

UNIVERSITY OF GHANA

COLLEGE OF BASIC AND APPLIED SCIENCES

**PHYSICOCHEMICAL AND SENSORY EVALUATION OF A
BREAKFAST CEREAL MADE FROM SPROUTED FINGER
MILLET-MAIZE COMPOSITE FLOUR**

BY

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DECLARATION

I, Reuben Acheampong, hereby declare that except for the references which have been duly cited, the work in this thesis, “**PHYSICOCHEMICAL AND SENSORY EVALUATION OF A BREAKFAST CEREAL MADE FROM SPROUTED FINGER MILLET-MAIZE COMPOSITE FLOUR.**” was done entirely by me in the Department of Family and Consumer Sciences, College of Basic and Applied Sciences, University of Ghana, Legon. This work has never been presented either in whole or in part for any other degree in this University or elsewhere.

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ABSTRACT

Underutilized and marginalized food crops are less regarded with respect to promotion and exploration. Nonetheless, they are more adapted to adverse climatic changes, a global food security problem, especially in third world countries. This has necessitated the exploration and promotion of the potential of deserted indigenous food crops on the verge of extinction, to safeguard food security in developing countries. This research studied the performance of finger millet flour (FMF) in breakfast cereal production. The study developed a process for the production of flour from finger millet, maize and date fruit and followed a one factor design in which Maize flour (MF) was substituted with FMF at 0%, 40%, 50%, 60% and 70% levels of incorporation. The tristimulus colour (L^* value), pH, amount of water and oil absorption capacity, proximate composition, emulsion capacity and stability, swelling power and solubility index, particle size distribution and pasting properties of composite flour samples were analyzed. Breakfast cereal samples made from composite flour were analyzed for sensory characteristics and tristimulus colour (L^* value). Moisture, ash and fiber content of composite flour samples increased with increasing SFMF, while carbohydrate and protein content decreased ($p \leq 0.05$). Water and oil absorption capacities, emulsion capacity and stability, swelling power and solubility index increased with increasing levels of SFMF in the composite flour samples while pasting properties (final viscosity and peak viscosity) decreased ($p \leq 0.05$). Tristimulus L^* value decreased (darker breakfast cereal) as SFMF increased in composite breakfast cereal samples, with 70% FMF recording the lowest L^* value ($p \leq 0.05$). Sensory analysis of the breakfast cereal samples showed that breakfast cereal with 40% and 50% SFMF had the highest overall acceptability, colour, and taste scores ($p \leq 0.05$). Results from this study indicate that nutritious breakfast cereal samples with high ash and crude fiber, but low carbohydrate and moisture content can be made from finger millet-maize composite flour. MF can be partially substituted with 40% to 50% FMF

for breakfast cereal production. This can go a long way to address food insecurity resulting from the neglect of most indigenous nutritious food crops, by increasing the use of this marginalized indigenous adverse weather resistant crop, while providing food manufacturers with an option to partially substitute MF in breakfast cereal applications.

DEDICATION

This thesis is primarily dedicated to the Almighty God, my supervisors and the ACHEAMPONG family. I also dedicate it to the AMISSAH and DANQUAH families, and friends who have always cared, supported, and loved me throughout my education. May the Almighty God bless and keep you always. I finally dedicate it to all prospective researchers and entrepreneurs who uphold the quality standards in food processing and manufacturing in Ghana.

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TABLE OF CONTENTS

CONTENTS	PAGE
DECLARATION	i
ABSTRACT	ii
DEDICATION	iv
ACKNOWLEDGEMENTS	v
LIST OF TABLES	xiii
LIST OF FIGURES	xiv
LIST OF ACRONYMS	xv
CHAPTER ONE	1
1.0 INTRODUCTION	1
1.1 BACKGROUND INFORMATION	1
1.2 STATEMENT OF THE PROBLEM	5
1.3 AIM OF THE STUDY	5
1.4 OBJECTIVES	6
1.5 HYPOTHESES	6
1.6 SIGNIFICANCE OF THE STUDY	7
CHAPTER TWO	8
2.0 LITERATURE REVIEW	8
2.1 PRODUCTION, PHYSIOLOGY, VARIETIES AND DISTRIBUTION OF FINGER MILLET IN GHANA	8

2.1.1 Finger Millet Production and Distribution	8
2.1.2 Physiology of Finger Millet	9
2.1.3 Finger Millet Varieties in Ghana	10
2.1.4 Importance of Finger Millet	11
<i>2.1.4.1 Nutritive Value of Finger Millet</i>	12
<i>2.1.4.2 Economic Importance of Finger Millet</i>	13
<i>2.1.4.3 Agricultural Significance of Finger Millet</i>	14
2.1.5 Post-Harvest Processing Technologies of Millet	15
2.1.6 Utilization of Finger Millet	17
2.1.7 Value Addition	19
2.1.8 Phytates Inhibition of Mineral Bioavailability	19
2.2 DATE FRUIT	20
2.2.1 Fruit Description and Production	20
2.2.2 Importance of Date Fruit	21
2.3 FLOUR AND COMPOSITE FLOUR PRODUCTION	22
2.3.1 Maize Production	22
2.3.2 Importance of Maize and Maize Flour	23
2.3.2.1 Nutritional Significance	23
2.3.3 Traditional Processing of Sprouted Millet into Flour	24
<i>2.3.3.1 Sorting and Washing</i>	24
<i>2.3.3.2 Soaking</i>	24

2.3.3.3 Sprouting and Roasting	24
2.3.3.4 Milling and Sieving	26
2.3.3.5 Fermentation	26
2.3.3.6 Packaging and Storage	27
2.3.4 Industrial Processing of Cereal-Based Food Products	28
2.3.4.1 Drum Drying	28
2.3.4.2 Extrusion Cooking	28
2.3.5 Importance of Cereal Crop Flour Production	29
2.3.6 Economic Impact of Cereal Flour Production	30
2.3.7 Composite Flour	31
2.3.7.1 Composite Flour Production	31
2.3.7.2 Importance of Composite Flour	32
2.4 PRODUCTION OF BREAKFAST CEREALS	33
2.4.1 Cereal – Fruit Complementation	34
2.5 PHYSICOCHEMICAL CHARACTERISTICS OF COMPOSITE FLOUR	
SAMPLES	35
2.5.1 Physical Characteristics of Composite Flour Samples	35
2.5.1.1 Particle Size Distribution	35
2.5.1.2 Colour and Total Colour Difference	36
2.5.2 Chemical and Functional Characteristics of Composite Flour	37

<i>2.5.2.1 Proximate Composition</i>	37
<i>2.5.2.2 pH</i>	37
<i>2.5.2.3 Water and Oil Absorption Capacity</i>	37
<i>2.5.2.4 Pasting Properties</i>	39
<i>2.5.2.5 Emulsion capacity and stability</i>	40
2.6 CONSUMER PURCHASING BEHAVIOUR TOWARDS INSTANT FOODS	41
2.7 SENSORY EVALUATION OF FOOD PRODUCT	42
2.8 MICROBIOLOGICAL STUDY OF INSTANT FOOD PRODUCTS	43
CHAPTER THREE	45
3.0 MATERIALS AND METHODS	45
3.1 MATERIALS	45
3.1.1 Ingredients	45
3.1.2 Tools and Equipment	45
3.2 METHODS	45
3.2.1 Processing of Sprouted Finger Millet and Maize Flour	45
3.2.1.1 Sorting, Washing and Soaking	45
3.2.1.2 Sprouting, Drying, Winnowing and Milling	46
3.2.1.3 Packaging and Storage	46
3.2.2 Formulation of Composite Flour	49
3.2.3 Instant Breakfast Cereal Preparation	49
3.2.3.1 Proportion of Ingredients in Composite Breakfast Cereal Preparation	49

3.2.3.2 <i>Breakfast Cereal Preparation</i>	50
3.2.4 Determination of the Physical Characteristics of the Composite Flour Samples	52
3.2.4.1 <i>Determination of Colour and Total Color Difference of Composite Flour Samples</i>	52
3.2.4.2 <i>Determination of Particle Size Distribution of Composite Flour Samples</i>	54
3.2.5 Determination of the Chemical and Functional Characteristics of Composite Flour Samples	55
3.2.5.1 <i>pH of the Composite Flour Samples</i>	55
3.2.5.2 <i>Oil and Water Absorption Capacities of the Composite Flour Samples</i>	55
3.2.5.3 <i>Pasting Properties of the Composite Flour Samples</i>	56
3.2.5.4 <i>Emulsion Capacity and Stability of the Composite Flour Samples</i>	57
3.2.5.5 <i>Swelling Capacity and Solubility Index of Composite Flour Samples</i>	59
3.2.6 Instrumental Analysis of Composite Breakfast Cereal	60
3.2.6.1 <i>Determination of Colour and Total Colour Difference of Composite Breakfast Cereal</i>	60
3.3 SENSORY EVALUATION OF COMPOSITE BREAKFAST CEREAL	60
3.4 DATA COLLECTION	61
3.5 DATA ANALYSES AND PRESENTATION	61
CHAPTER FOUR	63

4.0 RESULTS AND DISCUSSION	63
4.1 Physical Characterization of Composite Flour Blends	63
4.1.1 Colour (L*a*b* Values) of Composite Flour Samples	63
4.1.2 Particle Size Distribution of Composite Flour Samples	65
4.2 CHEMICAL CHARACTERISTICS OF THE FLOUR SAMPLES	68
4.2.1 Proximate Composition	68
4.2.2 Moisture Content	68
4.2.3 Fat Content	70
4.2.4 Total Ash Content	71
4.2.5 Protein Content	72
4.2.6 Carbohydrate Content	72
4.2.7 pH of Flour Samples	74
4.3 FUNCTIONAL CHARACTERISTICS OF COMPOSITE FLOUR SAMPLES	75
4.3.1 Water and Oil Absorption Capacities of Composite Flour Samples	75
4.3.1.1 Water Absorption Capacity of Flour Samples	75
4.3.1.2 Oil Absorption Capacity of Flour Samples	77
4.3.2 Emulsion Capacity and Stability of Composite Flour Samples	78
4.3.3 Pasting Properties of Composite Flour Samples	80
4.3.4 Swelling Power and Solubility Index of Composite Flour Samples	83
4.4 SENSORY EVALUATION OF COMPOSITE BREAKFAST CEREAL SAMPLES	85

4.5 TEST OF HYPOTHESES	87
4.5.1 Null Hypothesis One (1)	87
4.5.2 Null Hypothesis Two (2)	88
4.5.3 Null Hypothesis Three (3)	88
CHAPTER FIVE	90
5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS	90
5.1 SUMMARY	90
5.2 CONCLUSION	91
5.3 RECOMMENDATIONS	92
REFERENCES	93
APPENDICES	123
APPENDIX 1	123
APPENDIX 2	126
APPENDIX 3	130
APPENDIX 4	132

LIST OF TABLES

TABLE	PAGE
Table 1: Nutrient Composition of Finger Millet /100g	11
Table 2: Percentage of Sprouted Finger Millet Flour to Roasted Maize Flour and Date Fruit Flour in composite flour formulations	49
Table 3: Proportion of Ingredients for Making Breakfast Cereal	50
Table 4: Mean Colour (L*a*b*) and Total Colour Difference (ΔE^*) Values of Composite Flour Samples	64
Table 5: Particle Size Distribution of Composite Flour Samples	66
Table 6: Proximate composition of Finger Millet and Maize Composite Flour Samples	69
Table 7: pH of Composite Flour Samples	74
Table 8: Emulsion Capacity and Stability of Composite Flour Samples.	79
Table 9: Pasting Properties of Composite Flour Samples	82
Table 10: Swelling Power and Solubility Index of Composite Flour Samples	84
Table 11: Sensory Evaluation of Composite Breakfast Cereal Samples	85
Table 12: Statistical test of null hypothesis one	87
Table 13: Statistical test of null hypothesis two	88
Table 14: Statistical test of null hypothesis three	89

LIST OF FIGURES

FIGURE	PAGE
Figure 1: Structure of the Millet Grain	9
Figure 2: Frequently grown finger millet varieties in Ghana.	10
Figure 3: Flow Chart for Good Quality Sprouted Cereal Flour Production.	25
Figure 4: Flow Chart for Sprouted Finger Millet Flour Production.	47
Figure 5: Illustration of the Process for Sprouted Finger Millet Flour Production	48
Figure 6: Flow Chart for Composite Breakfast Cereal Production	51
Figure 7: Procedure for Breakfast Cereal Preparation	53
Figure 8: Process for Determining the Particle Size Distribution of Composite Flour Samples	54
Figure 9: Test for Pasting Properties of Composite Flour Samples	58
Figure 10: Water Absorption Capacity of Composite Flour Samples	76
Figure 11: Oil Absorption Capacity of Composite Flour Samples	78

LIST OF ACRONYMS

AACC	American Association for Clinical Chemistry
AOAC	Association of Official Analytical Chemists
ANOVA	Analysis of Variance
BOPP	Biaxially Oriented Polypropylene
CBAS	College of Basic and Applied Sciences
DFF	Date Fruit Flour
FMF	Finger Millet Flour
FAO	Food and Agriculture Organization
FAOUN	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
IFBC	International Food Biotechnology Council
IFPRI	International Food Policy Research Institute
LDPE	Low-Density Polyethylene
MF	Maize Flour
MoFA	Ministry of Food & Agriculture
PP	Polypropylene
RS	Resistance Starch
SFMF	Sprouted Finger Millet Flour
SRID-MoFA	Spatial Reference System Identifier - Ministry of Food and Agriculture
UN	United Nations
USA	United States of America
WHO	World Health Organization.

CHAPTER ONE

1.0

INTRODUCTION

1.1 BACKGROUND INFORMATION

Underutilized and marginalized food crops are less regarded plant species in terms of their promotion and exploration, but are nonetheless well adapted to diverse and adverse climatic conditions (Padulosi *et al.*, 2002). Even though the indigenous potential and ethnobotanical information of these wonderful crops are well known to individuals, their commercial importance as well as market values are not well known to the public (Thakur, 2014). Hence these crops are gradually going extinct. Therefore, ensuring their existence on planet earth is of tremendous importance to ensure that enough foods are produced to feed the exponentially growing world's population for decades to come (Food and Agriculture Organization, 2009).

While there is the need to ensure the continuity of these lost crops, it is crucial for this to be done in a sustainable way, such as researching into the potential food applications of these indigenous crops (Lawson, 2013). Developing countries are the most affected with regards to food insecurity and as such must strategize to embrace novel technologies in order to better manage their natural resources so as to reduce poverty and hunger (Stringer, 2000). It is worthy to note that increasing food production alone, is not adequate to attain food security but rather, it must be accompanied by feasible policies to improve food accessibility by fighting hunger and poverty in rural areas (Food and Agriculture Organization, 2009).

Finger millet (*Eleusine coracana (L.) Gaertn*) formerly a Ghanaian staple food crop in the northern region of Ghana and one of the minor cereal crops of Ethiopia, Nigeria, Burkina Faso and Niger is an underutilized and marginalized cereal crop. It is cultivated extensively

in India and Asia but marginally grown in Africa. In Ghana, finger millet is predominantly cultivated in the north, alongside other cereal crops such as maize and sorghum (SRID-MoFA, 2011). It is an important staple food crop for small-holder farmers who grow it as well as individuals in areas where they are cultivated (Rooney & Serna-Saldivar, 2000). Finger millet, a chief dryland crop, has the tendency to tolerate adverse environmental conditions when grown in areas not liable to flood, or in soils with poor water holding capacity (FAO, 2001). As a result, this group of small grains can be widely grown in varied and adverse environments, typically in the semi-arid to sub-humid drought-prone agro ecosystems (Chandra *et al.*, 2016).

The finger millet grain is round, consists of pericarp, endosperm, and germ and is part of the Poaceae family of the mono-cotyledon group. It is a unique cereal grain with starch granules present in the pericarp (Rooney & Serna-Saldivar, 2000). Finger millet has been classified as one of the top six cereal crops grown globally, along with rice, wheat, oats, maize and barley and has the highest productivity level among millet grains (FAO, 2007). Studies have revealed that finger millet supplies a significant percentage of calories and protein to large segments of the population in Asia and Africa particularly for people of low-income (Hulse, 1991).

Finger millet has gained importance in recent years because of its nutritional asset in terms of starch pattern, dietary fiber and high mineral content (Pore & Magar, 1979). Regardless of these benefits, the harvested area and consumption of finger millet have reduced significantly due to urbanization, changing food preferences, non-exposure and unavailability of products suiting the taste of rural and urban inhabitants. Therefore further promotion of finger millet requires diversification of products in terms of healthy food,

bakery products and ready-to-eat foods (Sinha & Sharma., 2017). Attention has been given to the utilization of millet flour in the production of baked products such as bread, cookies and crackers with the objective of targeting gluten sensitive or diabetic consumers (Rai *et al.*, 2014). Cereal products such as “Tombrown” and “weani-mix” typically have processed maize and rice flour as their sole ingredients. The replacement of these refined flour with finger millet flour will advance the nutritional quality of such products (Sinha & Sharma, 2017).

Finger millet is a non-acid forming food crop which is easy to digest. It is regarded as one of the cereal crops with the least allergic property and its warming ability makes it helpful to maintain the body temperature of individuals during cold or rainy seasons (Bhatt *et al.*, 2003). Yet, finger millet utilization is marginal owing to the coarse nature of the grain, its thick fiber content and an outer cover which makes its processing difficult, thus gives a poor sensory quality (Kang *et al.*, 2008). Similarly, there is a higher demand for mill-polished rice competing with ancient crops such as finger millet. This hinders the use of finger millet beyond food applications such as in pharmaceuticals and nutraceuticals. This clearly indicates that, even though the grain is an ancient food crop, little research has been done on its food applications (Pragya, 2012).

Studies conducted on the amino acid content of finger millet have established that the albumin and globulin fractions of finger millet contain a good complement of essential amino acids. On the other hand, the prolamin fraction which also contains higher proportions of essential amino acids is low in lysine, arginine and glycine (FAO, 1995). As a result of this, in order to develop a nutritious composite breakfast cereal from finger millet, the incorporation of date fruits, a good source of these essential amino acids lacking in finger

millet (Pragya, 2012) is considered necessary in the production of the composite breakfast cereal. Dykes & Rooney (2006) established that food products with maize as a constituent offered acceptable sensory scores and improved nutritional profile in terms of its fiber, monounsaturated fat and minerals.

Composite flour technology presents an excellent potential for developing countries. While consumer trials have been scarce in recent years, food products made from composite flours have been well accepted in places like Sri Lanka, Sudan, Kenya, Nigeria and Senegal (Pragya, 2012). Investigations reveal that composite flour made up of cereal-fruits blends are relatively good sources of minerals, fats and water-soluble vitamins since fruits can supply the essential amino acids cereals lack (McKevith, 2004). Other studies have shown that cereal-based food products without enrichment with vitamins and minerals can result in mineral and vitamin deficiencies, especially iron and vitamin A among infants fed with cereal-based complementary foods (Bhaskarachary *et al.*, 2008). Moreover, supplements such as mineral and vitamin are not readily available and accessible for use by most middle and low socioeconomic status families at the household-level in Africa as a result of cost and illiteracy (Sinha & Sharma, 2017). Thus, making a breakfast cereal from sprouted finger millet, maize and date fruit composite flour, would provide a nutritious, affordable and easily accessible meal to all at the household-level

This study developed a process for making composite breakfast cereal from sprouted finger millet, maize and date fruit composite flour. Studied the suitability of using finger millet with maize and date fruit composite flour as a basic ingredient in developing an instant breakfast cereal. This, not only added value to the finger millet crop but also promoted its cultivation and utilization in Ghana and subsequently, improved the standard of living of those who grow finger millet and intermediate processors.

1.2 STATEMENT OF THE PROBLEM

Studies into finger millet has become key recently since this staple cereal crop in the northern part of Ghana is going extinct due to the over-dependence on its close substitutes (pearl millet and maize) and limited agronomic research. With the general growing concern for food security and food diversity as a result of climate change, globalization is opening up new markets and creating opportunities for fair trade and business. An international rising concern in healthy food products has also given room to an enormous potential, which can be explored. Owing to the ignorance of people about the cultivated plants as a good ingredient for food products, there is a high demand for commercial seed, the production of which is seldom enough to meet the nutritional needs of the growing population. Opportunities for maximizing finger millet potentials are available, however, factors such as limited research into potential food applications and identification of novel approaches to unleash the potentials of finger millet are hindering its utilizations. Investigation have been done to explore the potentials of cereal crops in Ghana but little has been done on finger millet especially in the development of breakfast cereals. Confirming the potential of finger millet as a partial substitute for maize and rice flour in composite breakfast cereal development will improve the utilization of finger millet and enhance its economic importance.

1.3 AIM OF THE STUDY

The aim of this study was to develop an instant breakfast cereal from Sprouted Finger Millet, Maize and Date Fruit Composite Flour and evaluate its physical, chemical, functional and sensory properties.

1.4 OBJECTIVES

The specific objectives of this study were to;

1. Develop a process for the production of flour from Sprouted Finger Millet, Maize and Date Fruit.
2. Determine the ratio of Finger Millet Flour (FMF) to Maize Flour (MF) and Date Fruit Flour (DFF) that was optimal for the production of the instant breakfast cereal.
3. Determine a procedure for the production of the instant breakfast cereal from Sprouted Finger Millet, Maize and Date Fruit Composite Flour.
4. Determine the physical, chemical, functional and sensory characteristics of the instant breakfast cereal developed from Sprouted Finger Millet and Maize Composite Flour.

1.5 HYPOTHESES

The study tested the following hypotheses:

H₀1: The addition of FMF to MF does not affect the physicochemical characteristics of the composite flour.

H₀2: The addition of FMF to MF does not affect the functional properties of composite flour.

H₀3: Sensory attributes of the instant breakfast cereal are not affected by the addition of FMF to MF.

1.6 SIGNIFICANCE OF THE STUDY

This study has the following significance:

1. It will document a protocol for making Sprouted Finger Millet Flour and its use in instant breakfast cereal formulations.
2. It will help researchers improve the nutritive value of breakfast cereal for adults and serve as complementary food for infants.
3. The procedure can be adopted, further refined and up-scaled to be used by interested entrepreneurs to process fortified sprouted finger millet based breakfast cereals for commercial purposes.

