Development of Process for Foxtail Millet and Barnyard Millet Biscuits

कांगनी और सांवा बिस्किट्स के लिए प्रक्रिया का विकास

Thesis

Master of Technology in Agricultural Engineering

(Processing and Food Engineering)

Yogesh Tak

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Department of Processing and Food Engineering

College of Technology and Engineering

Maharana Pratap University of Agriculture & Technology, Udaipur

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Master of Technology in Agricultural Engineering
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By

Yogesh Tak

2023

COLLEGE OF TECHNOLOGY AND ENGINEERING

MAHARANA PRATAP UNIVERSITY OF AGRICULTURE & TECHNOLOGY, UDAIPUR

CERTIFICATE - I

CERTIFICATE OF ORIGINALITY

The research work embodied in this thesis titled **“Development of Process for Foxtail Millet and Barnyard Millet Biscuits”** submitted for the award of degree of **Master of Technology** to Maharana Pratap University of Agriculture and Technology, Udaipur (Raj.), is original and bonafide record of research work carried out by me under the supervisionof **Dr. S. K. Jain**, Professor and Head, Department of Processing and Food Engineering, College of Technology and Engineering, Udaipur. The contents of thesis, either partially or fully, have not been submitted or will not be submitted toany other Institute or University for the award of any degree or diploma.

The work embodied in the thesis represents my idea in my own words and where others ideas or words have been included. I have adequately cited and referenced the original sources. I also declared that I have adhered to all principle of academic honesty and integrity and have not misrepresented or fabricated or falsified anyidea/data/fact source in my submission. I understand that any violation of the above will cause for disciplinary action by the University and can also evoke penal action from the sources, which have thus not been properly cited or from whom proper permission has not been taken when needed.

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CERTIFICATE - II

Date: /07/2023

This is to certify that this thesis entitled titled **"Development of Process for Foxtail Millet and Barnyard Millet Biscuits"** submitted for the award of degree of **Master of Technology** in the subjectof **Processing and Food Engineering** embodies bonafide research work carried out by **Mr. Yogesh Tak** under my guidance and supervision and that no part of this thesis hasbeen submitted to any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of the thesis was alsoapproved by the advisory committee on 07/07/2023.

The manuscript has been subjected to plagiarism check by softwareURKUND. It is certified that as per check, the similarity index of the content is 8% and is within permissible limit as per the MPUAT guidelines on Checking Plagiarism.

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CERTIFICATE - III

Dated: / /2023

This is to certify that this thesis entitled **"Development of Process for Foxtail Millet and Barnyard Millet Biscuits"** submitted by **Mr. Yogesh Tak** to Maharana Pratap University of Agriculture & Technology, Udaipur, in partial fulfillment of the requirements for the degree of **Master of Technology** in Agricultural Engineering in the subject of **Processing and Food Engineering** was after recommendation by the external examiner and defended by the candidate before the following members of the examination committee. The performance of the candidate in the oral examination on her thesis has been found satisfactory; we therefore, recommend that the thesis be approved.

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CERTIFICATE - IV

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This is to certify that **Mr. Yogesh Tak** student of Master of Technology in Agricultural Engineering in the subject of Processing and Food Engineering, Department of **Processing and Food Engineering** has made all corrections/ modifications in the thesis entitled **"Development of Process for Foxtail Millet and Barnyard Millet Biscuits"** which were suggested by the external examiner and the advisory committee in the oral examination held on 17/10/2023. The final copies of the thesis duly bound and corrected were submitted on __/___/ 2023 are enclosed here with for approval.

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Place: Udaipur

Date: / / 2023 (**Yogesh Tak)**

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LIST OF ABBREVIATIONS

Symbol	Abbreviation
±	plus or minus
°	degrees
%	Per cent
AACC	American Association of Cereal Chemists
AOAC	Association of Official Agricultural Chemists
ANOVA	Analysis of Variance
cm	Centimeter
cm^3	Cubic centimeter
^{o}C	Degree Celsius
DF	Dietary fiber
et al.	et alia (and others)
etc.	et cetera (and so forth)
Fig.	Figure
FMCG	Fast Moving Consumer Goods
FAO	Food and Agriculture Organization
h	Hour
IS	Indian standard
INR	Indian rupees
kg	kilogram
kcal	Kilo calorie
mm	millimeter
mg	milligram
min	Minute
s	seconds
TA	Texture analyzer
TPC	Total phenolic contents
USDA	United States Department of Agriculture

