated furnace at 550°C for 10 minutes. 2 gram of the sample placed in the pre-heated, cooled and weighed crucible and then reweighed. The temperature allowed rising to 550°C and the ash carried out for one hour at this temperature. The crucibles was be removed from the furnace, allowed to cool in desiccators and reweighed. The percentage ash content was calculated (Horsefall and Ayebaemi, 2004).

$$Ash(\%) = \frac{mass\ of\ ash(g)}{mass\ of\ sample(g)} \times 100$$

Upon ash, 3 drops of 1M HNO_3 acid was added to the sample in the crucible to digest the ash. Then about 50ml of distilled water used to rinse the digest into 100 ml flasks. The flasks then filled up to the marks with distilled water. The digest filtered into sample bottle using the whatman filter paper (125mm) prior to analyses. The Mn, K, Fe, Zn, Ca, and Mg content in the samples was determined using Atomic Absorption Spectrometer (AAS) at 279.5nm, 766.5nm, 248.3nm, 213.9nm, 422.7nm, and 285.2nm wavelengths respectively; using the air-acetylene flame. The concentrations of the elements in the samples are calculated using the formula:

$$concentration\left(\frac{mg}{100g}\right) = \frac{consentration \times 10}{sample\ weight\ (g)}$$

Declaration

This thesis paper is my original work and it has not been done or presented for any university or other organization in the form of thesis or other scientific papers and this is declared by the signature hereunder.

By
Kalekristos Yohannes

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Addis Ababa, Ethiopia

Date of Submission:____

This has been submitted for examination with the approval of university advisor

Dr. Eng. Shimelis Admassu

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