CHAPTER TWO

2.0

LITERATURE REVIEW

2.1 PRODUCTION, PHYSIOLOGY, VARIETIES AND DISTRIBUTION OF FINGER MILLET IN GHANA

2.1.1 Finger Millet Production and Distribution

Gangaiah (2006), revealed that finger millet is among the cereal crops of the tropics and sub-tropics and can be raised effectively from sea level to an altitude between 1,000m and 2,000m on plains and hilly slopes. It is best cultivated in regions with rainfall up to 100 cm and can also be grown as a transplanted crop in places of higher rainfall and areas under irrigation. Finger millet prefers a warm climate and is cultivated on varieties of soils with varying fertility (Araus *et al.*, 2002). It requires a minimum temperature of 8 – 10 °C to germinate but needs a mean temperature of 26 to 29 °C for its optimum growth. The grain does well in porous and well-drained soils and has the ability to tolerate soil salinity than other related classes of cereals. In terms of the specific soil, loamy and alluvial soils with pH of 4.5 to 7.5 are suitable for its optimum growth (Araus *et al.*, 2002).

Finger millet starts flowering in 60 to 80 days after planting and matures in approximately 120-130 days depending on the variety and other biotic and abiotic factors. Harvesting finger millet is done in two ways. One is the use of the ordinary sickle to harvest earheads before straw is cut to the ground. Three to four days are set aside to heap earheads to cure and then thresh with hand or bullocks. The second is employed at regions or places under rainfed condition, where the plant with earhead is cut, heaped and threshed. Rainfed finger millet has an average yield that ranges from 1.0 to 1.5 tonnes of grain/ha, whereas the irrigated ones yield up to 5.0 tonnes/hectare. The fodder yield ranges from 3.0 to 9.0

tonnes/hectare in the case of early group and 9.5 - 10.0 tonnes/hectare in the late group (Gangaiah, 2006).

2.1.2 Physiology of Finger Millet

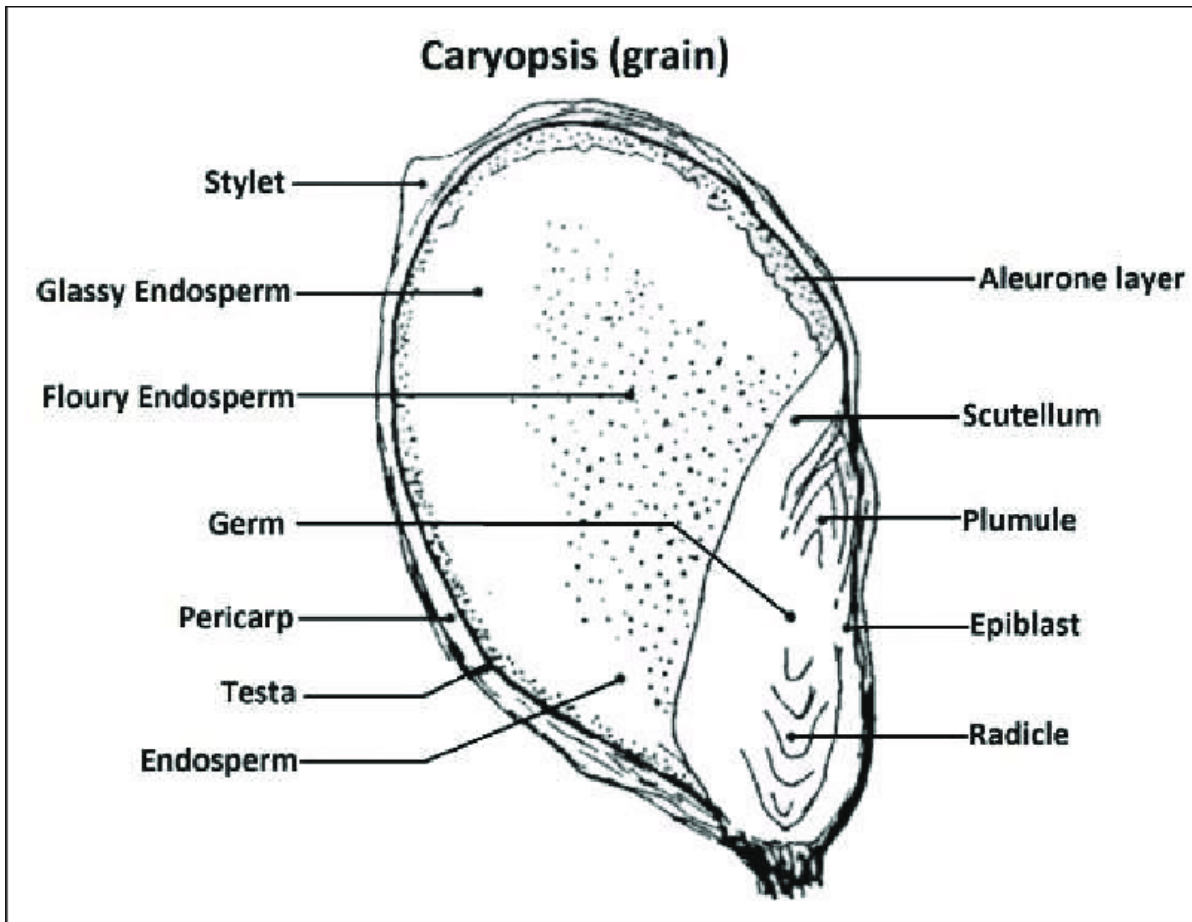


Figure 1: Structure of the Millet Grain

Source: <https://www.researchgate.net/profile/> Accessed on 6th December, 2018

Finger millet is a tufted annual crop which grows to 170 cm in height and matures in approximately 120 – 130 days (Global Strategy for the Ex Situ Conservation of Finger Millet and Its Wild Relatives. (2012). It has narrow leaves, grass-like and proficient in producing numerous whorls and nodal branches (Ashwini *et al.* 2014). The spikelet consists of 4 – 10 florets organized serially on the finger. The panicle consists of a group of digitally organized spikes. The grain comes in an oval to oblong and round, brownish red in

colour with the surface of the grain excellently grooved. Its seeds are very small and hard, the size being up to 2 mm in diameter (Upadhyaya *et al.*, 2007).

The number of branches of finger millet ranges from 4 to 19 and can be conventional (3 to 10 cm long) or curved like a hand with fingers partly closed (thus the name finger millet). The seeds of finger millet are formed in florets usually arranged in two rows along the panicle branch. The colour of the vegetative organs differs from green to purple. The plant has straight inflorescence and open spikes, curved inward or closed spikes and branched spikes, resembling the comb of a cock (Jyoti & Kumar, 2017).

According to FAO (2013), the second largest producer of millet next to India is Nigeria while the production of millet in Ghana is about 0.5% of the world's production. Hence, Ghana is ranked 19th in the world in terms of millet production. Ghana produced approximately 159,017 tonnes in 2016 (FAO, 2018). The three northern regions of Ghana, account for all the production of millet in Ghana because of the high tolerance of the crop to the dry weather conditions prevailing in these regions (Wood, 2013).

2.1.3 Finger Millet Varieties in Ghana

Figure 2 shows the two main varieties of finger millet cultivated in Ghana. They are the brown and red-skinned varieties.



Brown-Skinned Variety of Finger Millet



Red-skinned variety of Finger Millet

Figure 2: Frequently grown Finger millet varieties in Ghana.

Source: <http://www.desiutthana.com/uploads/product/2016/0f7bc3e65ea94ac81da33c74159f744b.jpg> n.d

Two main varieties of finger millet are cultivated in Ghana. They include the brown-skinned and red-skinned varieties. More of the red skinned variety is cultivated in Ghana. However, both are grown together as production of the crop is informally done on subsistence basis.

2.1.4 Importance of Finger Millet

Table 1: Nutrient Composition of Finger Millet /100g

COMPOSITION	PER 100g
Energy	336 Kcal
Carbohydrate	59.0 g
Protein	7.3 g
Fat	1.3 g
Total Dietary Fibre	19.1 g
Total phenol	10.2 g
Calcium	0.33 mg
Iron	46.0 mg
Thiamin	0.48 mg
Riboflavin	0.12 mg
Niacin	0.30 mg

Source: Shobana *et al.* (2013)

2.1.4.1 Nutritive Value of Finger Millet

According to Yang *et al.* (2012), finger millet is a valuable staple cereal crop found in Eastern and Central Africa and parts of Asia such as China and India. Finger millet is a rich source of phosphorus, iron, fiber, calcium and vitamins. Iodine and calcium constituents, for example, were found to be higher in finger millet than all the other cereal and food grains (Devi *et al.*, 2014). It was also found to have the best quality protein having almost all the essential amino acids. In addition it contains vitamin A and vitamin B. For these reasons, finger millet can be a worthy source of nutrients for growing children, pregnant and lactating mothers, the aged and patients recovering from a surgical operation.

Shukla & Srivastava (2014) and Mathanghi & Sudha (2012) showed in their studies that finger millet is beneficial with regards to controlling blood glucose levels in diabetic patients and the slower digestion rates and the weight of the fibers of finger millet make one feel fuller with fewer calories. As a result of its high dietary fiber and polyphenolic content, finger millet shows antimicrobial, antioxidant and antidiabetic attributes.

Chandrasekara & Shahidi (2010) revealed that, unprocessed finger millet has more radical quenching activity than refined finger millet. They therefore proposed that phytic acid and tannins were accountable for this activity. Similarly, Mathanghi & Sudha (2012) investigated the nutraceutical significance of finger millet and revealed that rising public awareness of health care and nutrition research validates the potentials of phytochemicals. A classic example is the dietary fiber and polyphenols on their health beneficial properties. This gave rise to the quest to identify novel sources of nutraceuticals and further investigate other nutritional materials with the desired functional physiognomies.

Shukla & Srivastava (2014) investigated the nutritional value of finger millet and discovered that it contains 81.5% carbohydrate, 9.8% protein, 4.3% crude fiber and 2.7% mineral relatively to other close cereals like rice, wheat and maize. Its mineral and crude fiber contents are remarkably higher than wheat (1.5% minerals and 1.2% fiber) and rice (0.6% minerals and 0.2% fiber). The protein profile of finger millet is well balanced as it provides more of the essential amino acids such as isoleucine (4.4 g), methionine (3.1 g), leucine (9.5 g), and phenylalanine (5.2 g) that are undersupplied in other starchy cereals.

Likewise, Sripriya *et al.* (1997) discovered that 8.71 mg/g dry weight and 8.47 g/g dry weight fatty acid and protein respectively are contained in finger millet, which also contains dietary minerals like phosphorus (250 mg), manganese (3.5 mg), iron (6.3 mg), calcium (344 mg), and magnesium (130 mg) per 100 g, hence it is superior to wheat and rice regarding its micronutrient and mineral contents. Phosphorus, calcium, zinc and iron contents of the finger millets were specifically studied and revealed that these minerals were of nutritive significance in the nourishments of a population that consume finger millet as its staple food crop.

2.1.4.2 Economic Importance of Finger Millet

The transformation of agriculture into more industrious and effective systems has often been complemented with maximizing production in fewer crop species (Doss *et al.*, 2011). Simultaneously, the area and cultivation of a great diversity of conventional crops have dropped, even though these crops play a significant role in maintaining sustainable forms of agriculture in many parts of the world (Hobbs *et al.*, 2008). Underutilized and marginalized crops are the least studied species in terms of research and trade, (Joshi *et al.*, 2002).

Even though finger millet possesses encouraging nutritional and industrial importance for a diversity of food and pharmaceutical applications, its commercial standings and market worth are unidentified. It is undervalued and graded as an inferior food item due to the wrong view individuals have (Adhikari, 2012). A study conducted by Mal *et al.* (2010) revealed that finger millet has the ability to progress resource management in Nepal by serving as a staple food, weaning food, and cash crop which will go a long way to provide income-generating opportunities for the people thereby improving the economic status of those who grow it. Gull *et al.*, (2014), stated that finger millet is a sustainable crop that is particularly significant for its cultural and nutritive values and exceptional storage qualities. Relatively, the crop has less storage pests than other cereals (Obilana *et al.*, 2002).

The grain is found to have a delayed deterioration period in terms of nutritional quality and hence makes it an important food security crop in areas liable to famine (Upadhyaya *et al.*, 2007). Again, Vinoth & Ravindhran (2017) reported that finger millet has been identified as one of the healthy food crops for feeble and immuno-compromised individuals in developing countries in Africa and Asia.

Therefore, an extensive study and improvement efforts are deemed necessary to explore the potential of finger millet, to increase agricultural production, ensure the diversification of cereal crops and improve the nutritional status of individuals. Improvements in small-scale brewing and distilling and market development are also suggested (Adhikari, 2012).

2.1.4.3 Agricultural Significance of Finger Millet

Finger millet is at present a crop of minor importance in terms of agricultural produce in Africa, however, it can serve as a promising and sustainable source of revenue for small-

scale farming households especially in areas where they are mostly cultivated (Takan *et al.*, 2004; Sreenivasaprasad *et al.*, 2005). Finger millet has been shown to have exceptional characteristics as a subsistence food crop because of its small seeds which make it ideal for it to be stored for years without being attacked by insects. This makes finger millet a traditional component of agriculturalists' risk prevention strategies in drought-prone areas in Eastern Africa and Southern Asia (Mitaru *et al.*, 2012).

Finger millet receives little or no inorganic fertilizers (Abebe & Deressa, 2017). Investigations have indicated that, it is not economical to apply fertilizers owing to their high costs and the relatively low price of the millet grain. The crop grows well in harsh climatic conditions and hence is suitable to be grown in areas prone to adverse weather conditions (Heinrich & Rusike, 2004). Finger millet is found not to be demanding in terms of labour as the grain does well with little attention.

2.1.5 Post-Harvest Processing Technologies of Millet

Conventionally, moistened or dry cereal grains are routinely pounded using the wooden pestle in a stone or wooden mortar. The removal of the fibrous bran and the separation of the germ from the endosperm are facilitated by moistening the grain with the addition of about 10% water. This process of softening the grain before pounding has been found to produce marginally moist flours. As soon as they are harvested, plant based foods need to be controlled effectively till they are consumed in order to avoid post-harvest losses and hence safeguard food security (Chakraverty *et al.*, 2003). The most performed post-harvest processes include threshing, grading, drying and storage. However, field harvesting, transportation, threshing, grading, drying, storage, dehulling and milling are the vital post-harvest operations commonly done regarding millets (Lanka, 2014). According to FAO

(2001) field inspection is principal before the harvesting operation is done in order to ensure consistent ripening of the cereal crops. If not, then selective harvesting is employed to harvest only matured head of the cereal crops.

Field harvesting of millet entails the detachment of the heads that contain the eatable grains from the plant, just after the period of maturation has been reached. Typically, the traditional and ancient method which employs small hand knives or sickles are used to harvest millets (FAO, 2001) by plucking each head by hand from the plant stalk.

Threshing is done on the harvested millet cobs with the purpose of removing the edible grains from the cobs. Likewise, this process is also done manually. In places like Tanzania, Kenya, Zimbabwe and Ghana, this method is done by beating the harvested chaff (containing the millet grains) against the floor, using sticks. This is done until all the grains are completely detached from the chaff (FAO, 2001).

Applying drying to any food material, especially cereal crops, is key in order to maintain their quality and avoid germination and mold growth during storage (Mrema, 2011). Even though information concerning the drying of millets is scanty, FAO (2001) has shown that sun drying is a common method used in drying millets; though, mechanical dryers are also employed on a commercial basis. A maximum of two weeks is the ideal period for drying millet depending on the season of harvest (FAO, 2001).

Cleaning the millet is key because during threshing and drying, the millet is exposed to contaminants like metal pieces, stones, sand and chaff since millet is spread out on the ground to dry. This is locally done by a method known as “winnowing”. This is where in a

raffia-woven basket the threshed and contaminated grains are winnowed in up and down strokes in order to separate unwanted lightweight particles from the millet grains (FAO, 2001). The cleaned grains are then stored in hessian/sisal bags in order to preserve and hence prevent any losses in terms of quality and quantity before it gets to the consumer (Padulosi *et al.*, 2002). Ideally, there are three crucial factors that need to be considered during millet storage: moisture, temperature and humidity, in order to preserve millet quality and quantity during storage (FAO, 2001). For instance, reducing the temperature, humidity (60 - 65%) and moisture content during storage has been shown to maintain the quality of millet (Padulosi *et al.*, 2002).

2.1.6 Utilization of Finger Millet

Singh & Raghuvanshi (2012) investigated the significance of finger millet in food application and concluded that finger millet is an important cereal crop with regards to serving as an important food, traditional needs and source of revenue for small farm holders and households. By increasing investigations with respect to cultivation and utilization, finger millet exhibits a lot of possibilities in efficiency, industry and commerce. Traditional methods such as popping and flaking and novel methods like extrusion cooking and drum drying of cereal grain could be perfect food application technologies used in making millet-based ready-to-eat products (Krishnan *et al.*, 2012).

FAO (2001) revealed that the most common and simple food prepared from millets is porridge. The thick porridges are consumed in almost all countries but especially in developing countries where millets are marginally or extensively cultivated. Thin porridges are also a simple food product from millets. In Ghana and some African countries, the thick porridges are solid, and are eaten with the hand. However, the thin porridges are fluid and can be drunk from cups or soup bowls and eaten by a spoon. In Ghana specifically, the

preparation of thick porridge involves the addition of flour to boiling water in increments by vigorous stirring simultaneously. The flour is cooked until it forms a thick, homogeneous and well gelatinized mass without lumps. Again, the thick porridges can be made by adding plain water without any additives which results in a neutral pH medium (FAO, 2001). *Ogi* is the most important fermented soft porridge consumed in some parts of Ghana and Nigeria. It may be prepared from either millets or sorghum. After several processes that the millet goes through, the *ogi* is cooked in fresh water, or sometimes the same decanted water to produce *ogi* porridge, which is free flowing, with a creamy consistency. Traditionally, *ogi* is consumed the same day it is prepared, but if stored overnight, it solidifies in to a gel (FAO, 2001).

Finger millet is commonly used in flour production and can be used to make porridge, pudding and roti (Mgonja *et al.*, 2007). With changes in the utilization pattern of refined food products and the awareness of consumers regarding the benefits of finger millet, it has gained a significant standing. For instance, it has the ability to digest slowly owing to the resistant starch it contains. However, its key food application has continued only in areas where it is grown and harvested for traditional food applications (Wadikar *et al.*, 2007).

Regardless of the rich nutrient profile of finger millet, current studies show a low intake of millets in general by urban Ghanaians (Singh & Raghuvanshi, 2012). Finger millet can be processed by malting, fermentation, milling, decortication and popping (Krishnan *et al.*, 2012). Vermicelli, noodles, pasta, soups and bakery products are also developing from the utilization of finger millet grain (Verma & Patel, 2013). Finger millet has been revealed to have excellent malting properties and as a result, can be processed into local beers.

However, a great potential also exists for advanced product diversification (Mitaru *et al.*, 2012).

2.1.7 Value Addition

Wild indigenous healthy crops are gradually going extinct, and if their existence has to be ensured, it is very important to encourage utilization of these food crops by adding value to them (Bharucha & Pretty, 2010). In order to ensure sustainable food security particularly in the rural areas where approximately 80% of people who live there are poor and hungry, value addition in the form of processing indigenous healthy food crops into flour or fortification programs is very crucial to improving indigenous local foods (FAO, 2009). For instance, processing technologies such as popping, malting, roasting and fermentation can be applied to improve micronutrients bioavailability to enhancing the diets quality of finger millet. Similarly to the findings of Rathore *et al.* (2019), for the consumption of finger millet to be amplified, proper processing and value addition from rural to urban area must be encouraged through education.

2.1.8 Phytates Inhibition of Mineral Bioavailability

Breakfast cereal and complementary foods are mainly plant based and are the main source of energy and nutrients for adults and many young children living in resource-deprived families in third world countries (WHO, 1998). Such plant-based breakfast cereal and complementary foods are mostly lacking micronutrients, particularly zinc, iron and calcium, worsened in part by poor bioavailability, particularly when these breakfast cereal and complementary foods are made with unrefined cereal crops and legumes. These unprocessed cereals and legumes have been found to have high levels of phytates, an indication of a strong inhibitor of mineral absorption (Gibson *et al.*, 2010).

Deficiencies of such micronutrients such as zinc, iron and calcium may have a long-term adverse effect on cognitive development and the overall growth throughout childhood. Several interventions, comprising the addition of organic acids (particularly lactic acid and ascorbic acid), have the ability to lessen the adverse effect of phytates on mineral absorption in cereal and/or legume-based food products (Teucher *et al.*, 2004). The term “bioavailability” refers to “the proportion of an ingested food nutrient that is absorbed and utilized through normal metabolic pathways” (Hurrell, 2004). It is predisposed by host-and diet-related influences such as chelators and inhibitors (Gibson *et al.*, 2010).

The main form of storage of phosphorus in cereals is Phytate, also referred to as “phytic acid” consisting of an inositol ring with six phosphate ester groups, and its related salts: calcium, magnesium, or potassium phytates” (Hurrell, 2004; Mbithi-Mwikya *et al.*, 2000). Phytic acid is found to chelate metal ions, chiefly zinc, calcium and iron forming insoluble complexes in the intestinal tract that are indigestible in humans as a result of the absence of intestinal phytase enzymes (Gibson *et al.*, 2010; Frølich, 2011). Phytate also forms complexes with minerals such as zinc and calcium rendering them inaccessible for reabsorption in the body (Iqbal *et al.*, 1994).

2.2 DATE FRUIT

2.2.1 Fruit Description and Production

Date palm (*Phoenix dactylifera*) is a diploid and monocotyledonous plant which belongs to Palmaceae (Barrow, 1998). The origin of the name of date palm is from the fruit; “Phoenix” a Greek word which means purple or red (fruit), and “Dactylifera” which denotes the finger-like nature of the fruit bunch. It has separate male and female trees hence it is dioecious.

There have been numerous reports over the years that the male trees have the ability to develop into female characteristics (Sudharsan & Abo El-Nil, 1999). The inflorescences are the only morphological distinction between the male and the female trees and both are surrounded with a hard, fibrous cover (the spathe) that guards the flowers against sunlight and heat at the beginning phase of flower enlargement (Chao & Krueger, 2007).

The date plant is commonly pollinated by wind, however, insect pollination is possible depending on climate. Cultivation is on a commercial basis, few male trees are grown in date farms, and pollens are collected for the artificial pollination which is very significant for the success of production (Zaid & de Wet, 2002; Chao & Krueger, 2007).