CHAPTER –I

INTRODUCTION

Millets are traditional grains, grown and consumed in the Indian subcontinent from the past more than 5000 years. Millets are small - grained, annual, warm - weather cereals belonging to grass family. They are rainfed, hardy grains which have low requirements of water and fertilitzers when compared to other popular cereals. Millets have played a significant role as a staple meal, especially in Asia and Africa. Millets were easily available and were cheap in price. They are generally highly adaptable and can be grown in practically any circumstance (Shadang and Jaganathan, 2014). In terms of global agriculture production, millet ranks as the sixth cereal crop and one of the most drought-resistant crops. In addition, compared to other major cereals, millet has a shorter growing season, a greater yield during droughts, and greater resilience to diseases and pests (Devi *et al*., 2011).

Millets are underutilised despite having great nutritional value and producing well in challenging environments. According to the size of the grain, millets are divided into two categories: major millets and small grain millets. Sorghum and pearl millet are considered major millets, whereas finger millet, foxtail millet, kodo millet, proso millet, barnyard millet, and little millet are considered small grain millets. Compared to rice and wheat, millets are higher in mineral and vitamin contents, and they have a significant potential to improve health, nutrition, fodder, fibre, livelihood, and the environment (Gowri and Shivakumar, 2020).

The most important cultivated species of millets are proso millet, pearl millet, barnyard millet, foxtail millet, finger millet, brown top millet and kodo millet (Baker, 2003).

Millets might be the first cereal grain employed in household cooking and also one of the earliest foods consumed by humans. They are incredibly nutrient-dense, non-glutinous, and acid-free meals. They are therefore calming and easy to digest. They are regarded as the least sensitive for climate. Millets release glucose at a lower percentage and over a longer duration than paddy rice, particularly polished paddy rice. The millet consumption lowered diabetes risk. Millets are particularly high in minerals like iron, magnesium, phosphorous and potassium (Michaelraj and Shanmugam, 2013).

Foxtail millet belonging to the Poaceae family, is an important source of food for people in Africa and Asia. One of the oldest crops in existence 80% of the world's production of foxtail millet comes from the Yellow River Basin region of China, with 10% of the global production, India is the second-largest producer of foxtail millet. One of the principal food crops in northern China is foxtail millet, which is mostly grown in arid and semiarid regions (Lingyan *et al.,* 2017).

Anciently grown millet crops like foxtail millet require warm temperatures and little water in order to mature quickly during the hot and dry months. Since ancient times in China, foxtail millet has been the most common crop. It grew to prominence 4100 years ago. This millet is heavily consumed for food in India and millet bran is used as animal feed in China. It plays a very significant role in the agriculture of many developing nations because of its sustainability to grow under extreme heat and little rainfall conditions (Vithal and Girish, 2006).

The advanced processing and value adding may be useful to enhance the physio-chemical and health benefits of foxtail millet and prepare more palatable food items. Significant amounts of protein, fibre, minerals, and phytochemicals are present in foxtail millet. Additionally, the millet is said to have antioxidant, low-glycemic index, and hypolipidemic properties. Foxtail millet is still not used as much as other millet as a source of nutrition. The foxtail millet has a good future in boosting dietary quality and food security (Sharma and Niranjan, 2018).

The first domesticated tiny millet is barnyard millet. It is grown in a variety of nations, including India, China, Japan, Malaysia, the East Indies, United States of America and Africa. Orissa, Maharashtra, Madhya Pradesh, Tamil Nadu, Bihar, Punjab, Gujarat, and the hills of Uttarakhand are the key growing regions in India (Kaur *et al*., 2020).

Barnyard millet is one of the potential crop in terms of nutrition. It offers a decent amount of protein, it has good proportions of soluble and insoluble fibre and highly digested. The low and slowly digesting carbohydrate content of barnyard millet makes it a gift from nature for today's sedentary human population. Even though barnyard millet, like any other small millet, is more nutritious than other cereals, its consumption is only moderate. The arduousness of its processing is the main thing preventing its cultivation and consumption with an increase in living standards or urbanisation. However, there is a requirement to revive interest in millets, which should be valued for their nutritional attributes and potential health advantages. (Verma *et al.,* 2015).