2.2.2 Importance of Date Fruit

Date fruit is an important fruit for many semi-arid and hot arid regions in the Middle East, America and some places in Africa (Singh *et al.*, 2013). The fruits are highly nutritious and favorite fruit for those who consume it as their staple. In addition to its being consumed fresh, several value addition products such as soft date, dry dates, syrup, jam, pickle and beverages (Singh & Dhandar, 2007), mouth freshener (Rathore *et al.*, 2013) are made from the fruits.

The fruit can serve as a supplement to the dietary needs of individuals at places where there is inadequate nutritious food. Date fruits provide abundant quantities of simple sugar, iron, potassium, calcium and nicotinic acid and some amounts of protein, copper, magnesium, chlorine, sulphur and vitamins (Singh *et al.*, 2013). The date fruits have been found to be a rich source of energy to the human systems as the pulp of the developed date fruits approximately contains 80% sugars on a dry weight basis and these sugars are easily

digestible (Vayalil, 2012). Despite this importance, very little work has been done on the post-harvest utilization of date fruits in Ghana.

2.3 FLOUR AND COMPOSITE FLOUR PRODUCTION

2.3.1 Maize Production

Maize (*Zea mays* L.) farming has remained ongoing over the years in Ghana, and after being introduced in the sixteenth century, it has been recognized as an indispensable staple crop in southern Ghana to be precise. Maize is chiefly grown and consumed in Ghana hence its production has realized a rising trend since the mid-90s (Morris *et al.*, 1999; FAO, 2009). In Ghana, maize cultivation is for the most part done under rain-fed conditions by resource-poor small holder farmers and households (Darfour & Rosentrater, 2016). Maize is cultivated globally and has remained a staple food at different parts of the world.

Regardless of this, one of the major contaminants of maize has been found to be Aflatoxins. For example, early surveys conducted in Ghana by Dadzie *et al.* (2019) indicated that maize samples collected from silos and warehouses in Ejura one of the leading cultivators of maize in Ghana contained aflatoxin levels in the range of 20–355 ng/g, fermented maize dough which were also collected from major food processing sites contained aflatoxin levels of 0.7–313 ng/g. Similarly, James *et al.* (2007) found high levels aflatoxin in maize collected samples from North Kwahu (153 ng/g) and Nkoranza (134 ng/ g), significantly beyond the acceptable limits recommended by the USA and the European Union.

Research results have indicated that maize is one of the major sources of calories in Ghana, and has almost substituted millet and sorghum as staple cereal crops in northern Ghana (SRID-MoFA, 2011; Darfour & Rosentrater, 2016). As at the period between 2007 and 2010, the annual regular maize cultivation was testified to reach 1.5 million Metric Tonnes (Rondon & Ashitey, 2011), with a mean harvest of approximately 1.7 t/ha (Darfour &

Rosentrater, 2016). Maize makes up for over 50% of the entire cereal crop production in Ghana, and a growth of 1.1% has been reported to be the annual yield (IFPRI, 2014).

2.3.2 Importance of Maize and Maize Flour

2.3.2.1 Nutritional Significance

The nutritive part of the maize plant that is eaten is the kernel. It has been found to contain B vitamins such as vitamin B₁ (thiamine), vitamin B₂ (riboflavin), vitamin B₃ (niacin), vitamin B₅ (pantothenic acid), vitamin B₆ (pyridoxine), folic acid and vitamins C, E, and K. The proportion of potassium, a major macronutrient present in the kernel of maize plant has a good impact since investigations show that an average human diet lacks potassium (Kumar & Jhariya, 2013). The germ also contains about 45 to 50% of the oil that is extracted by the wet milling process and can be used in cooking (Orthoefer *et al.*, 2003).

The acceptance and user-friendliness of the maize crop make it an ideal constituent of a good and balanced porridge for most households. It also possesses core nutritional properties in a significant proportion such as starch, protein, fatty acid, mineral and vitamins. The endosperm of the maize plant has been investigated and was concluded that per 100 g, 39.4 mg of Resistant Starch (RS) is contained in the endosperm (Jiang, 2010). The Resistant Starch from maize, known as high-amylose maize, presents numerous valuable health benefits including dropping cholesterol levels, enhancing its fecal excretion, increasing short-chain fatty acid production and fermentation in the large intestine and minimizing the risk of obesity-related diseases (Murphy *et al.*, 2008).

2.3.3 Traditional Processing of Sprouted Millet into Flour

2.3.3.1 Sorting and Washing

Finger millet is sorted to get rid of foreign matter such as stones and washed under running water to clean residues of soil on the grains. The water that will be left in the grains after washing is drained off. The grains are then weighed to determine their weight before soaking in order to know the amount of water that will be imbibed after the stipulated time of soaking (Onyango *et al.*, 2012).

2.3.3.2 Soaking

Soaking has remained one of the popular methods of preparing both thin and thick porridges from grains and cereal/legume flours. According to Hotz & Gibson (2001) when water is drained off after soaking, there is a higher likelihood of getting rid of phytates and water-soluble sodium, potassium and magnesium is high depending on factors such as species, pH, soaking time and temperature.

Furthermore, when dried grains are soaked for a reasonable period of time, it quickens enzymatic activities and softens up the grains, hence shortening cooking time and maintains nutrients that would have been lost through prolonged cooking time (Zamindar *et al.*, 2013). Classical examples of grains that are usually soaked during processing include maize, millet, sorghum, and legumes such as beans, peas and soybeans.

2.3.3.3 Sprouting and Roasting

Sprouting (malting) of seeds is mostly used in the brewing industry during the preparation of beverages in addition to the preparation of infant formulas for thin porridges. In Ghana and in most African countries where cereals are chiefly cultivated, for example millet, sorghum and maize are malted for the preparation of alcoholic and non-alcoholic beverages like pito and nmadaa (Aka *et al.*, 2014). According to Palmer (2006), the sprouting process alters the

grains physically, chemically and biologically to give it desirable characteristics as proteins and starch are hydrolyzed respectively into amino acids and sugars.

Figure 3 illustrates the procedure used by Onyango *et al.*, (2012) to produce sprouted cereal flour.

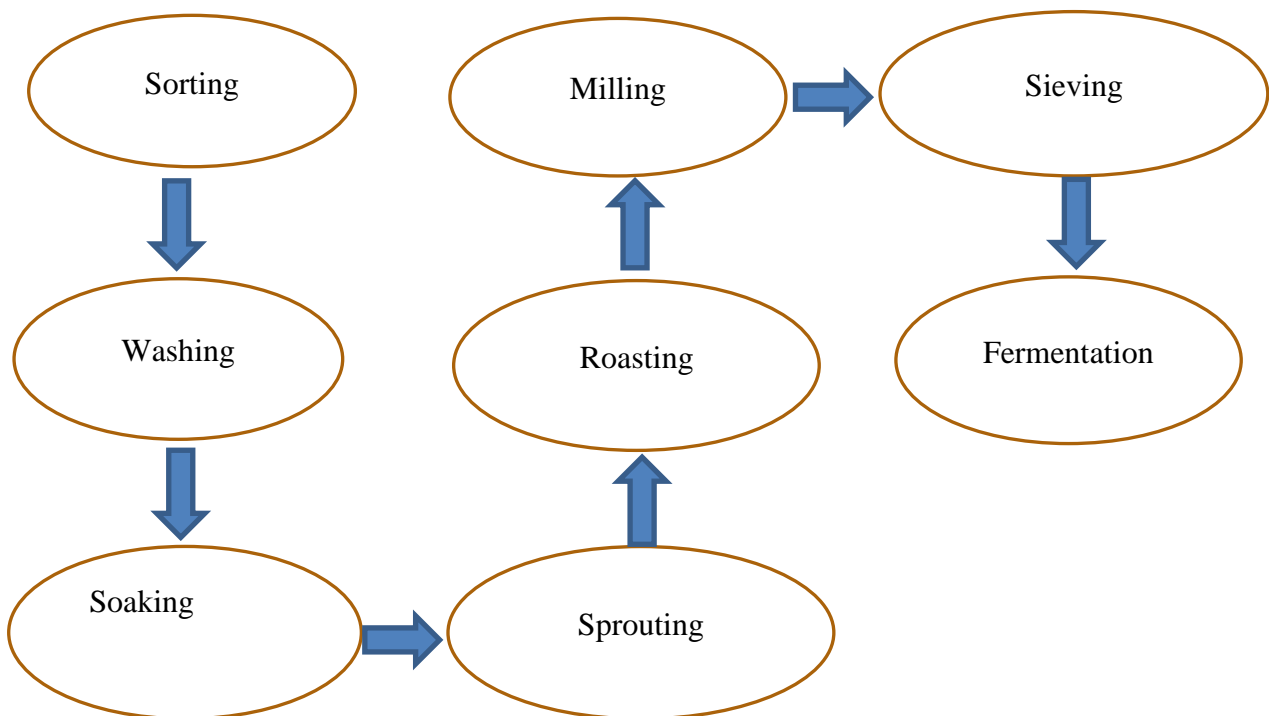


Figure 3: Flow Chart for Good Quality Sprouted Cereal Flour Production.

The sprouting process has been found to reduce the viscosity of porridges as in the case of maize-soybean weaning blends (Amankwah *et al.*, 2009).

Moreover, Camacho *et al.* (1992) reported that iron absorption is improved by sprouting as a result of the elimination of polyphenols and tannins in cereal through gradual degradation of oligosaccharides. Pradeep & Guha (2011), investigated the effect of processing methods on

the antioxidant and nutraceutical properties of little millet extracts and disclosed that roasting as a traditional method of cooking significantly enhanced the nutraceutical properties of little millet by increasing its antioxidant activities and phenolic content.

2.3.3.4 Milling and Sieving

Cereal grain samples are ground into the particulate material (whole grain flour) with the Cyclone sample mill (UDY Corp, Forth Collins, CO), with a vacuum system and an enclosure. The Cyclone sample mill depends on impact milling action. A screen with 0.5mm round openings is used and about 30 g of grains could be milled with each run (Liu, 2009).

Flour samples are sifted with carefully chosen U.S. standard sieves (Nos. 60 equivalent to sieve opening dimensions of 250µm) and a pan, close-fitted into a sieve shaker (DuraTap, Model DT168, Advantech Mfg. Co., New Berlin), according to two procedures. In the stacked sieve procedure, the selected sieve is stacked with the opening and flours are sifted (Liu, 2009).

2.3.3.5 Fermentation

The nutritional content and the physicochemical properties of cereal-based products are influenced by fermentation (Moreno-Montoro *et al.*, 2015). For instance, Lu *et al.* (2005) revealed in their studies that, fermentation improved the whiteness of rice flour as well as reduced some parameters of its pasting properties such as the peak viscosity and the gelatinization temperature. One of the ancient food technologies which employed biochemical activities of microorganisms changing the organic substrate into organic acids or alcohols and carbon dioxide is fermentation (MacDonald & Reitmeier, 2017).

Studies of fermented weaning blends have focused on maize, where it was reported that fortification of these weaning blends with locally available legumes, tubers and fruits is the

ultimate way of developing nutritious and energy dense weaning and complementary foods (Abeshu *et al.*, 2016). Nonetheless, few studies (Vijayakumar & Mohankumar, 2009 and Gull & Ahmad, 2016) have centered on the use of fermented millet-based products for beneficial reasons.

2.3.3.6 Packaging and Storage

Selvaraj *et al.* (2002) investigated the effect of storage materials on biscuits made from “Maida” and Finger Millet flour blend (80:20) and revealed that a product can have a shelf life of 120 days at 65% Relative Humidity at 27 °C when packaged and stored in a double pack of pre-sterilised Biaxially Oriented Polypropylene (BOPP) / polypropylene and metalized polyester/polylamine packs.

Nagi *et al.* (2012) combined defatted and full fat cereal brans with wheat flour at varied levels to make nutritious biscuits. The acceptability of the enriched biscuit was affected by advanced storage; yet, the product remained highly acceptable within the range of 3 months and concluded that packaging material had a significant impact on the quality of biscuit.

Similarly, Devi *et al.* (2014) prepared pasta from refined proso millet incorporated with wheat composite flour and water under different formulations with an aim to improving the shelf life of pasta through packaging interventions. It was reported that pasta prepared under equal amounts of millet and wheat flour was ranked the highest in terms of overall acceptability. Also, the rate of loss of most sensory attributes was lower in pasta stored under Low-Density Polyethylene (LDPE) samples relative to samples packaged under Polypropylene (PP).

2.3.4 Industrial Processing of Cereal-Based Food Products

2.3.4.1 Drum Drying

Drum drying is one of the major industrial hydrothermal processing technologies employed in the food industry to produce instant breakfast cereals (Valous *et al.*, 2002), fruit and vegetable pulp, breakfast cereal, cooked starch and mashed potatoes (Rodriguez *et al.* 1996; Courtois, 2013). Drum Drying also called Roller Drying is a hydrothermal process which involves the transformation of the main composition of a food product; which in this instance, is the starch structure, and other functional properties (Courtois, 2013). According to Courtois (2013), drum drying is an ideal drying choice for products which need to be cold water soluble, like starches and breakfast cereals.

Three forms of drum-dryers are primarily used in industry; the single drum-dryer, double drum-dryer and the twin drum-dryer (Ramli & Daud, 2016). The distinction between the double drum-dryer and the twin drum-dryer is that the former has two drums that rotate toward each other with the spacing in between both drums controlling the feed diameter on the drum surfaces. The later on the other hand revolves away from each other at the topmost (Demchenko, 2000). The use of drum drying technology to process instant breakfast cereals is employed in some industries in Ghana.

2.3.4.2 Extrusion Cooking

Extrusion cooking is where raw materials are transformed into products through a cooking process at very high temperatures for a relatively short period of time (Adekola, 2016). Extrusion permits for the amalgamation of raw materials and alteration of their molecular structures to a finished product with transformed rheological properties. The twin screw and the single screw extruders are the two types available. Extrusion has been widely used for production of food products such as breakfast cereals and snacks (Meuser & van Lengerich,

1992). On the other hand, millet flours as an ingredient in extrusion has not been studied extensively (Nkama & Bulus Filli, 2006).

Ding *et al.* (2005) studied the effects of screw speed, feed moisture, feed rate, and temperature on the physical, chemical and textural properties of an extruded cereal snack product with a co-rotating twin-screw extruder. Using extrusion cooking, defatted rice bran was added to develop a ready-to-eat breakfast cereal (Charunuch *et al.*, 2014). Extrusion cooking has also been without doubt proven to be a novel and satisfying processing technology in the food industry.

2.3.5 Importance of Cereal Crop Flour Production

Cereal flours are chief sources of ingredient locally used for food and beverages, for example, complementary foods, in developing countries. Cereal crops such as sorghum, millet and maize are used, for instance, for making thick and thin porridges such as ‘koko’; a common home-made porridge consumed as breakfast, main meal or as snacks by both infants and adults in Ghana (Llave, 2014).

Muhimbula *et al.* (2011) carried out a research which involved the formulation of complementary food from a combination of cereal crops (maize, sorghum and finger millet) and legumes (cow pea and green peas) in Tanzania and evaluated their sensory attributes. Saalia *et al.* (2012) also developed and evaluated low viscosity porridge (‘koko’) prepared by fermenting maize flour with millet malt to be used for complementary feeding. Saalia *et al.* (2012) also developed and evaluated low viscosity porridge (‘koko’) prepared by fermenting maize flour with millet malt to be used for complementary feeding. Amagloh *et al.* (2012) investigated the carbohydrate composition, solubility, viscosity, and sensory

acceptance of maize-based complementary foods. Results from these investigations have revealed that the use of cereal flours is important as they are frequently used in complementary feeding which is possibly determined because of the availability and favourable sensory attributes these cereal crops have.

Similarly, Lu *et al.* (2003) investigated the effect of fermentation of rice a raw material for the production of noodles and established favorable sensory properties of the noodle. Again, Perlas & Gibson (2002) also confirmed that complementary foods are usually cereal-based in most Asian countries especially in the Philippines.

2.3.6 Economic Impact of Cereal Flour Production

Producing enough food to meet the high demand of a speedily increasing global population is evolving as the greatest test to mankind. The global populace is anticipated to reach 9.1 billion individuals by the year 2050, and as a result approximately 70 per cent extra food production will be essential to feed this rapidly growing population (Kumar & Kalita, 2017).

Postharvest losses have been shown to determine physical and quality losses of crops that diminish their economic value and make them inappropriate for human consumption. Postharvest losses at its worst can be up to 80% of the total production globally (Abass *et al.*, 2014) but in African countries, these postharvest losses have been projected to range between 20% and 40%, which is extremely significant bearing in mind the low agricultural productivity in several regions of Africa (Fox, 2013).

Therefore, increasing the utilization of food crops such as finger millet in flour production can improve post-harvest management of cereal grains, which will lead to reduction in economic losses through value-added processing of food crops.

2.3.7 Composite Flour

2.3.7.1 Composite Flour Production

“Composite flour is a product obtained by blending flours prepared from plant food and/or their products”. It can also be made by the combination of grains/seeds before milling (Noorfarahzilah *et al.*, 2014). Similarly, Shittu *et al.* (2007) concluded that composite flours used were either “two or more mixtures of flour from other crops with or without wheat flour”. Composite flour technology was originally known as the process of blending wheat flour with cereal and/or legume flours for developing food products such as cookies, biscuits and bread. Nonetheless, the term is also used when non-wheat flour, tubers and roots, fruits, legumes or other raw materials are mixed together (Dendy, 1992).

One typical example is the combination of maize, soybeans, and groundnut for the production of “Tom Brown” in Ghana. Mixing wheat flour with available locally grown cereals and root crops is considered to be beneficial to encouraging the agricultural sector and reducing wheat imports in many developing countries (Hasmadi *et al.*, 2014). Composite flour utilization has been found to have few benefits for developing countries with regards to promoting high-yielding innate plant species, enhancing a proper source of energy and nutrients for human nutrition and improving the general use of agricultural produce domestically (Bugusu *et al.*, 2001).

Saha *et al.* (2011) revealed the prospect of finger millet utilization in the preparation of composite flour as a perfect replacement for wheat flour for the production of biscuits. Furthermore, Krishnan *et al.* (2011) reported in their study that wheat flour can be replaced with finger millet seed coat matter up to 20% for the preparation of biscuits suitable for diabetic patients. Yet, there were not many distinctions in the biscuit's diameter even though the width of the biscuit somewhat varied (Krishnan *et al.*, 2011).

Local alternative for wheat flour is on the rise as a result of the increasing market acceptability for confectioneries (Noor & Komathi, 2009). Consequently, there have been several initiations of programmes by developing countries to assess the alternatives of available flours as a partial substitute for wheat flour (Abdelghafor *et al.*, 2011). A report by FAO (2007) indicates that composite flour application in food production can be prudently beneficial if wheat importations could be reduced or eliminated completely. This could meet the demand for pastry products by the use of both domestic and commercially grown cereal crops instead of imported wheat (Jisha *et al.*, 2008).

2.3.7.2 Importance of Composite Flour

Dhingra & Jood (2001) reported that bakery products prepared from composite flour exhibit acceptable attributes, and have even similar characteristics to wheat-flour bakeries. Even though the texture of bakery products prepared from composite flour varied from those prepared from wheat flour, they showed to have an increased nutritional value and an acceptable appearance. Mohammed *et al.*, (2012) reported that wheat is classified to be nutritionally poor with the exception of being a good source of energy and nutrients, as its proteins are lacking some essential amino acids such as threonine and lysine hence there is the need to substitute wheat with other cereals rich in lysine and threonine.

Moreover, Abebe & Deressa (2017) revealed that there has been an ever-increasing demand for bakery products made from wheat such as bread in Africa, even though Africa is not known to be a major wheat cultivating area. However, it cultivates large quantities of other cereals such as millets, maize and sorghum which are good substitutes for wheat. FAO (2009) reported that substituting wheat with 20% non-wheat flour for bakery products would contribute tremendously to the total GDP of African countries. Hence composite flour technology has a promising potential for developing countries in Africa.

Even though studies on consumer trials on composite flour are still young, products prepared with composite flour have been given attention in places like Sri Lanka, Nigeria, Kenya, Senegal, and Sudan (Dendy, 1992). Furthermore, there are quite a developing number of small, medium and large profitable grain processors with millers in Eastern Africa, for the production of both composite flour and porridge blends, largely for the local market (Mitaru *et al.*, 2012).

2.4 PRODUCTION OF BREAKFAST CEREALS

Breakfast cereals can be categorized into two forms; Traditional (hot) Cereals and Ready-To-Eat (cold) Cereals. The traditional cereals are cooked to form a gelatinized starch before it is consumed. The ready-to-eat cereals, on the other hand, can be consumed instantly with or without milk and sugar. Conventionally, corn, rice, oats, wheat, rye, are the main cereal crops from which traditional breakfast cereals are made but majority of these traditional breakfast cereals on the market are made from oats and wheat (Fast, 2000). The processing technique used to manufacture ready-to-eat cereals are used to classify them. These include;

extruded shredded cereals, extruded flaked cereals, flaked cereals, gun-puffed whole grains, oven-puffed cereals, shredded whole grains and extruded gun-puffed cereals (Clerici, 2012).

2.4.1 Cereal – Fruit Complementation

The demand for wholesome and nutritious foods is growing globally, as eating a balanced diet is the endorsed way to correct or prevent nutrition related problems such as diabetes, heart disease, obesity, malnutrition, among other implications that largely have their root in dietary errors. According to Mahajan & Chattopadhyay (2000) cereals form the principal part of most weaning mixes, contributing approximately 70-80 % of the day's energy intake yet are deficient in one or more essential amino acids, minerals and vitamins. On the other hand, investigations reveal that cereal-fruits blends are relatively good source minerals, fats and water-soluble vitamins that cereals lack (Noorfarahzilah *et al.*, 2014).

Several studies have indicated the usefulness of incorporating fruit into breakfast cereal making. For example, Petrova & Kennelly (2013) investigated blueberries complement to cereals and reported that the polyphenols blueberries contain are of tremendous health advantages that can enhance the nutritional benefits of cereal-based foods.

Similarly, Usha *et al.* (2010) investigated the nutritional, physical and sensory evaluation of pumpkin flour combined into weaning mix and concluded that an increase in incorporation of pumpkin flour led in an increase in fibre, energy, protein, β -carotene and antioxidant levels. The study further reported that an increase in pumpkin fruit flour also increased the cooking time and gelatinization temperature which offer the weaning infant a less viscous but energy dense mix.

2.5 PHYSICOCHEMICAL CHARACTERISTICS OF COMPOSITE FLOUR

SAMPLES

2.5.1 Physical Characteristics of Composite Flour Samples

2.5.1.1 Particle Size Distribution

According to Liu (2009), sieving to obtain a uniform particle size has been the oldest but most vital unit procedure for manufacturing segregation of solid particles or as a laboratory method in particle size study. “Flour is a mixture of particles, and these particle sizes affect many of its characteristics and is a valuable indicator of quality and performance of flour” (Hatcher *et al.*, 2002). In the science of cereal, the focus of the particle size of flour has fascinated many researchers, typically for its outcome on flour quality (Neale, 1997). Studies have indicated that flours with varied particle sizes are distinct with regards to chemical composition and physical properties (Wang & Flores, 2000; Toth *et al.* 2005), as such these properties, in turn, impact flour performance in the finished products (Toth *et al.* 2005; Hatcher *et al.*, 2002). Flour qualities depend on a number of factors with the most vital factor being its particle size. In order to achieve the ideal particle size of flour for food product development, factors such as grain quality, a flow sheet of the mill, the adjustment of rolls and sifter sieves opening type have to be critically considered (Sakhare *et al.*, 2014).

Numerous researchers have documented that particle size of flours have an effect on the chemical and physical characteristics of flours, thus the separation of flours into varied fractions in terms of physicochemical properties have profitable and academic importance (Hoseney, 1994; Wang & Flores, 2000; Farheen *et al.*, 2012). Some studies over the years have revealed that medium flour particle size separated by sieving has had relatively better baking quality. On the other hand, a few studies have revealed that fine particle size flours separated by air classification had even better baking quality because of the increased

protein content these fractions exhibited. The finest fractions of flour with stronger quality gluten and dough has also been shown to exhibit a better balance of pliability and extensibility relative to other coarser segments with greater dough development time and stability. Likewise, many other operations regarding particle size reduction and techniques necessitate laboratory approximations to monitor changes in particle size including emulsification, homogenization and pulverizing (AACC, 2000). The detachment steps for instance, where screening and sifting might be tested by measuring particle size before and after the process, it is common to determine the particle size of flour which requires mixing because similar flours with narrower distributions have common effects on flavor, texture, and mouthfeel (AACC, 2000).

2.5.1.2 Colour and Total Colour Difference

Mridula *et al.* (2007), studied the impact of the incorporation of sorghum flour with wheat flour on the quality of biscuits and concluded that the color of flour samples eventually affects the appearance and color of products made with the flour. As a result, it is key for food processors to assess the color of flour and composite flour samples to be used for product development so as to make adequate provision to ensure the color of the finished product is one that would be accepted by consumers (Aprianita *et al.*, 2013). The color analyzer may be used to determine the color of flour to find the, a^* (redness), b^* (yellowness) and L^* (lightness) values which are used to analyze the total color difference (ΔE^*) of a product (Minolta, 1991).

2.5.2 Chemical and Functional Characteristics of Composite Flour

2.5.2.1 Proximate Composition

Proximate composition of the flours can be determined following the AOAC methods (AOAC, 2005). Parameters such as protein content (method 955.52), crude fat (method 948.22), moisture (method 925.40), and crude ash (method 935.52) can be determined.

Total carbohydrates can be determined as the difference between the sum of the other components and 100%.

2.5.2.2 pH

The pH of foods has a significant effect on pigments such as, carotenoids, anthocyanins and chlorophyll which are accountable for colors of foods such as fruit and vegetables (Andrés-Bello *et al.*, 2013). Perceptible observation and buyer approval of food products are influenced by vital qualities such as the color and texture of foods which are also affected by pH (Martin-Esparza *et al.*, 2013). pH has a noticeable effect on the water absorption capacity and the tenderness of food products. pH value can affect many characteristics and processes such as enzymatic activities, gelification, protein properties as denaturizing, growth and mortality of microorganisms, germination or the inactivation of bacterial spores and chemical reactions, for example, the Maillard reaction (Andrés-Bello *et al.*, 2013). These indicate that the information on the effects of pH and its control during the manufacturing of food is essential to come up with better and value-added products to suit consumer's preference.

2.5.2.3 Water and Oil Absorption Capacity

The absorption of water by flour is the quantity of water engrossed by the flour to produce a dough of feasible consistency. Since flavor and texture of foods are indispensable

determinant of the outcome of a food product, the interactions of oil and water with flours are very crucial in food systems because of their impacts on the flavor and texture of foods. According to Ohimain (2014), three important basic sensory characteristics of flour products play a major role in affecting the sensory perception and consumer acceptance of flour products. These are aroma, texture and flavor. Similarly, Pomeranz (1998) studied the relationship between the oil and water absorption ability of flour product and concluded that sensory characteristics of the flour food product are influenced by the water and oil absorption ability with respect to the flours in which products are made from.

Ikpeme *et al.* (2010) carried out a study on taro composite flour and suggested that addition of taro flour affected the water absorption of the flour. In this study, the taro starch essentially inhibited the absorption of water, for example, the 90:10 wheat: taro composite had the highest water absorption capacity. Correspondingly, Uzor-Peters *et al.* (2008), revealed that defatted soy flour or defatted groundnut cake flour addition for *Kokoro* (a finger-like maize-based snack food that is consumed unaccompanied or with roasted groundnuts) formulation may have resulted in the increased in the oil absorption capacity of the product which led to higher fat content of the products: 26.8% for defatted soya flour and 34.06% for defatted groundnut cake flour.

Studies have revealed that flour with good oil absorption capacity that is used in the manufacturing of food products is possible to have an acceptable flavor and aroma which are influenced by the reasonably high fat absorbed into the product (Popov-Raljić *et al.*, 2013 & Olliver *et al.*, 2003). This is because oil absorption has been found to act as a retainer of flavors in food products and subsequently helps to increase the mouthfeel of these food products.

Jitngarmkusol *et al.* (2008) studied the factors that can influence oil absorption in *macadamia* flours and concluded that the key chemical constituent affecting oil absorption is the protein which comprises both hydrophobic and hydrophilic portions since the non-polar amino acid side chain of the protein can form hydrophobic interactions with hydrocarbon chains of lipid.

Therefore, in order to produce, value-added, high-quality and wholesome products, information on the water and oil absorption ability and their control during processing is indispensable.

2.5.2.4 Pasting Properties

The carbohydrate structure of flour made from crops determines their pasting properties and these pasting properties are influenced by elements such as amylose content, granule volume fraction, granule-granule interaction, continuous phase viscosity, granule size distribution and granule shape (Sindhuja *et al.*, 2005; Singh *et al.*, 1993). According to Saha *et al.* (2011) and Kareem *et al.* (2015) gelatinization occurs and starch granules swell to numerous times relatively to their original volume when the starch suspension is cut during heating. Tester & Morrison (1990) defined swelling as the formation of a three-dimensional network. The swelling ability of flours hinges on the flour particles size, the variety type and the kind of processing techniques used. Likely, the flour of parboiled rice has more swelling capacity comparatively to raw rice (Chandra *et al.*, 2015).

Perdon *et al.*, (1997) and Zhou *et al.*, (2003) carried out a study on the effect of aging of rice flour on its pasting properties and concluded that aging of cereal crops such as rice can have an influence on their pasting properties. The study revealed increased viscosity of rice paste after milled and being stored for short to intermediate time frame (months), with a decrease

in viscosity when stored over an extensive time period (years). The pasting characteristics of flours are therefore central parameters that are used to determine the suitability of starch in flour for special uses and helps in the identification of sources of starch for varied food applications (Singh *et al.*, 2001; Shahzadi, 2004).

2.5.2.5 Emulsion capacity and stability

Factors that affect the choice of a protein for use in an industrial food processing is emulsion capacity and stability. Proteins have the ability to decrease tension at the oil-water interface and help prevent amalgamation. Protein stabilizing effect in an emulsion is as a result of the membrane matrix that engulfs the oil droplets and stops its amalgamation (Stamkulov *et al.*, 2009). High emulsion ability gives the assurance that a particular flour can be a good emulsifier with other foods when mixed with water.

According to Zhu *et al.* (2014), legumes with higher emulsion capacity with the dissociation and partial unfolding of globular proteins, lead to exposure of hydrophobic amino acid residues, which thus escalate the adsorption and surface activity at the oil and water interface. Kohajdova *et al.* (2011) incorporated chickpea in wheat flour and established that the ability to form an emulsion chiefly was as a result of the addition of chickpea flour and not the wheat flour.

Cheung (2017), made it clear that amino acids of proteins possess well stable proportions of hydrophilic and hydrophobic ends which make them well readily adsorb onto interfaces between water and hydrophobic fluids such as oil and water and thus, they could be used as thickeners, viscosity and adherence enhancers in addition to increasing flavor retention.

2.6 CONSUMER PURCHASING BEHAVIOUR TOWARDS INSTANT FOODS.

It is hypothesized that the purchasing behavior of consumers of instant food products is influenced by many factors being it social or economic. Indumathi *et al.* (2007) showed a contrasting result to that of Kamalareni & Nirmala (1996) in relation to factors that influence consumers purchasing behavior of instant foods. Indumathi *et al.* (2007) showed that the occupation of women, family income and cooking saving time are the most influencing factors in instant food products.

Moreover, Indumathi *et al.* (2007) revealed that the 200g packs of instant mixes are more preferred by consumers compared with 100g packs and therefore concluded that the size of packages and other economic factors such as income and family size influence consumer purchasing behavior towards instant mixes. On the contrary, Kamalareni & Nirmala (1996) proposed in their study that door to door supply of sample as used as the main tool of sales promotion by the instant food product manufacturers portrays that most of the consumers regularly purchase at least three varieties of instant food items.

Kumar *et al.* (1987) studied numerous factors affecting the buying decision making of diverse food products. The study cross-tabulated the brand and origin of the products as against the age, gender and income. Findings showed that education, age and income were the major factors affecting the purchasing decision making of consumers and that consumers were engrossed by the brand image rather than the origin of the product.

Ramasamy *et al.* (2005) studied the buying behavior that was vastly influenced by awareness and brand image towards the product and suggested that television and radio advertisement was the greatest source of information followed by retail outlets display. Based on the view of consumer's acceptance, the quality and price of the product is an

important factor to purchase. Even though Indumathi *et al.* (2007); Kamalareni & Nirmala (1996) and Kumar *et al.* (1987) indicated in their study that the income of the consumer determines their purchasing behavior, Ramasamy *et al.* (2005) argued that apart from the income of the consumer, advertisement is key in influencing consumer purchasing behavior.

2.7 SENSORY EVALUATION OF FOOD PRODUCT

Studies have shown that product acceptability is dependent upon the product's sensory appeal (Singh-Ackbarali & Maharaj, 2014; Pasricha *et al.*, 2012). "Sensory evaluation is a field that measures product attributes perceived by the human senses". The intrinsic variability of human responses has led to special procedures for their measurement (Gengler, 2009). The five human senses can be used to perceive food properties through: sight (e.g. color and shape of foods), smell (e.g. aroma of a rancid oily foods), taste (e.g. sweetness or bitterness intensity), touch (e.g. the firmness of a muscle food) and hearing (e.g. crunchiness of a plantain chip) (Melis & Barbarossa, 2017; Stone *et al.*, 2012).

The identified and measured characteristics of the food product are analyzed and interpreted based on three key categories (Lawless & Heymann, 2010; Stone *et al.*, 2012). These are;

1. Discrimination: this aims at examining if there is a difference that exists between two or more products,
2. Description: This describes the features of the product and/or measuring any dissimilarities that may occur between or among products.
3. Preference: this aims at describing the liking or acceptability of a product.

This study aims at using underutilized and marginalized millet (Finger Millet) to make composite flours with maize and dates flour. The grain is nutritious but the weakness is that it is difficult to process. The addition of Finger Millet flour, a rich source of protein and dates fruit flour to maize flour to form composite will certainly affect the swelling power,

solubility index and the gelling properties of the resulting composite flour and subsequently affect the final product. Finally, since consumers are the end users of the final product and thus have much say on the final product, the product's appearance, taste, smell and overall acceptability have to be determined by the consumers.

2.8 MICROBIOLOGICAL STUDY OF INSTANT FOOD PRODUCTS

Convenience foods play a significant role in individuals' daily food choices. In addition to this, individuals' daily nutritional needs are dependent on these foods, as a result of their ever-growing busy schedule which takes away the opportunity to eat home-prepared foods. Due to the self-serving availability of convenience foods, they are one of the primary food alternatives for city dwellers (Pfeiffer *et al.*, 2017).

Foodborne illnesses at worst can be very fatal. As a result, the expectation of the consumer is that foods that get to their table are wholesome for consumption (CAC, 2003). Nonetheless, this expectation and trust individuals have for foods manufacturers can easily be compromised. A classic example was the melamine contaminated baby formula in China, where powdered infant formula was contaminated with melamine, an inorganic chemical, which was meant to falsify the protein levels in low-quality milk. The WHO (2008) reported about this incidence that closely 300,000 infants were affected and more than 50,000 infants were hospitalized with six deaths recorded.

Therefore, microbiological testing of foods must be a crucial activity which must be undertaken in both public and private food manufacturing companies in order to check for the presence of microorganisms or to verify whether control measures are effectively

reducing the occurrence of microorganisms to acceptable levels (Food Standards Australia New Zealand, 2009).

According to Codex Alimentarius (2003), food safety is the assurance that food will not cause any harm in any way to the consumer once prepared and/or eaten according to its purpose. Due to this, for instance, more or less strict guidelines are given to producers of food products by authorities liable to the health hazard and the conditions in which food products ought to be handled and consumed. As such the necessary precautions must be ensured by the food industry to control all significant hazards for food products (ICMSF, 2002).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 MATERIALS

3.1.1 Ingredients: Finger Millet and Date Fruits were purchased from Tamale local market in the Northern Region of Ghana and transported to the University of Ghana, Legon Campus. Maize was purchased at the Madina market Accra, salt and Blue Band margarine were also purchased at Melcom Madina branch, Accra.

3.1.2 Tools and Equipment: Stainless steel baking sheets, wooden ladle, pot holder, strainer, plastic bowls and buckets, plain white cloth and jute sacks were purchased at Melcom Madina branch.

3.2 METHODS

3.2.1 Processing of Sprouted Finger Millet and Maize Flour

Sprouted Finger Millet and Maize Flour were produced following the procedure of Onyango *et al.*, (2012) with modification by altering the temperature and time for roasting and soaking (Figure 2). Date Fruit Flour was made following the method Singh *et al.*, (2013) with modifications.

3.2.1.1 Sorting, Washing and Soaking

Finger millet were sorted to remove damaged grains and unwanted materials such as stones and other foreign materials before washing three times under running water at ambient temperature (Onyango *et al.*, 2012). The sorted and washed finger millet were then steeped using tap water in the ratio **1:2** (finger millet: water) that is, every 100 g of finger millet

were soaked in 200 mL of tap water for 30 hours at ambient temperature. After the stipulated time, the soaked finger millet were washed, drained and made ready for sprouting (Onyango *et al.*, 2012).

3.2.1.2 Sprouting, Drying, Winnowing and Milling

The soaked finger millet were spread on a clean jute sack that had been lined with moistened clean white cloth and covered again with another moistened clean white cloth and allowed to sit for 48 hours at 25 °C. Tap water was sprinkled on the covered Finger Millet after stirring for every 6 hours just before the water was sprinkled until the stipulated time of 48-hour of sprouting was done (Onyango *et al.*, 2012). The sprouted finger millet were then uniformly spread on drying trays, and dried in a Gas Oven at 120 °C for 15 minutes. The dried Finger millet were rubbed between palms to remove some of the rootlets of the sprouted Finger millet, winnowed and milled afterwards using a Hammer Mill (Straub Company, Philadelphia, PA, USA) to obtain the Sprouted Finger Millet Flour (SFMF). The resulting flour was sieved through a 50 micron mesh size sieve to obtain a consistent mixture of flour particle size of Sprouted Finger Millet Flour (Onyango *et al.*, 2012).

3.2.1.3 Packaging and Storage

The resulting Sprouted Finger Millet Flour (SFMF) obtained was kept in airtight white polythene bags and stored in a cold room at a temperature of 16 °C until ready to use. (Onyango *et al.*, 2012).

Figure 4 shows the procedure used to process sprouted finger millet into flour.

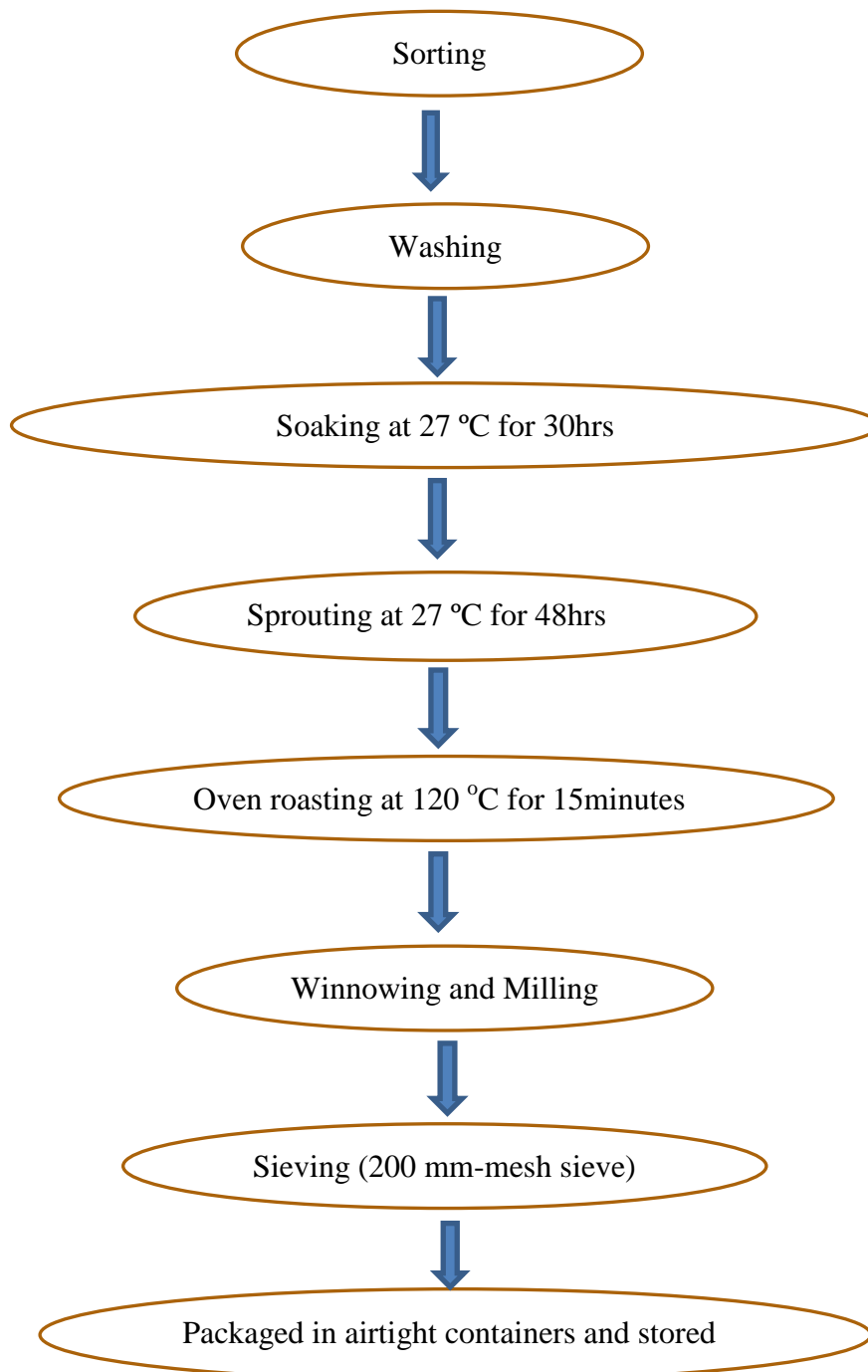


Figure 4: Flow Chart for Sprouted Finger Millet Flour Production.

The pictorial representation for the production of sprouted finger millet flour is presented in figure 5 below.

I



Sorting

II



Washing

III



Soaking

IV



Sprouting

VIII



Flour

VII



Milling

VI



Winnowing

V



Oven Drying

Figure 5: Illustration of the Process of Sprouted Finger Millet Flour Production

3.2.2 Formulation of Composite Flour

The resulting SFMF was used to formulate five (5) different flour combinations and a control (Table 2) with Maize Flour (MF) and Date Fruit Flour (DFF) using a universal fritter (QS513) to homogeneously mix each formulation to obtain uniform composite flour. These were subsequently referred to as composite flour samples. The proportions of the formulations are shown in Table 2.

Table 2: Percentage of Sprouted Finger Millet Flour to Roasted Maize Flour and Date Fruit Flour in Composite Flour Formulations.

Sample codes	% SFMF	% RMF	%DFF
346	00	90	10
457	40	50	10
345	50	40	10
102	60	30	10
490	70	20	10
302	90	00	10

% **SFMF**: percentage of Sprouted Finger Millet Flour in the formulation.

% **RMF**: percentage of Roasted Maize Flour in the formulation.

% **DFF**: percentage of Date Fruit Flour in the formulation.

3.2.3 Instant Breakfast Cereal Preparation

3.2.3.1 Proportion of Ingredients in Composite Breakfast Cereal

Preparation

The proportion of ingredients for making the breakfast cereal was modified according to the method of Onyango *et al.* (2012) as outlined in Table 3.

Table 3: Proportion of Ingredients for Making Breakfast Cereal

Ingredients	Quantity
Composite flour	100 g
Water	300 mL
Fat (Margarine)	5 g
Salt	5 g

3.2.3.2 Breakfast Cereal Preparation

The composite breakfast cereal was made following the procedure of Onyango *et al.* (2012) with modifications as presented in Figure 6. The preparation was done at the Food Product Development laboratory at the Department of Family and Consumer Sciences of the University of Ghana. Procedures were optimized before the composite breakfast cereal samples were made using the method of Onyango *et al.* (2012) with modifications as indicated in Table 3. Composite flour, fat (margarine) and salt were mixed thoroughly in a universal fritter (QS513) for 3 minutes to obtain a homogenous mixture. The resulting mixture was placed in a clean dry bucket. The mixture was then left overnight to naturally ferment for 12 hours at 27 °C. This was done for all six samples. The mixtures were then mixed with water in the ratio of 2:3, accordingly 2 parts of solid (mixture of composite flour, margarine and salt) and 3 parts of water to obtain a consistent slurry suitable for drum drying. The slurry was prepared by gradually adding the solid mixture (composite flour, margarine and fat) to the water while stirring until the solid mixture was evenly distributed in the water to obtain a uniform slurry. A double drum dryer (Andritz 60UDA Coenecoop 88 2741 PD Waddinxveen-Holland) was used to dry the slurry as described by Valous *et al.*

(2002). Steam was the source of heat for heating the counter rotating drums at 45 pound per square inch and then rotated at 5 rotations per minute.

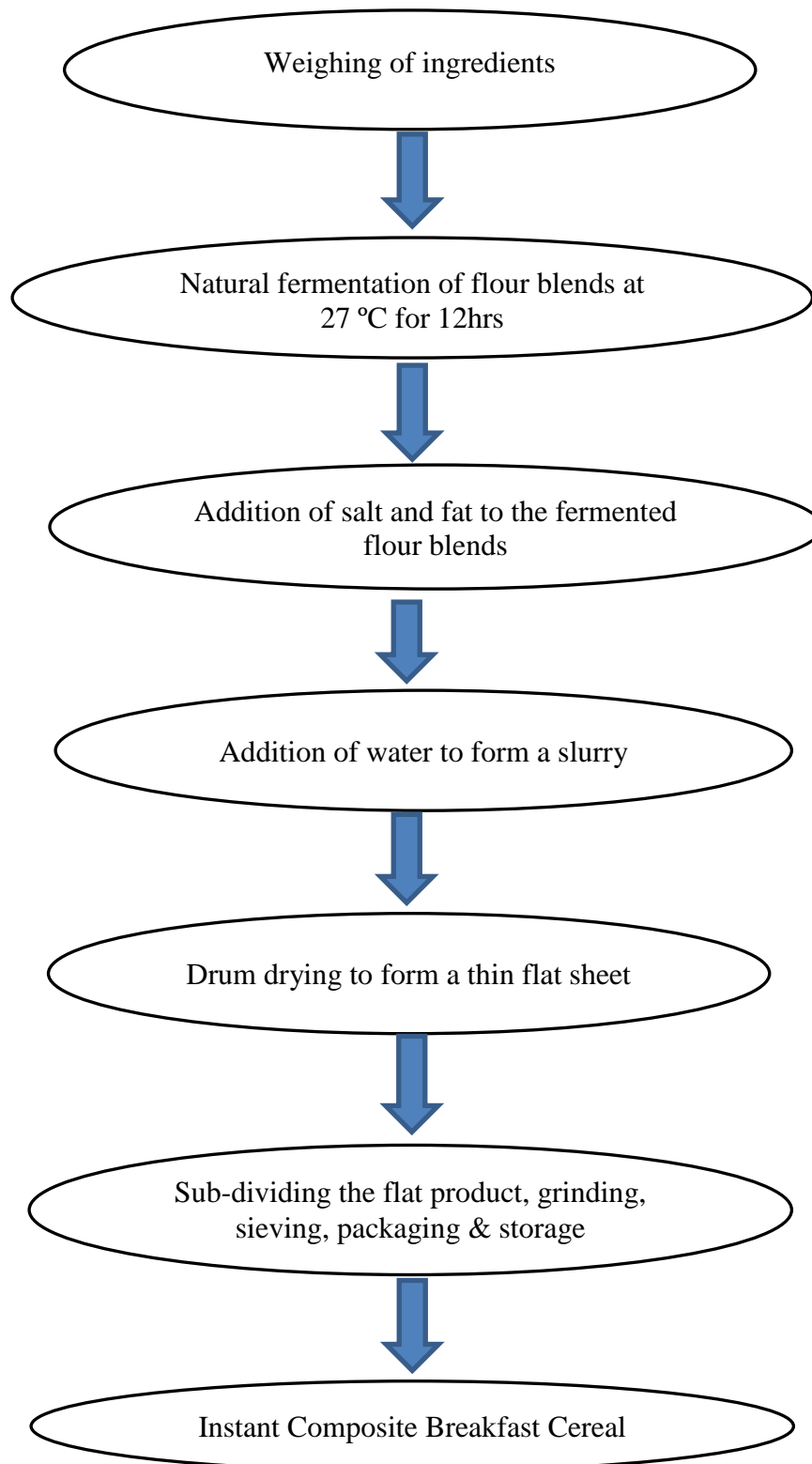


Figure 6: Flow Chart for Composite Breakfast Cereal Production.

The prepared slurry was fed into the dryer to form a thin paste on the heated rollers and was dried as the drum rotated towards the scraper blade, which scraped out the dried thin flat sheets from the drum surface. The thin flat sheets were aggregated in a collector just below the rollers and placed in a clean polyethylene bag. This procedure was done separately for all 6 samples to prevent mixing up samples. The thin flat sheets were crushed to form dried flakes which were then milled into a powdered product using the universal fritter (QS513) for 5 minutes, then sifted using a 50 microns aperture sieve to obtain the final composite breakfast cereal product.

Figure 7 shows the pictorial representation for the preparation of the composite breakfast cereal.

3.2.4 Determination of the Physical Characteristics of the Composite Flour

Samples.

3.2.4.1 Determination of Colour and Total Color Difference of Composite

Flour Samples

The colour of the composite flour samples were determined using a modified method from Yadav *et al.* (2012). The colour of the composite flour samples were determined with a Hunter Lab Colour Analyzer (CR310 Chroma meter, Konica Minolta, Tokyo, Japan 76981007) to obtain the L* (lightness), a* (redness) and b* (yellowness) values as well as the ΔE^* (total colour change). The formula for determining the total color difference is:

$$\Delta E_H = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$$

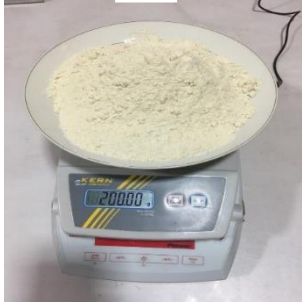
Where:

ΔE_H is the total color change

ΔL is the difference in brightness between two vivid surfaces

Δa and Δb are the differences in the color coordinates A and B, respectively.

A



Weighing Ingredients

B



Mixing Ingredients

C



Slurry Preparation

D



Drum Drying

H



Breakfast Cereal

G



Sieving

F



Milling Flakes

E



Dried Flakes

Figure 7: Procedure for Breakfast Cereal Preparation

3.2.4.2 Determination of Particle Size Distribution of Composite Flour

Samples

The particle size distribution of the composite flour samples was determined using the method of Sonaye & Baxi (2012) with modifications. The particle size distribution of the composite flour samples was determined by placing 150 g of each flour sample on the topmost sieve of a nest of sieves of successively decreasing apertures. The nest of test sieves was shaken for 3 min at an amplitude of 3.00 in a sieve shaker (Ro-Tap model RX-29, W.S. Tyler, Mentor, Ohio) using sieves with sizes 230, 200, 120, 100 and 50 microns.

The initial weight of the sieves were recorded. The final weight of the sieves after sample particles have been distributed was also measured and recorded. To obtain the weight of particles distributed in the sieves, the initial weight of the sieve was subtracted from the final weight after particles have been thoroughly distributed into the various sieves. Particles that passed through the 230 and 200 micron sieves were labelled coarse and those that passed through the 120, 100 and the 50 micron sieves were labelled fine. Figure 8 shows the pictorial representation of particle size distribution determination of composite flour samples.



Figure 8: Process for Determining the Particle Size Distribution of Composite Flour Samples

3.2.5 Determination of the Chemical and Functional Characteristics of Composite Flour Samples

3.2.5.1 pH of the Composite Flour Samples

The pH of the composite flour samples was determined according to Chinma *et al.* (2012) with modifications. 10 g of each sample was weighed and mixed with 100 mL of distilled water. The subsequent suspensions were stirred with a magnetic stirrer for 30 minutes. The resulting solutions were centrifuged at 5000 * g at 18 °C for 20 minutes. Forty mL each of the supernatants were used in the assay (Jenway 495r) and the pH of the supernatant of each sample was then measured with a standardized Mettler Toledo pH meter (model: SevenCompact S220, USA).

The total titratable acidity was determined by titrating 40 mL of supernatant with 0.5M NaOH (sodium hydroxide) until a pH of 8.5 was recorded. Results obtained were expressed as the mL of 0.1M NaOH needed to titrate 10 g of products.

3.2.5.2 Oil and Water Absorption Capacities of the Composite Flour

Samples

Water/oil absorption capacity of the Finger Millet- Maize composite flour was determined using the AACC method 56-20 (AACC, 2000) with modifications. 5 g of the composite flour samples were mixed with 20 mL of distilled water/oil in a weighed 45 mL centrifuge tube. The semi-liquid mixtures were agitated on a vortex mixer for two minutes, allowed to stand at 30 °C for 30 minutes, and then centrifuged (Eltek centrifuge, MP 400R, Electrocraft, India) at 500 x g for 20 minutes. The clear supernatant was dispensed and discarded. The adhering drops of water were removed with a white tissue paper and the tube was weighed.

The weight of the water/oil absorbed by 5 g of composite flour samples was calculated and expressed as water/oil absorption capacities as follows:

$$\text{WAC} = \frac{(\mathbf{V}_1 - \mathbf{V}_2) \times \mathbf{1}}{\text{Weight of sample}} \quad (\text{mLg}^{-1})$$

Where \mathbf{V}_1 = initial volume of distilled water

\mathbf{V}_2 = final volume of distilled water (supernatant)

1 = density of water

$$\text{OAC} = \frac{(\mathbf{V}_1 - \mathbf{V}_2) \times \mathbf{0.93}}{\text{Weight of sample}} \quad (\text{mLg}^{-1})$$

Where 0.93 is the density of oil.

3.2.5.3 Pasting Properties of the Composite Flour Samples

Pasting characteristics of the composite flour samples were determined using a method from Mariotti *et al.* (2011) with modifications. The pasting properties were determined using a Brabender (Viscograph – E, Brabender GmbH & Co. KG. 803301, 803301E000-02, Germany) that gives a precise control of the time-temperature and shear profile. The moisture content of the composite flour samples were corrected to 14%. The amount in grams of the sample to be tested was determined based on its moisture content. For instance, the control sample (composite flour without FMF) which had a moisture content of 9.25% required approximately 40 g to 400 mL of distilled water after the moisture content value was keyed into the Brabender software.

The slurry was first heated to 50 °C after it had been fed into the Brabender by holding the temperature for 5 minutes, increased further to 95 °C and held for 30 minutes then allowed

to cool at 50 °C while holding it for an additional 5 minutes. The suspensions were subjected (speed: 250 min⁻¹; measuring range: 300 cm gf; heating/cooling rate: 3°C/minute) to the following temperature profile, heating from 50 °C to 95 °C, holding at 95 °C for 30 minutes, cooling from 95 °C to 50 °C and holding at 50 °C for 30 minutes.

Parameters determined included the Gelatinization Temperature (GT), (temperature at which an early increase in viscosity occurs); Peak Viscosity (PV) (the highest paste viscosity achieved during the heating cycle); Breakdown (BD), index of viscosity decrease during the first holding period, corresponding to the peak viscosity minus the viscosity after the holding period at 95 °C; Setback (SB), the index of viscosity increase through the cooling cycle and Final Viscosity (FV), the paste viscosity achieved at the end of the cooling cycle). Results are the average of triplicates and the viscosity was expressed in terms of Brabender Units (BU).

The pictorial representation of the process for determining the pasting properties of the composite flour samples is presented in Figure 9 below.

3.2.5.4 Emulsion Capacity and Stability of the Composite Flour Samples

The emulsion capacity was determined following Yasumatu *et al.* (1972) with modifications. Three grams of the composite flour was suspended in a mixture of 10 mL of vegetable oil and 10 mL of distilled water in a weighed 45 mL centrifuge tube. The mixture was then emulsified by the use of a vortex mixer at high speed for 3 minutes.

A



Weighing of Composite Flour

B



Slurry Preparation

C



Feeding Brabender with Slurry

D



Construing Brabender for Operation

E



Pasting Test begins

F



End Product of Test

Figure 9: Test for Pasting Properties of Composite Flour Samples

The resulting emulsion was then centrifuged (Eltek centrifuge, MP 400R, Electrocraft, India) at 500 x g for 20 minutes. The ratio of the height of the emulsion layer to the total height of the mixture was calculated as emulsion capacity percentage. The formula for calculating the emulsion capacity is as follows;

$$\textit{Emulsifying Capacity} = \frac{\textit{Volume of emulsified layer}}{\textit{Volume of total sample in tube}} \times 100$$

The method of Okecie & Bello (1988) with modifications was used to determine the emulsion stability of the composite flour samples. Finger Millet-Maize composite flour (5.0 g) was suspended in a mixture of 10 mL each of vegetable cooking oil and distilled water. The mixture was then heated at 80 °C for 30 minutes in a water bath. The resulting mixture was then cooled under running water for 20 minutes and centrifuged (Eltek centrifuge, MP 400R, Electrocraft, India) at 500 x g for 20 minutes. With the same calculation method for the emulsion capacity, the emulsion stability was obtained. All tests were done in triplicate.

3.2.5.5 Swelling Capacity and Solubility Index of Composite Flour Samples

Swelling capacity was determined by the method of Okaka and Potter (1997). A 100 mL graduated cylinder was filled with 10 g of the flour sample and made up to the 10 mL mark with distilled water. Distilled water was then added to obtain a total volume of 50 mL. The top of the graduated cylinder was tightly covered using aluminum foil and mixed by inverting the cylinder. The suspension was afterwards inverted again after 5 minutes and left to stand for 20 minutes. The supernatant was carefully transferred into a weighed petri dish and the volume occupied by the sample was taken after the 20th minute. Swelling power was obtained by weighing the residue after the 20th minute then dividing the residue weight by the original weight of the composite flour on a dry weight basis.

The solubility index was determined by evaporating the supernatant contained in a weighed petri dish over a steam bath and finally dried in an incubator oven at 105 °C for 6 hours. The weight of the dissolved solid was determined with an electric balance, after all the solvent had been evaporated. The solubility index of the composite flour samples was calculated as follows:

$$\text{Solubility Index} = \frac{W2 - W1}{W3} \times 100$$

Where;

W1 = the weight of the of the petri dish

W2 = weight of the dissolved solid and the petri dish after drying

W3 = the original sample weight.

3.2.6 Instrumental Analysis of Composite Breakfast Cereal

3.2.6.1 Determination of Colour and Total Colour Difference of Composite Breakfast Cereal

The colour of the composite breakfast cereal was measured using a modification of Yadav *et al.*, (2012). Colour of the samples were determined by the use of a Hunter Lab Colour Analyzer (CR310 Chroma meter, Konica Minolta, Tokyo, Japan 76981007) to obtain the L* (lightness), a* (redness) and b* (yellowness) values as well as the ΔE^* (total change in colour).

3.3 SENSORY EVALUATION OF COMPOSITE BREAKFAST CEREAL

Blay's (2012) sensory evaluation method was followed to conduct two basic sensory tests. An affective test (Consumer Acceptance Test) was done on all samples of composite breakfast cereal. The Consumer Acceptance Test used 80 untrained panelists. The sensory test was done in the Sensory Laboratory of the Department of Nutrition and Food Science.

The specific attributes that were measured under the Consumer Acceptance Test were flavour, mouthfeel, aroma, colour, taste and overall acceptance. The samples were initially coded with random 3 digit codes and were served simultaneously to the panelists. Panelists were presented with 80 mL of each of the samples, which had been prepared by adding clean warm water of 60 °C temperature to the breakfast cereal 1hour before the test. The panelists were instructed to cleanse their palate with water before and after each evaluation.

3.4 DATA COLLECTION

Data was collected for every test and statistical analysis performed including those from the sensory evaluation and physicochemical characteristics of individual composite flour samples and the breakfast cereal samples. The data collected was organized in the wide format into excel csv file, and then converted into the extended format to make it easy for the statistical analyses software to comprehend data and the analyzed by the researcher.

3.5 DATA ANALYSES AND PRESENTATION

All data presented in tables are the average of triplicate observations. Statistical analyses of data was performed using R Statistical Software 64-bit version 3.3.1 (R Stats), and Microsoft Office Excel 2013. The data were entered into Microsoft Excel 2013, saved and imported into “R Stats”. The means and standard deviations of measured variables were calculated using R Statistical Software (version 3.3.1). Analysis of variance (ANOVA) which was used to compare treatment means was conducted at ($\alpha < 0.05$) while multiple range tests of treatments to be significantly different were done using R Stats (version 3.3.1). Mixture Regression models were developed in R Stats (version 3.3.1) employing the stepwise method to relate the effects of components on the sensory attributes of the

composite breakfast cereal formulations by employing the R Stats (version 3.3.1). In terms of which model best explains the changes in the sensory attributes, the R^2 values were used. Pairwise tests, specifically the students t-test, Fisher's least significant difference test (LSD), False discovery rate (FDR), and Tukey's test were all conducted in R stats (version 3.3.1) to identify where there was a statistically significant difference among samples. These were used to test the specified hypotheses at a significance level of ($\alpha < 0.05$). Results were presented in tables and charts where necessary to give a pictographic description of data and to classify trends in the data.

CHAPTER FOUR

4.0

RESULTS AND DISCUSSION

4.1 Physical Characterization of Composite Flour Blends

4.1.1 Colour ($L^*a^*b^*$ Values) of Composite Flour Samples

Colour was one of the physical characteristics determined on the different composite flour formulations. Three basic colour dimensions which are perceived are: Lightness coordinate (L^*), red (+)/green (-) colour attribute (a^*), and yellow (+)/blue (-) colour attribute (b^*) (Pathare & Opara, 2013). These three colour dimensions ($L^*a^*b^*$) intently characterize the colour sensitiveness of humans where ' L^* ' which is a psychometric index of lightness represents dark to lightness, ' a^* ' which is a chromaticity coordinate represents green to red and ' b^* ' which is also a chromaticity coordinate signifies blue to yellow (Pathare & Opara, 2013).

The shades of red and yellow coloration of the samples observed in the study of composite flour colours indicated a positive value indicator of the colour coordinates ' a^* ' and ' b^* ' (Minolta, 1991). The colour of the flour samples was analyzed and the results indicated that ' L ' values were lower as the percentage of Sprouted Finger Millet Flour (SFMF) increased in the formulations. This shows that the colour of the flour blends was negatively affected by increasing the percentage of Sprouted Finger Millet Flour (SFMF) in the composite flour formulations as they became darker. The mean $L^*a^*b^*$ values for the SFMF samples are shown in Table 4.

Table 4: Mean Colour (L*a*b*) and Total Colour Difference (ΔE^*) Values of Composite Flour Samples.

% OF SFMF IN BLEND	COLOUR PARAMETERS			
	L*	a*	b*	ΔE^*
0	73.91 ± 0.26 ^a	8.54 ± 0.01 ^d	26.07 ± 0.14 ^a	10.01 ± 0.09 ^a
40	69.62 ± 0.52 ^b	12.28 ± 0.03 ^c	23.89 ± 0.17 ^b	6.00 ± 0.02 ^b
50	66.73 ± 0.23 ^c	13.63 ± 0.02 ^b	22.91 ± 0.03 ^b	2.79 ± 0.04 ^c
60	64.40 ± 0.41 ^d	13.89 ± 0.01 ^b	21.57 ± 0.04 ^c	0.86 ± 0.00 ^d
70	63.34 ± 0.17 ^c	14.09 ± 0.02 ^a	21.19 ± 0.02 ^c	2.87 ± 0.02 ^c
90	62.30 ± 0.06 ^c	14.23 ± 0.27 ^a	21.05 ± 0.04 ^c	2.89 ± 0.07 ^c

L* - lightness, {dark (0) to white (100)}, a*/-a* = redness / greenness, b* /-b* = yellowness / blueness, 0% = control 0%, 40%, 50%, 60%, and 70%, are Sprouted Finger Millet Flour percentages in the composite flour formulations. Means in same column with different superscripts are significantly different ($p \leq 0.05$)

The effect of increasing Sprouted Finger Millet Flour (SFMF) in composite flour formulations on L* (brightness) value were determined using the Analysis of variance (ANOVA) in R stat. The findings indicated that there was a significant difference ($p \leq 0.05$) in the L* values between the composite flour sample with 0% Sprouted Finger Millet Flour (FMF) and composite flour samples with different levels of SFMF incorporation. It is further deduced that the values of L* decreased with increasing Sprouted Finger Millet Flour (SFMF) in the formulations even though it was difficult to observe the colour difference among the composite flour samples with Sprouted Finger Millet Flour by sight. It can therefore be inferred that, the addition of SFMF to Maize and Date Fruit flours decreased L* value for the composite flour samples with SFMF relative to the composite flour sample with 0% SFMF. The total colour difference (ΔE^*) shows the degree of colour change in the composite flour samples with different level of SFMF incorporation compared with Composite Flour formulation with 0% SFMF. It can be inferred from Table 4 that the sample with the least ΔE^* (0.86) was the sample with 70% level of SFMF substitution while the highest (21.89) was recorded in the sample with 0% level of SFMF. The effect of colour change decreased with increasing level of SFMF substitution in the composite flour samples.

4.1.2 Particle Size Distribution of Composite Flour Samples

The most common method used for particle size analysis of flour in the grain industry is a sieve shaker method using the AACC standard. This study involved the determination of mean particle size of Finger Millet and Maize composite flour samples from five different formulations at sieving times of 3 minutes and at an amplitude of 3 using the U.S sieve series numbers 50, 100, 120, 20 and 230. Table 5 shows the particle size distribution of the composite flour samples.

Table 5: Particle Size Distribution of Composite Flour Samples

% of SFMF IN	SIEVE APERTURE (μm)				
	50	100	120	200	230
BLEND					
0	85.23 \pm 0.12 ^d	59.72 \pm 0.39 ^a	4.91 \pm 0.09 ^d	0.14 \pm 0.02 ^d	0.00 \pm 0.00 ^c
40	96.83 \pm 0.25 ^a	49.51 \pm 0.27 ^e	2.36 \pm 0.05 ^f	1.25 \pm 0.31 ^c	0.05 \pm 0.02 ^b
50	92.98 \pm 0.14 ^b	52.35 \pm 0.72 ^d	3.56 \pm 0.34 ^e	1.11 \pm 0.28 ^c	0.00 \pm 0.00 ^c
60	88.39 \pm 0.34 ^c	53.28 \pm 0.39 ^d	7.76 \pm 0.68 ^c	1.82 \pm 0.97 ^b	0.13 \pm 0.01 ^a
70	76.98 \pm 0.24 ^e	56.64 \pm 0.57 ^c	14.56 \pm 0.26 ^b	1.89 \pm 0.21 ^b	0.00 \pm 0.00 ^c
90	60.78 \pm 0.57 ^f	58.13 \pm 1.02 ^b	25.40 \pm 0.05 ^a	5.78 \pm 0.12 ^a	0.00 \pm 0.00 ^c

0%, 40%, 50%, 60%, 70% and 90% are Sprouted Finger Millet Flour percentages in composite flour formulations. 0% has no sprouted Finger millet. Values are means and standard deviations of triplicates. Means in same column with different superscripts are significantly different ($p \leq 0.05$).

Particle size of the composite flour samples, measured as the geometric mean particle diameter, is a critical influence in determining the usefulness and application of composite flour samples in food applications and processes such as baking, drum drying and extrusion. This study investigated the particle size distribution of composite flour samples and the particle size analysis results were compared for the six composite flour samples within each sieve size at constant time and amplitude. Table 5 indicates a significantly increase ($p < 0.05$) in the amount of SFMF incorporation in the composite flour formulations with decreasing the particle size for all the six composite flour samples. However, the composite flour with 90% SFMF was relatively finer in terms of particle size as more of the flour was retained on the sieve with the U.S. No. (200 μm) aperture followed by formulations with SFMF 70%, 60%, 50%, 40% and 0% respectively. This characteristics prevented flour particles from being agglomerated and lodged in the screen openings, hence allowing particles to pass through the sieves with ease (Belorio *et al.*, 2019). This observation could result from the small grainy nature of SFMF which might have contributed to the reduced particles sizes of SFMF. Hence, particle size decreased as SFMF increased in the composite flour formulations. Similarly to the results of Belorio *et al.* (2019) who investigated the impact of flour particle size distribution on the quality and acceptance of maize gluten-free cookies, reported that an increase in maize flour particle size decreases water holding capacity and swelling power values. However, other studies were not able to establish a correlation between particle size of flours and their functional characteristics whiles some also showed no decrease in WAC with decreased in particle size (Ahmed *et al.*, 2016). Belorio *et al.* (2019) again found a decrease in other important functional properties such as solubility index and emulsion capacity and stability of the composite flour samples with increased particle size.

4.2 CHEMICAL CHARACTERISTICS OF THE FLOUR SAMPLES

Food is made up of key constituents which affect the nutritional and sensory quality of the food product. Each component of food has its own chemical characteristics which contribute to the final properties of the food. Determining the composition of food is essential for food production (Wijaya *et al.*, 2015). The chemical characteristics determined in this study include proximate composition (Table 5) and pH (Table 6).

4.2.1 Proximate Composition

The proximate composition determined on the composite breakfast cereal include moisture content, protein, total crude carbohydrates, fat and total ash. The proximate composition was expressed on dry matter basis, except for moisture. Table 6 shows the proximate composition of the composite flour samples.

4.2.2 Moisture Content

It is essential for the moisture content of food products to be determined to enable the proper monitoring of the quality of the food and its wholesomeness with regards to microbial load. The moisture content of the composite flour samples was determined as the mass of water in a specified mass of composite flour sample eliminated through evaporation.

Table 6 illustrates significant differences ($p \leq 0.05$) in moisture content for all composite flour samples. The composite flour samples had moisture contents ranging from 8.00 to 9.25%. Composite flour sample with 0% SFMF (control) recorded the highest moisture content while the composite flour sample with 90% SFMF recorded the least moisture content.

Table 6: Proximate composition of Sprouted Finger Millet and Maize composite flour samples.

% OF SFMF IN BLEND	Moisture %	Fat %	Ash %	Protein %	Carbohydrate %
0	9.25 ± 0.05 ^a	2.49 ± 0.65 ^a	2.21±0.02 ^e	12.75 ± 0.07 ^a	73.30 ± 0.22 ^a
40	8.51 ± 0.68 ^b	2.19 ± 0.02 ^a	4.09 ± 0.54 ^d	12.25 ± 0.11 ^a	72.96± 0.15 ^a
50	8.23 ± 0.94 ^b	2.12 ± 0.01 ^b	5.89 ± 0.26 ^c	11.72 ± 0.00 ^b	72.04 ± 0.06 ^a
60	8.21 ± 0.01 ^b	2.02 ± 0.58 ^c	6.66± 0.37 ^b	11.69 ± 0.05 ^b	71.01 ± 0.06 ^b
70	8.19 ± 0.03 ^b	1.93 ± 0.47 ^d	7.60 ± 0.42 ^a	11.23 ± 0.16 ^c	70.97 ± 0.09 ^b
90	8.01±0.57 ^c	1.29 ± 1.02 ^e	7.40 ± 0.05 ^a	11.02 ± 0.12 ^d	69.10 ± 0.15 ^c

0%, 40%, 50%, 60%, 70% and 90% are Sprouted Finger Millet Flour percentages in composite flour formulations.

Values are means and standard deviations of triplicates. Means in same column with different superscripts are significantly different ($p \leq 0.05$). The values were reported as % dry matter, except for moisture content values.

This could be as a result of an inverse relation between the rate of absorption of moisture and seed size, since a larger seed offers a smaller surface area per unit mass (specific surface area) for moisture transfer (Hsu *et al.*, 1983). It was observed that the moisture content of composite flour samples decreased with increasing percentage of SFMF. There was a significant difference ($p \leq 0.05$) in moisture content between the composite flour sample with 0% SFMF and the composite flour samples with 40, 50, 60, and 70% SFMF. However, there was no significant difference ($p \leq 0.05$) in moisture content among composite flour formulations with 40, 50, 60, and 70% SFMF incorporations. The moisture content in all samples was however within standards since the threshold for moisture in flour-based products is 13% (Butt *et al.*, 2004). Moisture content above 13% may lead to yeast and mould growth as well as hydrolytic rancidity in the product within a short period of time (Ihkoronye & Ngoddy, 1985). Moisture content of foods has been thoroughly studied and reports indicate that it has an influence on the taste, texture, weight, appearance and shelf life of food products (Appoldt & Raihani, 2017). Hence a slender deviation from a regulated standard for moisture content can impact on the physical qualities of a food product. In the light of this, the assessment of moisture in food analysis is of prime importance to ensure consistency with regards to food safety and quality (Appoldt & Raihani, 2017).

4.2.3 Fat Content

The fat content of the composite flour formulations with different percentage incorporations of SFMF showed significant differences ($p \leq 0.05$) as presented in Table 6. The fat content decreased significantly ($p \leq 0.05$) with increasing amount of SFMF incorporation. This could be attributed to the fact that total solid loss during soaking and use of fat as a source of energy during sprouting led to the decrease in fat content of the sprouted finger millet (Shah *et al.*, 2011). Even though the fat content of finger millet has been reported to be as low as

1.3 - 1.8% (Bhatt *et al.*, 2003), the fat levels of the samples as shown in Table 6 were a little above the reported range. The fat content of the samples studied ranged from 1.87 - 2.49. Antony *et al.* (1996) have reported higher amount of fat (2.1%) in finger millet. Fat content of the flour samples is considered as a useful indicator of their use in food applications especially in enhancing the flavour of food. The fat content of flour can influence processing, packaging and storage of the products made from them (Rios *et al.*, 2014).

4.2.4 Total Ash Content

The total ash determination was by the combustion of flour samples and measured as the mineral content of the flour samples (Blitz *et al.*, 2009). The total ash content determined for all the composite flour samples differed. The ash content increased with increasing incorporation of SFMF. As observed in Table 6, composite flour samples with 0% SFMF differed significantly ($p \leq 0.05$) from the composite flour formulations with 40%, 50%, 60% and 70%. However, there was no significant difference ($p \leq 0.05$) among composite samples with 40%, 50% and 60% SFMF incorporations. The ash content ranged from 2.21 – 4.89% among the composite flour samples. The highest total ash content was observed in composite flour sample with 70% SFMF while the least total ash was recorded in the composite sample with 0% SFMF. The ash content obtained for the composite flour samples are slightly higher as compared with the findings of Singh and Srivastava (2006), who reported the total ash content of sixteen varieties of finger millet as a range from 1.47 to 2.58%. On the other hand, Rao *et al.*, (1973) has reported ash content of finger millet to be as high as 4.13%. Minerals such as calcium, phosphorus, iron, magnesium, sodium, potassium, manganese, and zinc have been found to differ significantly among millet varieties since factors such as genetic make-up and the environmental conditions dominant in the growing region affect the mineral content of these grains (Singh & Raghuvanshi,

2012). This could account for the higher ash content recorded in the composite flour samples studied, especially the samples with SFMF incorporation, but low in composite flour sample with no SFMF. Minerals are important in foods with respect to the essential role they play nutritionally and physiologically. Hence the need for the determination of the ash content of food products.

4.2.5 Protein Content

There are significant differences ($p \leq 0.05$) in protein content among all the flour samples, with composite flour sample with 0% SFMF incorporation having the highest protein content of 12.75%, and composite flour sample with 70% SFMF having the lowest protein content of 9.80% as shown in Table 6. These protein levels are within the reported range (4.88 to 15.58%) of protein content in sixteen finger millet studied by Singh and Srivastava (2006) with a mean value of 9.728%. Table 6 also indicates with regards to protein content of flour formulations that composite flour formulations decreased significantly ($p \leq 0.05$) as percent SFMF increased in the composite flour formulations. This trend is due to the fact that even though finger millet contains relatively high amounts of essential amino acids in its albumen and globulin fractions, its prolamin fraction is very low in lysine, arginine and glycine. This accounted for the varied amount of protein content in the composite flour formulations as percent FMF increased. It is therefore important for cereal-fruit complementary food to be developed in order for fruits to make up for the essential amino acids deficits in cereals like the Finger millet.

4.2.6 Carbohydrate Content

One of the major components of food which is of prime importance to the human body is carbohydrates, as it is the immediate source of glucose converted to energy to be utilized by

the body to support its activity (WHO/FAO, 1998; Maureen & Beth, 2012). They also contribute to the sweetness, appearance and textural characteristics of many foods having carbohydrates as their major constituent. The crude carbohydrate content of the flour samples was assessed as the percent difference after all the other proximate components (Table 6) had been determined. The carbohydrate content of the composite flour samples ranged from 70.97- 73.30%. These carbohydrate levels obtained from the composite flour samples are below the range reported by Joshi and Katoch, (1990), and Bhatt *et al.*, (2003) for some finger millet (72 - 79.5%) and Salifu *et al.* (2012) for some maize (75.35 – 77.85%) in Ghana. It was observed that the carbohydrate content of composite flour formulations decreased significantly ($p \leq 0.05$) as percent SFMF increased. The reduction in carbohydrates content with increasing percentage of SFMF in the composite flour samples could be attributed to the fact that the finger millet was sprouted for 24 hours, hence some of the complex long chain carbohydrates might have been broken down into simple short chain polysaccharide and easily used up during the process of sprouting. This is in conformation with the findings of Chinma *et al.* (2009) as there was a decrease in carbohydrate content with increasing sprouting time of grains. Ife (2017) also found similar results, reporting a reduction in the carbohydrate content of *Moringa* seed as germination time increased.

Table 6 indicates no significant differences ($p \leq 0.05$) in carbohydrate content between MF and composite flour samples with 40, 50 and 60% FMF. However, there were significant differences ($p \leq 0.05$) in carbohydrate content of composite flour samples with 0% FMF and composite flour with 70% FMF. Composite flour formulation with 40% FMF had the highest carbohydrate content whiles the composite flour sample with 70% FMF had the least amount of carbohydrate content.

4.2.7 pH of Flour Samples

pH is an indication of a material's acidity, alkalinity or neutrality, depending on its concentration of hydrogen ions in an aqueous solution (Andrés-Bello *et al.*, 2013). Ten percent solution of each flour samples were prepared. Ten mL of each of the prepared solutions was pipetted into different non-graduated test tubes and their pH were determined using the Mettler Toledo pH meter (model: SevenCompact S220, USA). The findings of the pH of the various flour samples are shown in Table 7.

Table 7: pH of Composite Flour Samples

% OF SFMF IN BLEND	pH
0	5.62 ^a
40	5.41 ^a
50	5.10 ^a
60	5.10 ^a
70	4.98 ^b

0%, 40%, 50%, 60%, 70%, and 90% are Sprouted Finger Millet Flour percentages in the composite flour formulations. Values are means and standard deviations of triplicates. Means with different superscripts are significantly different ($p \leq 0.05$).

The pH of the composite sample with 70% SFMF varied from that of the other composite flour formulations. The pH values ranged from 4.98 – 5.62, with composite flour with 0% Sprouted Finger Millet Flour having the highest value of 5.62. The pH values obtained on the composite flour samples also indicate that the composite flour samples are acidic but weak. Again it can be inferred from Table 7 that the pH of the composite flour samples decreased with increasing SFMF percentage in the composite flour formulations. This supports the finding of Saalia *et al.*, (2012) that sprouting had an effect on the pH of fermented dough since it significantly influenced pH by the increased amount of malting

tine. Typically, when low or no malt was added to the fermenting dough system, higher pH was observed compared to when higher amounts of malt were added which caused a decrease in pH. Similarly, Adedeji *et al.* (2014) also reported that pH decreased with increasing sprouting time of maize grains used in the preparation of cookies. pH is an important parameter in food applications, packaging and storage as it can affect the shelf life of a food product (Fekria *et al.*, 2012). Andrés-Bello *et al.*, (2013) reported that sensory characteristics such as taste, colour, texture, and flavour can be influenced by pH especially in cereal products. The pH of flour and flour-based food products affect their functional properties such as pasting properties, swelling power and solubility index, and chemical reactions such as the Maillard reaction. Therefore, it is important for food processors to have a thorough knowledge on the effects of pH and its control during processing in order to ensure product quality, wholesomeness, and value-addition (Andrés-Bello *et al.*, 2013).

4.3 FUNCTIONAL CHARACTERISTICS OF COMPOSITE FLOUR SAMPLES

4.3.1 Water and Oil Absorption Capacities of Composite Flour Samples

4.3.1.1 Water Absorption Capacity of Flour Samples

The ability of proteins in a substance to absorb water refers to the Water Absorption Capacity (WAC) of that substance (Singh, 2001). The water absorption capacity of cereal flour greatly influences the types of food they are made with. A classic example is taro-wheat composite flour in food applications. Ikpeme *et al.* (2010) revealed that product made from such a composite flour improved its water absorption capacity significantly as it helped maintain the soft texture and flavour of the product.

Figure 11 indicates the water absorption capacity for composite flour sample with 0, 40, 50, 60 and 70% SFMF. There was no difference ($p \leq 0.05$) with regards to water absorption capacity between the formulations with 50% and 60% SFMF. The water absorption capacity

values for the flour samples ranged from 2.13 mLg⁻¹ to 2.92 mLg⁻¹. The formulation with 90% SFMF had the highest water (2.92 mLg⁻¹) absorption capacity while formulation with 0% SFMF had the least water (2.13 mLg⁻¹).

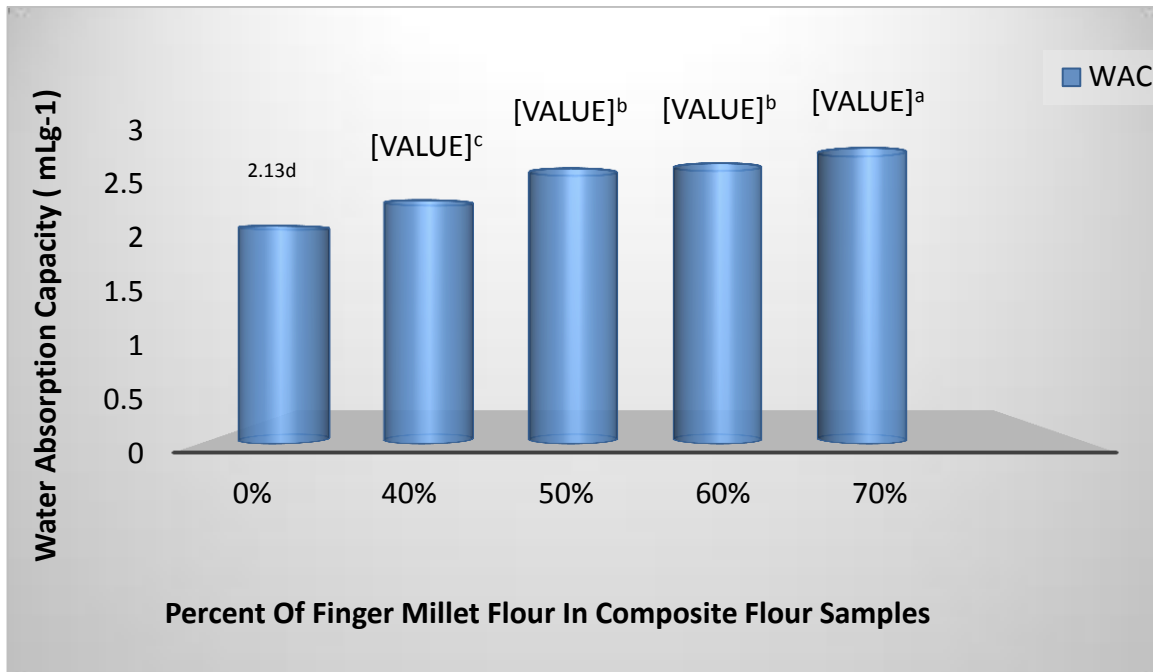


Figure 10: Water Absorption Capacity of Composite Flour Samples

It can be inferred from Figure 10 that, the water absorption capacity increased with increasing SFMF in the composite flour formulations. This is in agreement with the study of Gernah *et al.* (2011) who studied the effects of malting and fermentation on some chemical and functional properties of maize grains, and found an increase in the water absorption capacity (from 3.70 mLg⁻¹ to 3.92 mLg⁻¹) of germinated maize.

Okaka and Porter (1997) reported that the water holding capacity of a food substance largely depends on the water binding capacity of food constituents. As a result, this observed trend of the composite flour samples with regards to WAC could be attributed to the fact that the Finger Millet was steeped and sprouted. Hence the polar hydrophilic ends of the major chemical constituents of the flour samples which are carbohydrates and proteins accounted

for this. Also, the production of compounds such as soluble sugars during sprouting that have loose starch structure polymers have good water holding capacity, hence the higher WAC (Adedeji *et al.*, 2014). Similarly, Chinma *et al.* (2009) reported an increase in water absorption capacity of different flour samples from steeped yellow and brown tiger nuts. However, flour with lower water absorption capacity is beneficial for making soft porridge especially for infants.

4.3.1.2 Oil Absorption Capacity of Flour Samples

The oil absorption capacity of cereal flour is very important in the textural and flavour characteristics of food products. Factors such as particle size, starch content, protein content and the type of protein influence Oil Absorption Capacity of flour (Chandra & Samsher. (2013). Figure 11 shows the OAC of flour samples, which ranged from 0.87 - 1.69 mLg⁻¹.

The flour formulation with 70% SFMF recorded the highest OAC value 1.29 mLg⁻¹ while the formulation with 0% SFMF recorded the least OAC value 0.87 mLg⁻¹. This is similar to the findings of Zubair & Osundahunsi (2016) who studied the effect of steeping period on the physicochemical and pasting properties of sorghum starch and found an increase in the oil absorption capacity (1.31 to 1.79 mLg⁻¹) as a result of increased steeping time. According to Deepali *et al.* (2013) this increase in OAC with increasing SFMF percentage could be associated with the solubilization and dissociation of proteins leading to the exposure of the non-polar components contained in the protein molecules. High oil absorption capacity makes flour/starches suitable for the enhancement of flavour and mouth feel when used in food preparations.

This trend could be as a result of the limited variation in the presence of non-polar side chains, which might bind the hydrocarbon side of the oil among the composite flour formulations (Chandra *et al.*, 2015)

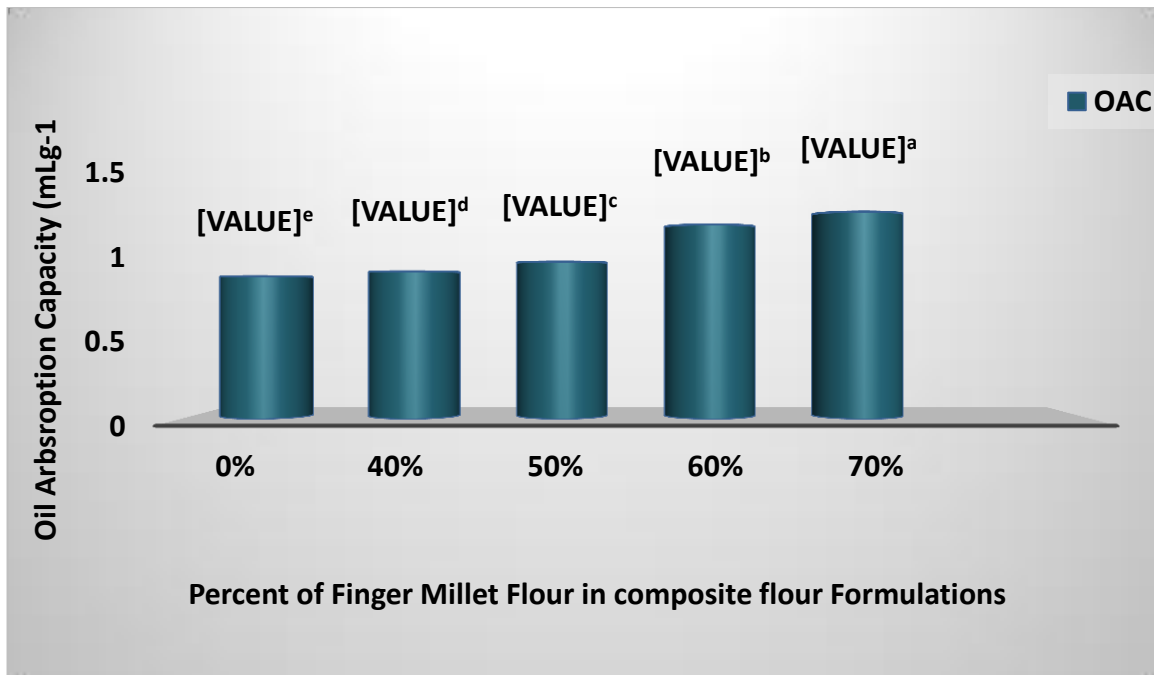


Figure 11: Oil Absorption Capacity of Composite Flour Samples

4.3.2 Emulsion Capacity and Stability of Composite Flour Samples

Emulsion properties play a central role in many food systems where protein binds fat such as those found in meat product and salad dressing (Okezie & Bello, 1988). The percentage emulsion capacity and stability of composite flour sample are presented in Table 8.

The emulsion capacity reveals the capability of the sample to rapidly adsorb at the water-oil interphase through the development of emulsion, thereby preventing flocculation and coalescence (Subago, 2006) however, the emulsion stability is key for an emulsifier to perform well, as it depends on its ability to uphold the emulsion in succeeding processing stages such as cooking and canning (Tsaliki *et al.*, 2004).

All composite flour samples showed a significant difference in their emulsifying capacities and stabilities (Table 8). The composite flour sample with 90% SFMF had a higher emulsifying capacity and stability while the composite flour sample without SFMF recorded the least emulsifying capacity and stability.

Table 8: Emulsion Capacity and Stability of Composite Flour Samples.

% OF SFMF IN BLEND	Emulsion Capacity (%)	Emulsion Stability (%)
0	50.12 ± 0.26 ^e	46.25 ± 0.36 ^d
40	57.60 ± 0.96 ^d	36.65 ± 0.75 ^f
50	57.81 ± 0.44 ^d	41.29 ± 1.09 ^e
60	58.84 ± 1.02 ^c	52.33 ± 0.25 ^c
70	60.04 ± 0.64 ^b	53.19 ± 0.94 ^b
90	61.24 ± 0.38 ^a	59.96 ± 1.59 ^a

Values are means ± standard deviations of triplicate determinations. Means in the same column followed by different superscript are significantly different ($p \leq 0.05$).

Similarly, Ocheme *et al.* (2015) reported that the emulsion capacity of the flour made from finger millet with different germinating times, increased from 58.6% to 65.5% with increasing order of germination. According to Imtiaz *et al.* (2011) the increase in emulsion capacity with increasing germination time could be as a result of an increase in the area of the stabilized oil droplet at the interface signifying a function of the food components. Sikorski (2002) reported that the emulsification of food materials may be as a result of insoluble and soluble polysaccharides and proteins. With regards to the emulsion stability which increased with increasing the amount of sprouted SFMF, Ahmed *et al.* (2011) found an increasing level of emulsion stability with decreasing pH. It is worth noting here that the pH of the composite flour samples decreased with increasing incorporation of sprouted SFMF. These results were similar to those of Khalid *et al.* (2003) who found that the emulsion stability of sesame protein isolate was higher at acidic pH (75.0 %) than at alkaline pH (62.0%). Yan *et al.* (2007) stated that low emulsion stability at higher pH is due to colloidal particles carrying electrical charges that promote the stability of the colloid as well

as in the formed emulsions by aiding particles of similar charge to resist each other thereby inhibiting their precipitation. These variations might be due to differences in protein subunit, molecular weight distribution and amino acid composition.

4.3.3 Pasting Properties of Composite Flour Samples

The starch structure and composition of food material is exhibited in its pasting characteristics (Osako *et al.*, 2010). Food materials exhibit some pasting characteristics when the starch they contain in a suspension form is sheared while heating. These include gelatinization and swelling of starch granules to numerous times their original volume. Starches are made up of linear and helical amylose and branched amylopectin networks. These networks and factors such as granule volume fraction, particle size distribution, shape of the granules, interaction between granules and continuous phase viscosity greatly affect the pasting properties of flour (Tahir *et al.*, 2011; Malomo *et al.*, 2011). The pasting characteristics are important parameters used to determine the suitability of starch in flour for certain uses and also help in the identification of starch sources for diverse use (Malomo *et al.*, 2011). Results of the pasting properties of the flour samples are shown in Table 9. Pasting properties reflect the changes in viscosity of flour with heating. Variations in flour formulations significantly affected ($P < 0.05$) the pasting time and temperatures of the composite flour samples. Particularly, the composite flour formulation with the least pasting time and temperature was the formulation with 40% SFMF, whereas the highest was recorded in the flour formulation with 90% SFMF. This variation could be linked with the stronger bond strength within the starch molecules of 90% SFMF composite flour compared with the inter-granular bonds in the formulation with 40% FMF (Eliason & Karlson, 1983).

Higher pasting temperatures are linked to stronger inter-granular bonds as in the case of the formulation with 90% SFMF (Table 9) demonstrating the presence of stronger inter-granular bonds within the flour granules. Again, these stronger inter-granular bonds require more energy to break down the bonds within the amylose-rich starches, hence leading to the highest pasting temperature recorded in the flour sample with 90% SFMF. Similarly, Xu *et al.* (2012) observed the same trend in wheat and brown rice flour.

Peak Viscosities (PV) and Final Viscosities (FV) of the flour formulations were significantly different ($p < 0.05$) with respect to differences in SFMF composition. The highest Peak Viscosity and Final Viscosity were recorded in formulation with 0% SFMF at 51.00 BU and 82.04 BU respectively, whereas the formulation with 70% SFMF recorded the least Peak Viscosity and Final Viscosity at 36.00 BU and 43.15 BU respectively. It can be observed from Table 9 that Peak Viscosity decreased with increasing percentage of SFMF. The decrease in viscosity as the percentage of SFMF increased may be due to the action α -amylase during sprouting and the Amylograph test, acting on the granules, making them more fragile hence, contributing to their breakdown easily and faster, during mechanical agitation. This finding is similar to what Romee *et al.* (2017) observed in studying the effect of germination on the pasting properties of *Chenopodium* and attributed it to the fact that enzymatic degradation of starch may have occurred during the sprouting process.

Starch retrogradation is the process through which gelatinized starch granules experience rearrangements upon cooling to form a more ordered higher degree structure of crystallinity (Wang *et al.*, 2015). Retrogradation is relatively faster in larger particle sized granules as compared to smaller particle sizes owing to the extremely compressed nature of the smaller granules, and hence, is faster in amylose than in amylopectin (Ottenhof & Farhat, 2013).

Table 9: Pasting Properties of Composite Flour Samples

% OF SFMF IN BLEND	PARAMETERS					
	P Time (min)	P Temp (°C)	PV (BU)	BD (BU)	SB (BU)	FV (BU)
0	18.55 ± 0.23 ^a	77.40 ± 0.36 ^a	51.00 ± 0.23 ^a	3.40 ± 0.21 ^d	30.80 ± 0.35 ^a	82.04 ± 0.34 ^a
40	18.15 ± 0.59 ^a	61.40 ± 0.94 ^b	46.00 ± 0.54 ^b	9.20 ± 0.36 ^b	25.75 ± 0.41 ^b	71.10 ± 0.29 ^b
50	18.20 ± 0.67 ^a	69.10 ± 0.06 ^c	42.00 ± 0.39 ^c	4.46 ± 0.14 ^c	20.12 ± 0.02 ^c	55.23 ± 1.45 ^c
60	18.35 ± 0.10 ^a	76.90 ± 0.61 ^d	42.00 ± 0.82 ^c	2.90 ± 0.68 ^d	15.95 ± 0.08 ^d	48.75 ± 0.95 ^d
70	19.05 ± 0.25 ^b	76.10 ± 0.18 ^d	36.00 ± 0.19 ^d	1.33 ± 0.29 ^e	12.19 ± 0.21 ^e	43.15 ± 0.67 ^e
90	19.67 ± 0.81 ^b	77.70 ± 0.11 ^e	45.00 ± 0.96 ^{bd}	13.56 ± 0.22 ^a	11.11 ± 0.07 ^f	70.06 ± 0.98 ^b

Values are means of triplicate determinations. Means in the same columns with different superscripts differ significantly ($p \leq 0.05$). P Temp. = Pasting temperature (in Degrees Celsius); P Time = Pasting time (minute); PV = Peak Viscosity; FV = Final Viscosity; BD = Break Down; SB = Set Back, BU= Brabender Units.

This was observed when increased setback viscosity was recorded in the formulation with 0% FMF as indicated in Table 9. Overall, setback viscosity decreased significantly ($p < 0.05$) with increasing SFMF in the flour formulations. Moreover, it was not surprising that the formulation with 0% SFMF recorded higher peak viscosity and lower pasting temperature and showed greater resistance to retrogradation as suggested by Pham Van *et al.* (2006) that flour with lower starch amylose contents corresponded to higher peak viscosity, lower pasting temperature and greater resistance to retrogradation.

Low setback, peak and breakdown viscosities of the composite flour samples with SFMF, as compared with flour without SFMF, induced by sprouting is necessary for the preparation of weaning foods for children. Weaning foods with low viscosity can make infants consume more food because it is relatively lighter but nutrient dense and of the solid that is added and subsequently help increase the nutrient density of porridges and gruels prepared from flours with low viscosity (Tizazu *et al.*, 2010).

4.3.4 Swelling Power and Solubility Index of Composite Flour Samples

Solubility is the amount of starch leached out into the supernatant in the determination of swelling volume (Singh *et al.* 2005). The amount in mL/g of the swelling power and the percentage of the solubility index of composite flour samples are presented in Table 10.

The solubility index of the composite flour samples ranged from 2.40% to 27.34%. The solubility index of the composite flour samples increased with increasing sprouted FMF incorporation ($p < 0.05$). The highest value (27.34%) was obtained with the composite flour with 90% sprouted FMF and the composite flour with 0% sprouted FMF recorded the least value (2.40%). The increase in solubility index as the incorporation of sprouted FMF increased could be as a result of the increased amylase activity and similar increase in the

levels of shorter chain polysaccharide or soluble sugars as a result of germination (Almeida-Dominguez *et al.*, 1993; Nefale & Mashau, 2018).

Table 10: Swelling Power and Solubility Index of Composite Flour Samples

% of SFMF IN BLEND	Swelling Power (mL/g)	Solubility Index (%)
0	2.53 ± 0.07 ^f	2.40 ± 0.67 ^f
40	3.02 ± 0.12 ^e	9.80 ± 0.59 ^e
50	3.58 ± 0.29 ^d	15.60 ± 0.35 ^d
60	3.83 ± 0.18 ^c	17.40 ± 0.09 ^c
70	4.28 ± 1.25 ^b	21.60 ± 0.64 ^b
90	4.89 ± 0.38 ^a	27.34 ± 0.24 ^a

Values are means ± standard deviations of triplicate determinations. Means in the same column followed by different superscript are significantly different ($p \leq 0.05$).

High solubility of composite flour samples with increasing sprouted FMF indicates that the flour will nutritionally be suitable for infants (Tumwine *et al.*, 2019). Swelling power indicates the water holding capacity of starch. The swelling power in commercial starches is important for the quality and texture of some food products because it stabilizes them against effects such as syneresis, which occasionally occurs during retorting or freezing (Baker *et al.* 1994).

The swelling power ranged from 2.53 mL/g to 4.89 mL/g. similarly, Ocheme and Chinma (2008) carried out a study on the effects of soaking and germination on the physicochemical characteristics of millet flour for porridge production and reported an increase in the

swelling power of millet flour as a result of soaking and germination. The increase in swelling power was as a result of an increase in soluble solids led to by the breakdown of lipid, fiber and larger amount of amylose–lipid complex in flour that could inhibit the swelling of starch granules (Ocheme *et al.*, 2015). According to Ocheme and Chinma (2008), the observed higher swelling power of the composite flour samples could be as a result of the reduced fat content of the sprouted finger millet indicating the utilization of fat by the growing finger millet during soaking and germination. Phattanakulkaewmorie *et al.*, (2011) also reported that fats form complexes with starch and in turn limit swelling of flour.

4.4 SENSORY EVALUATION OF COMPOSITE BREAKFAST CEREAL SAMPLES

Table 11 shows the mean liking scores of the sensory attributes and the mean overall acceptability scores for the five (5) composite breakfast cereal samples.

Table 11: Sensory Evaluation of Composite Breakfast Cereal Samples

Attributes	FM ₀	FM ₄₀	FM ₅₀	FM ₆₀	FM ₇₀
Overall liking	7.23 ^d	8.16 ^a	7.99 ^b	7.86 ^b	7.59 ^c
Taste	8.05 ^d	8.51 ^b	8.23 ^c	8.83 ^a	8.85 ^a
Colour	6.08 ^c	8.02 ^a	7.89 ^b	6.15 ^c	5.53 ^d
Aroma	7.15 ^e	8.58 ^d	8.65 ^c	8.77 ^b	8.90 ^a
Mouthfeel	7.48 ^a	7.41 ^a	7.38 ^a	7.29 ^a	7.22 ^b
Aftertaste	7.94 ^a	7.49 ^b	7.18 ^c	6.68 ^d	6.14 ^e

10 ≤ Like Extremely; 5 ≤ Neither Like nor Dislike; 0 ≤ Dislike Extremely; FM₀, FM₄₀, FM₅₀, FM₆₀, and FM₇₀ represent breakfast cereal samples with 0%, 40%, 50%, 60% and 70% respectively of FMF in the composite breakfast cereal sample. Means in the same row with different superscripts are significantly different ($p \leq 0.05$).

Sensory scores given by panelists ranged from 5.53 to 8.90, an indication of different levels of liking the product. Breakfast cereal samples had significant differences in all sensory

attributes. However, the mean liking scores for breakfast cereal with 50% and 60% Finger millet flour did not show any significant differences ($p \leq 0.05$) in overall acceptability while breakfast cereal with 60% and 70% finger millet flour did not show any significant differences ($p \leq 0.05$) in taste. No significant difference recorded for mouthfeel for breakfast cereal samples with 0% - 60% Finger millet Flour may be due to the uniformity of the particles size in the composite flour used (Okpala *et al.*, 2013), as a result, panelist could not differentiate between the mouthfeel of the breakfast cereal samples made with 0 to 60% Finger Millet Flour. The mean scores recorded for aroma, flavour and overall acceptability were significantly different among some composite breakfast cereal samples (Table 10). However, the mean overall acceptability scores were also generally high (with all greater than 7) based on the 9-point hedonic scale used. The significant variations in the mean liking scores among some composite breakfast cereal samples indicate that addition of Finger millet flour to breakfast cereal samples significantly influenced the sensory acuity and acceptability of the composite breakfast cereal samples.

The lower liking scores with regards to aftertaste and colour for composite breakfast cereal samples with increasing addition of Finger millet flour (60% to 70%) may be due to the rather strong unfamiliar aroma and colour of Finger millet flour which was not completely concealed by the mixture of the other ingredients used in making the composite breakfast cereal. Overall, panelists preferred composite breakfast cereal samples made from composite flour with 40% and 50% Finger millet flour more than the control made from maize flour WF (Table 9). This finding suggests that substituting breakfast cereal formulations with 40% to 50% Finger millet flour would produce composite breakfast cereal that will be preferred over breakfast cereal with only maize as its main ingredient.

4.5 TEST OF HYPOTHESES

4.5.1 Null Hypothesis One (1)

The tristimulus colour and proximate composition of the breakfast cereal is not affected by the substitution of MF with FMF in the formulation. The p values for tristimulus colour and proximate composition analysis was less than the alpha ($\alpha = 0.05$) indicating statistically significant differences in the tristimulus colour of composite breakfast cereal samples ($p < 0.05$) as presented in table 12. Therefore, there is not enough evidence to accept the null hypothesis one which states that the addition of SFMF to MF in the breakfast cereal formulation does not affect the physical and chemical characteristics of the breakfast cereal samples. This means that the addition of SFMF to MF in the production of the breakfast cereal will cause a significant change in tristimulus colour and the proximate composition of the breakfast cereal made relative to breakfast cereal with no SFMF.

Table 12: Statistical test of null hypothesis one

H₀	ANOVA Tests	P values
H₀₁	Tristimulus (L) Colour of Composite Flour with SFMF vs Composite Flour with 0% SFMF	0.005
	Tristimulus (L) Colour of Breakfast Cereal with SFMF vs Breakfast Cereal with 0% SFMF	0.017
	Proximate composition of Composite Flours with SFMF vs Composite Flour with 0% SFMF	0.039

4.5.2 Null Hypothesis Two (2)

The functional property (emulsion capacity and stability, swelling power and solubility index) of composite flour samples are not affected by the substitution of maize flour with Finger millet flour in the formulations. The p values for the functional property (emulsion capacity and stability, swelling power and solubility index) analysis was less than ($\alpha = 0.05$) indicating statistically significant differences in the functional property (emulsion capacity and stability, swelling power and solubility index) of composite flour samples ($p \leq 0.05$) as presented in table 13. Therefore, there is not enough evidence to accept the null hypothesis two which states that the addition of SFMF to MF in the breakfast cereal formulation does not affect the functional properties of the composite flour samples. This means that the addition of FMF to MF in the composite flour formulations will cause a significant change in the functional properties of the composite flour made relative to composite flour with no FMF.

Table 13: Statistical test of null hypothesis two

H₀	ANOVA Tests	P values
H₀₂	Functional Properties of Composite Flours with SFMF vs Composite Flour with 0% SFMF	0.029

4.5.3 Null Hypothesis Three (3)

The sensory properties of breakfast cereal samples are not affected by the substitution of maize flour with Finger millet flour in the formulation. The p values for sensory evaluation were less than 0.05 indicating statistically significant differences in the perceived sensory

characteristics of composite breakfast cereal samples ($p \leq 0.05$) as presented in table 14. Therefore, there is not enough evidence to accept the null hypothesis three which states that the addition of SFMF to MF in the breakfast cereal formulation does not affect its sensory characteristics. This means that the addition of SFMF to MF in the breakfast cereal samples made will cause a significant change in its sensory characteristics relative to composite breakfast cereal with no FMF.

Table 14: Statistical test of null hypothesis two

H₀	ANOVA Tests	P values
H₀₃	Sensory attributes of Breakfast Cereal with SFMF vs Breakfast Cereal with 0% SFMF	0.047

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY

This research was done to investigate the performance of SFMF in breakfast cereal production. The study developed a process for making FMF and followed a one factor design in which SFMF was substituted with MF at 0%, 40%, 50%, 60% and 70% levels of incorporation. The tristimulus colour ($L^*a^*b^*$ - values), pH, amount of water and oil absorption capacity, emulsion capacity and stability, swelling power and solubility index, particle size distribution, proximate composition and pasting characteristics of composite flour samples were analyzed. Breakfast cereal samples made from the formulations were analyzed for sensory characteristics and tristimulus colour (L-value). Moisture, ash and crude fiber content of the composite flour increased with increasing SFMF. There was however a decrease in carbohydrate and protein content ($p \leq 0.05$). pH and the particle size distribution decreased significantly ($p \leq 0.05$) with increasing SFMF in the composite flour formulations. The particle size of the composite flour samples decreased with increasing SFMF.

The swelling power and solubility index, water and oil holding capacity and emulsion capacity and stability of composite flour samples increased as SFMF increased in composite flour formulations ($p \leq 0.05$). Tristimulus L value reduced (became darker) compared with the control (MF) as SFMF increased in breakfast cereal samples, with 70% SFMF recording the lowest L value ($p \leq 0.05$). Sensory analysis of the breakfast cereal samples showed that breakfast cereal with 40% and 50% SFMF had the highest overall acceptability, colour and taste scores ($p \leq 0.05$). Results from this study indicate that nutritious breakfast cereal

samples with high ash and crude fiber but low in carbohydrate and fat content can be made from SFMF. Wheat flour can be partially substituted with 40% - 50% Finger millet for breakfast cereal production. This has the potential to address food insecurity in the food system in Ghana by increasing the use of this underutilized and marginalized, adverse weather resistant crop, while providing food processors, both commercial and domestic, with a partial substitute for maize flour in food applications.

5.2 CONCLUSION

This study showed that finger millet can be processed into flour and used in food applications such as the production of breakfast cereals. The addition of SFMF to MF and DF produced composite flour with higher fiber and ash content but lower carbohydrates, protein and fats compared with MF. Increasing the amount of SFMF in composite flour formulations impacted on the physical, chemical and sensory characteristics of composite flour samples and the breakfast cereal. Composite breakfast cereal made with 40% and 50% SFMF were the most preferred with regards to their sensory characteristics and had the least difference among the composite breakfast cereal samples, when compared with 0% SFMF. The increase in ash and fiber and the decrease in carbohydrate and moisture content of the composite flour samples improved the nutritional content of the instant breakfast cereal. Thus, SFMF can be a useful ingredient in the production of nutritious breakfast cereal, thereby facilitating decision making by food processors and researchers who want to harness the nutritional properties of SFMF and use it as a substitute for maize and other cereal flour in food applications.

5.3 RECOMMENDATIONS

- I. Finger millet flour has been shown to have excellent physical, chemical and functional properties. Thus, it may be promoted as a substitute for MF in food applications. This will help decrease the cost of importing wheat flour for food applications.

- II. This research focused on the consumer acceptability of finger millet, maize and date fruit composite flour samples in only one food matrix, that is, breakfast cereal. Since the results showed that breakfast cereal samples were liked moderately, further studies should look at incorporating the flour samples into different food matrices like bread, cookies and biscuits to assess consumer liking of these products.

- III. The effect of sorption behaviour on short and long term storage of the composite flour samples should be determined since the composite flour samples had an increased moisture content. This is to determine how the composite flours will behave during storage.

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APPENDICES

APPENDIX 1:

CONSENT FORM

Project Title: Physicochemical and Sensory Evaluation of Breakfast Cereal Made From Finger Millet-Maize Composite Flour

Supervisors:

Dr. Niilante Amissah, Professor Angelina O. Danquah and Professor Firibu K. Saalia

Sensory Supervisor:

Dr. Maame Yaakwaah Blay Adjei

Investigator:

Reuben Acheampong

Address:

Sensory Evaluation Laboratory, Department of Nutrition and Food Science. School of Biological Sciences, College of Basic and Applied Science, University of Ghana, Legon, Accra.

General Information about Research

You have been invited to participate in a sensory evaluation involving breakfast cereal. Sensory evaluation involves the use of all your basic senses to evaluate and assess a food's characteristics. You will be presented with six samples, one after the other and tell us how much you like or dislike the product. Food taste test is an individual work activity and will involve no discussion with other participants on how you feel about the foods we show you. In any instance, the researcher will provide you with further details on the test you are to perform and the assessment protocol you should use.

Possible Risks and Discomforts

In general, this consumer acceptance test is non-invasive and should not be a source of risk to your health or person. The products you have to taste are all normal foods or the ingredients used to make normal foods. Unless you react adversely to **Finger Millet, Maize and Date Fruit**, this test should not pose a risk to you. If you feel uncomfortable at any point, please call the attention of the researcher who will be able to help you.

Possible Benefits

By participating in the food taste test, you are contributing immensely to the development of breakfast cereal. This is a huge emotional benefit to you as you will have contributed significantly to improved food security in Ghana.

Confidentiality

The data you provide to us will be kept confidential by the research team. You will never be personally identified in any work published as a result of your participation in any taste test without your prior consent. We will protect your personal information and not hand this to any third party. Unless you give us permission to contact you again for any sensory work we carry out at the Department of Nutrition and Food Science, we will not keep your contact information after the end of the research project. If you allow us to contact you again, we will only keep your contact details for the purpose of contacting you for sensory studies only and will not give your contact information to any third party. Your details will be kept in a secure file with the sensory research team.

Compensation

At the end of the study, you will be given a small token to show our appreciation for your time spent on the project. You should understand that there is no economic benefit to you for participating in a sensory study, only the emotional benefit of knowing that you have contributed significantly to the development and improvement in the quality of our local foods. This benefit cannot be overlooked.

Additional Cost

There is no additional cost to you for participating in a sensory study organized by the Department of Nutrition and Food Science.

Voluntary Participation and Right to Leave the Research

Although we would like you to complete the study, you should know that your participation in is purely voluntary and you have the right to withdraw from the study without giving us any explanation and without any penalty to you. Your withdrawal from the study will not negatively affect your personal relationship with the investigator, the department or the university as a whole.

Termination of Participation by the Researcher

It is possible that for some tests you sign up to participate in, some exclusion criteria will exempt you from participating. You will be notified of such studies at the onset. If in the middle of a test the investigator realizes that you are not capable of completing a test the investigator may ask you to discontinue the test. This does not have any negative consequence on your relationship with the investigator, the department or the university. You should understand that such decisions are made purely on the basis of preserving the scientific quality of the data we collect from our volunteering participants and have no personal bias to you.

Notification of Significant New Findings

To preserve the scientific quality of the data we collect in sensory testing, we are unable to disclose too much information about the products we test at the onset of the project. However, if your interest in the product is raised through your participation in the project, we can provide additional information about the product to you at the end of the project. You will have to leave your details with the investigator to share such information about the product with you at the end of the study.

Contacts for Additional Information

For information and questions about this study and general sensory tests and protocols at the Department of Nutrition and Food Science at the University of Ghana, please contact:

Dr Maame Yaakwaah Blay,
Department of Nutrition and Food Science,
University of Ghana
Email: myblay@ug.edu.gh
Tel: 0545525974

Your rights as a Participant

This research has been reviewed and approved by the Ethics Committee for Basic and Applied Science (ECBAS).

If you have any questions about your rights as a research participant you can contact the ECBAS Office through the address below

Administrator, Ethics Committee for Basic and Applied Sciences
College of Basic and Applied Sciences
University of Ghana
P. O. Box LG 68

Legon – Accra

Tel: +233244692728

Email: saddo@staff.ug.edu.gh / saddo@ug.edu.gh

VOLUNTEER AGREEMENT

The above document describing the benefits, risks and procedures for the sensory evaluation of foods has been read and explained to me. I have been given an opportunity to have any questions about the research answered to my satisfaction. I agree to participate as a volunteer.

Date

Name and signature or mark of volunteer

If volunteers cannot read the form themselves, a witness must sign here:

I was present while the benefits, risks and procedures were read to the volunteer. All questions were answered and the volunteer has agreed to take part in the research.

Date

Name and signature of witness

I certify that the nature and purpose, the potential benefits, and possible risks associated with participating in this research have been explained to the above individual.

Date
Consent

Name & Signature of Person Who Obtained

APPENDIX 2

**RECRUITMENT QUESTIONNAIRE FOR CONSUMER ACCEPTANCE TEST OF
SIX BREAKFAST CEREAL.**

Thank you for showing an interest in this project. Kindly read this information sheet carefully before deciding whether or not to participate. If you decide not to be a part, there will be no disadvantage to you of any kind and we thank you for considering our request.

The aim of this project is to select, recruit and screen potential panelists to be a ‘selected assessor’ of a Consumer Acceptance test under the project topic ‘Physicochemical and sensory evaluation of breakfast cereal made from finger millet-maize composite flour’. By participating in this consumer test, you will get the emotional benefit that comes with giving your candid opinion on developing a flour product which will have nutritional and some health benefits to the general populace.

This test will take place at the Sensory Laboratory of the Department of Nutrition and Food Science between 3rd-5th April at 2-5pm each day excluding weekends.

Please tick the appropriate response to all questions asked.

A. DEMOGRAPHIC INFORMATION

1. Age

- a) 18-24
- b) 25-34
- c) 35-44
- d) 45-54
- e) 55+

2. Gender

- a) Male

- b) Female

3. Occupation

- a) Lecturer
- b) Teaching and Research Assistant
- c) Student
- d) Other

B. SCREENING

1. Have you heard about breakfast cereal before?

- a) Yes
- b) No
- c) Maybe

2. Which of these breakfast cereal are you familiar with? Tick all that apply

- a) Cerelac
- b) Yumvita
- c) Tom brown
- d) Cereal flakes
- e) Other (please specify).....

3. Which of these product is your most preferred breakfast cereal? Please select only one.

- a) Cerelac
- b) Yumvita
- c) Tom brown
- d) Cereal flakes
- e) Other (please specify)

5. How often do you consume your most preferred breakfast cereal?

- a) Everyday
- b) At least once a week
- c) Once every two weeks
- d) Once a month
- e) Less than once a month

6. How much do you spend averagely purchasing your most preferred breakfast cereal per a month?

- a. <2.00GHC
- b. 2.00 – 3.00 GHC
- c. 3.50 - 4.50 GHC
- d. 5.00 - 5.50GHC
- e. More than 5.00 GHC

7. Have you heard of any millet flour being used for making breakfast cereal?

- a. Yes (please specify if any).....
- b. No
- c. Maybe
- d. Never

If the answer to question 7 is yes, kindly list the millet flours you have heard about

If the answer is no, please skip to the next question.

8. Which of the category of foods below are you allergic to?

- a) Cereal
- b) Fruits
- c) Dairy products
- d) None

If you ticked d in the above question, please proceed to question 9.

9. Which of these are you allergic to?

- a) Finger millet
- b) Maize
- c) Date fruit
- d) Sugar
- e) None

If you ticked in the above question, please proceed to question 10.

10. How do you like your breakfast cereal in terms of level of sweetness?




- a) Highly sugary
- b) Moderately sugary
- c) Low sugary
- d) No sugar

C. OTHER INFORMATION

The sensory test will take place between the hours of 2-5pm for each session but each panelist will not spend more than 20 minutes on the test.

You will be given a little token for your participation in this exercise.

Kindly confirm your availability on the dates below;

-  Wednesday 3rd April, 2017
-  Thursday 4th April, 2017
-  Friday 5th April, 2017

Please provide us with your names, telephone numbers and email addresses so that I can reach you to remind you when the test date is almost due.

Name

.....

Telephone number

.....

Email address

.....

THANK YOU FOR YOUR PARTICIPATION!!!!!!

APPENDIX 3

WORK SHEET TEMPLATE FOR CONSUMER ACCEPTANCE TEST

DATE: 20th March, 2019

TEST DATE(S): 1st April, 2019

SENSORY PROJECT NAME: Captain Planet

PROJECT TITLE: Physicochemical and Sensory Evaluation of Breakfast Cereal Made from Sprouted Finger Millet-Maize Composite Flour.

TEST METHOD: Consumer Acceptance Test

TEST OBJECTIVE: to assess consumer's overall acceptability of the manufactured product

PANEL DETAILS: Untrained panel (18+)

SAMPLE DETAILS: the samples are made of sprouted finger millet, maize and date fruits.

<i>Sample</i>	<i>Details</i>	<i>Sensory code</i>	<i>Other information</i>
1	Made up of 0% sprouted finger millet, 90% maize and 10% date fruits only (control)	458	Other ingredients added are fats, water and salt
2	Made up of 40% sprouted finger millet, 50% maize and 10% date	852	Other ingredients added are fats, water

	fruits		and salt
3	Made up of 50% sprouted finger millet, 40% maize and 10% date fruits	357	Other ingredients added are fats, water and salt
4	Made up of 60% sprouted finger millet, 30% maize and 10% date fruits	159	Other ingredients added are fats, water and salt
5	Made up of 70% sprouted finger millet, 20% maize and 10% date fruits	789	Other ingredients added are fats, water and salt
6	Made up of 90% sprouted finger millet, 0% maize and 10% date fruits	456	Other ingredients added are fats, water and salt

SAMPLE PREPARATION AND SERVING INSTRUCTIONS:

No sample preparation required

Serve samples warm at temperature ($30 \pm 2^{\circ}\text{C}$)

Serve approximately 40 mL of each sample into 80 mL shito cups

Serve all six samples one at a time.

Ensure environmental controls

TEST PROTOCOL

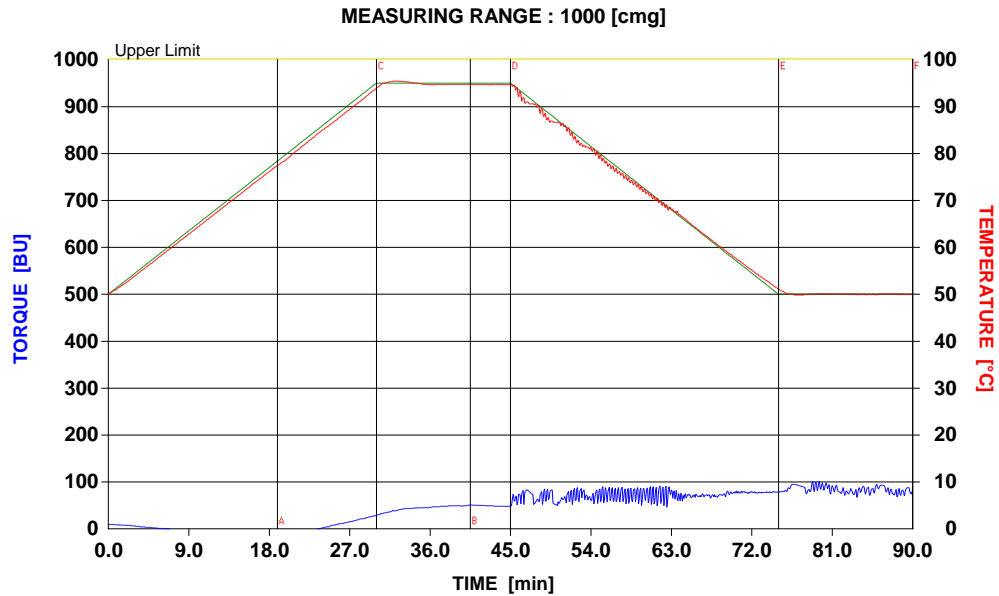
Present panelists with all six samples, one at a time. For all the questions asked, they are to indicate how much they like or dislike each sample by assigning numbers to the modalities according to the 9-point hedonic scale. They are to rinse their mouth with the water provided after tasting each sample.

APPENDIX 4

BRABENDER VISCOGRAPH

Parameter

Operator	: REUBEN	Date	: 12-Mar-19
Sample	: ACHEAMPONG	Method	:
Moisture	: 9.25 [%]	Correction	: 10 [%]
Sample weight	: 40 [g]	Corr. to 10%	: 39.6 [g]
Water	: 400 [ml]	Corr. to 10%	: 400.3 [ml]
Note	:		
Note	:		
Speed	: 75 [1/min]	Meas. range	: 1000 [cmg]
Start temperature	: 50 [°C]	Heat./Cool. rate	: 1.5 [°C/min]
Max. temperature	: 95 [°C]	Upp. hold. time	: 15 [min]
End temperature	: 50 [°C]	Fin. hold. time	: 15 [min]



Evaluation

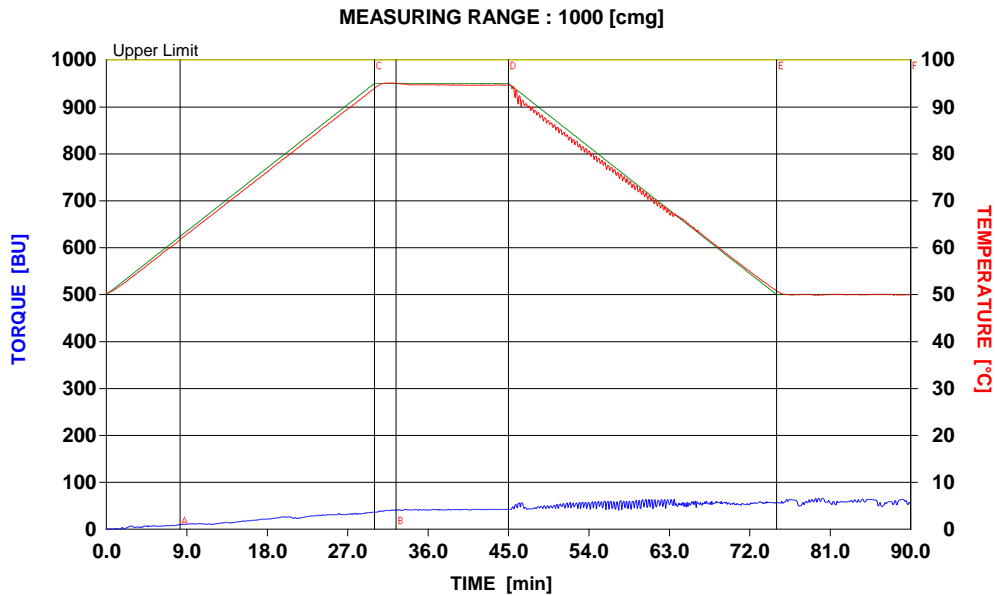
Point	Name	Time [HH:MM:SS]	Torque [BU]	Temperature [°C]
A	Beginning of gelatinization	00:18:55	-11	77.4
B	Maximum viscosity	00:40:30	51	94.7
C	Start of holding period	00:30:00	29	93.9
D	Start of cooling period	00:45:00	47	94.7
E	End of cooling period	01:15:00	78	51.1
F	End of final holding period	01:30:00	82	50.0
B-D	Breakdown		3	
E-D	Setback		30	

File : Measurement V: 2.3.16

BRABENDER VISCOGRAPH

Parameter

Operator	: REUBEN	Date	: 13-Mar-19
Sample	: ACHEAMPONG	Method	:
Moisture	: 3.46 [%]	Correction	: 10 [%]
Sample weight	: 40 [g]	Corr. to 10%	: 37.2 [g]
Water	: 400 [ml]	Corr. to 10%	: 402.7 [ml]
Note	:		
Note	:		
Speed	: 75 [1/min]	Meas. range	: 1000 [cmg]
Start temperature	: 50 [°C]	Heat./Cool. rate	: 1.5 [°C/min]
Max. temperature	: 95 [°C]	Upp. hold. time	: 15 [min]
End temperature	: 50 [°C]	Fin. hold. time	: 15 [min]



Evaluation

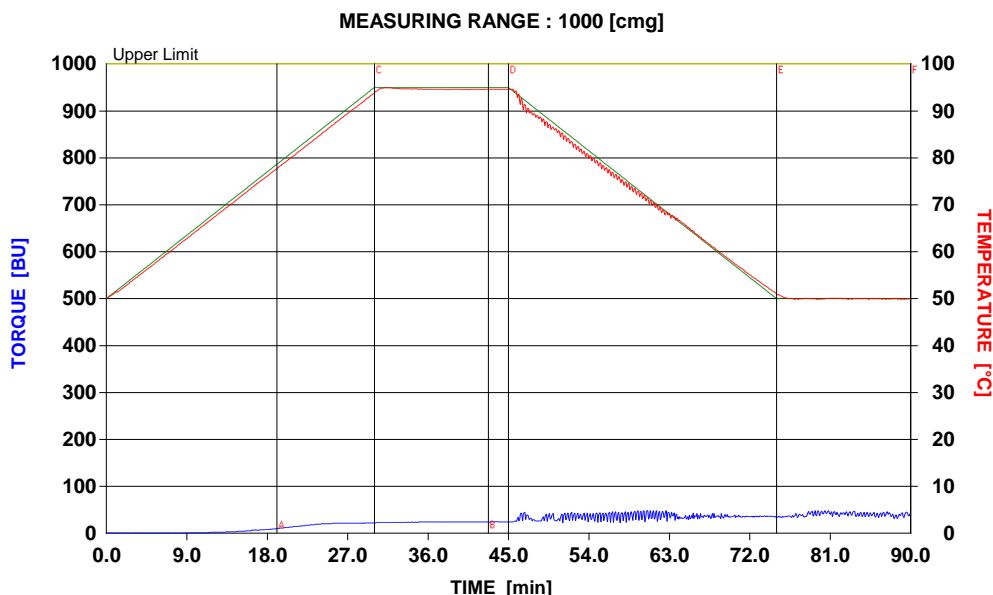
Point	Name	Time [HH:MM:SS]	Torque [BU]	Temperature [°C]
A	Beginning of gelatinization	00:08:15	10	61.7
B	Maximum viscosity	00:32:25	42	95.0
C	Start of holding period	00:30:00	36	93.9
D	Start of cooling period	00:45:00	42	94.6
E	End of cooling period	01:15:00	56	50.8
F	End of final holding period	01:30:00	55	50.0
B-D	Breakdown		0	
E-D	Setback		15	

File : Measurement V: 2.3.16

BRABENDER VISCOGRAPH

Parameter

Operator	: REUBEN	Date	: 13-Mar-19
Sample	: ACHEAMPONG	Method	:
Moisture	: 3.47 [%]	Correction	: 10 [%]
Sample weight	: 40 [g]	Corr. to 10%	: 37.2 [g]
Water	: 400 [ml]	Corr. to 10%	: 402.7 [ml]
Note	:		
Note	:		
Speed	: 75 [1/min]	Meas. range	: 1000 [cmg]
Start temperature	: 50 [°C]	Heat./Cool. rate	: 1.5 [°C/min]
Max. temperature	: 95 [°C]	Upp. hold. time	: 15 [min]
End temperature	: 50 [°C]	Fin. hold. time	: 15 [min]



Evaluation

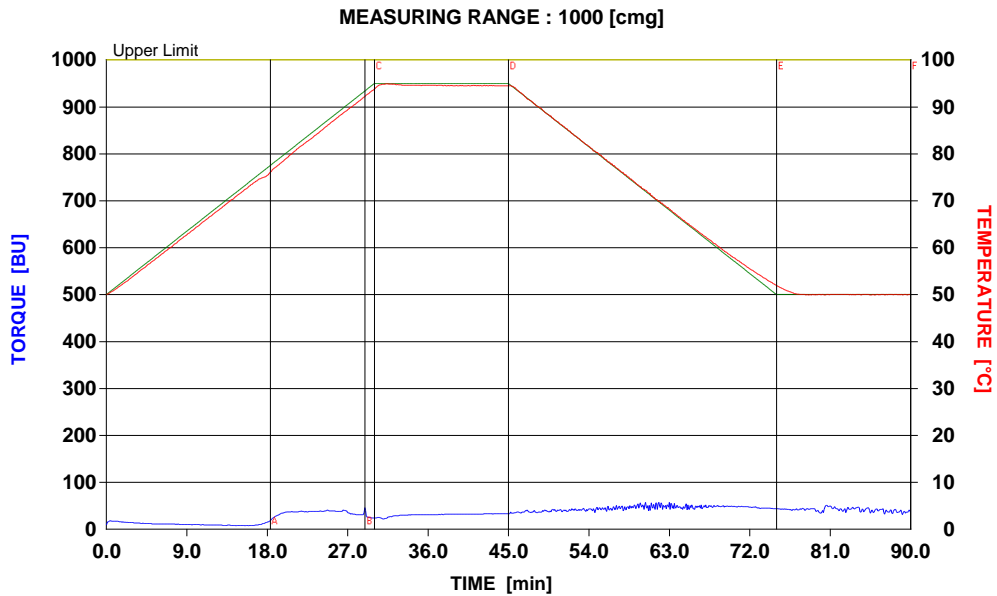
Point	Name	Time [HH:MM:SS]	Torque [BU]	Temperature [°C]
A	Beginning of gelatinization	00:19:05	9	77.7
B	Maximum viscosity	00:42:45	25	94.6
C	Start of holding period	00:30:00	22	93.8
D	Start of cooling period	00:45:00	24	94.6
E	End of cooling period	01:15:00	34	51.0
F	End of final holding period	01:30:00	43	50.0
B-D	Breakdown		1	
E-D	Setback		12	

File : Measurement V: 2.3.16

BRABENDER VISCOGRAPH

Parameter

Operator	: REUBEN	Date	: 12-Mar-19
	: ACHEAMPONG		
Sample	: FM 60	Method	:
Moisture	: 8.00 [%]	Correction	: 10 [%]
Sample weight	: 40 [g]	Corr. to 10%	: 39.1 [g]
Water	: 400 [ml]	Corr. to 10%	: 400.8 [ml]
Note	:		
Note	:		
Speed	: 75 [1/min]	Meas. range	: 1000 [cmg]
Start temperature	: 50 [°C]	Heat./Cool. rate	: 1.5 [°C/min]
Max. temperature	: 95 [°C]	Upp. hold. time	: 15 [min]
End temperature	: 50 [°C]	Fin. hold. time	: 15 [min]



Evaluation

Point	Name	Time [HH:MM:SS]	Torque [BU]	Temperature [°C]
A	Beginning of gelatinization	00:18:20	18	76.1
B	Maximum viscosity	00:28:55	46	92.2
C	Start of holding period	00:30:00	24	93.8
D	Start of cooling period	00:45:00	33	94.5
E	End of cooling period	01:15:00	44	52.0
F	End of final holding period	01:30:00	36	50.0
B-D	Breakdown		13	
E-D	Setback		11	

File : Measurement V: 2.3.16