India is considered as the third largest producer of biscuits after USA and China. Bakery industry is the rapidly growing in our country. It is the largest industries with annual turnover of about INR 30 Billion. Biscuits represent a fast growing segment of food in India. Biscuits have low moisture, good shelf life, convenient and nutritious food products. The consumers demand has increased for the quality food products with taste, safety, convenience and nutrition. Thus nutrition has emerged as an added dimension in the chain of food product development. Because of competition in the market and increased demand for healthy, natural and functional products, attempts are being made to improve the nutritive value of biscuits and functionality by modifying their nutritive composition. Such effects are very often achieved by increasing the ratio of millets and whole grain in raw materials other than wheat in basic recipes with the attempt to increase biscuits protein and mineral content for quality or increase dietary fibre content and improve prebiotic characteristics of the final product (Gallagher *et al*., 2003).

Justification

People are shifting to fast food items to prepare their daily meals because of growing urbanisation and a competitive lifestyle. Therefore, in order to address the lack of nutrition in modern eating habits, high-quality and healthful foods must be produced. Biscuits consist of flour, fat, sugar and other additives. Most of the ingredients used in biscuit lack important nutrients. The refined flour lacks in dietary fibre and micronutrients which are important health promoting components. The hydrogenated fat comprises of harmful transfat.

There is a growing awareness among the food consumers regarding the constituents that affect health. The number of health conscious consumers is fast increasing. There is ample scope to enhance the nutritional value of cookies both quantitatively and qualitatively using nutritious food ingredients. There are several food ingredients with exceptional nutritional qualities because of their nutraceutical and nutritional components, such as millets, oil seeds, condiments *etc*. Value addition to existing foods with such ingredients is a simple and feasible way of enhancing nutritional values of foods and in turn the health benefits.

Biscuits are a rapidly expanding food category in India because of their low moisture content and long shelf life. Consumers are increasingly demanding convenient and wholesome food items. The demand from consumers for high-quality food products that are savoury, secure, practical, and nourishing has increased. As a result, nutrition has become a new component in the process of creating food products. Due to market competition and growing consumer demand for healthy, natural, and useful products, efforts are being made to adjust the nutritional composition of biscuits to raise their nutritive value and functionality (Tyagi *et al*. 2007).

This research work aims to develop biscuits by mixing foxtail millet and barnyard millet in different proportion. The biscuits may be used in fast with many health benefits. Physical and physio-chemical properties of biscuits were also determined and sensory evaluation was also investigated. The present research work was carried out with following specific objectives:

1. To prepare biscuits using of foxtail millet and barnyard millet

2. To evaluate the quality of developed biscuits

CHAPTER II
REVIEW OF LITERATURE

This chapter include reviews relating to food value, biscuit preparation, and the evaluation of biscuit's quality. The literature related to the current study is presented as follows:

2.1 Nutrient Composition of Millets

2.2 Products from Foxtail Millet

2.3 Products from Barnyard Millet

2.4 Development of Biscuits

2.5 Health Benefits of Millets

2.6 Textural and Engineering Properties of Biscuits

2.1 Nutrient Composition of Millets

The nutritional composition of foxtail millet and barnyard millet and presented in Table 2.1. It provides an overview of their respective contents per 100 grams of dry weight. Barnyard millet has higher carbohydrate and iron content compared to foxtail millet. Barnyard millet has more fibre, iron, and lower fat content. Both millets provide moderate protein and are relatively low in fat. Foxtail millet has 8g of fibre, while barnyard millet has 10.1g per 100g of dry weight. Foxtail millet contains 31mg of calcium and 2.8mg of iron, whereas barnyard millet has 11mg of calcium and 15.2 mg of iron per 100g of dry weight. Foxtail millet has 331 Kcal, and barnyard millet has 307 Kcal per 100g of dry weight.

Table 2.1 Nutritional fact of foxtail millet and barnyard millet per 100g dry weight

Component	Foxtail millet	Barnyard millet
Carbohydrate (g)	60.9	67.9
Protein(g)	12.3	10.2
Fat (g)	4.3	2.2
Fibre (g)	8	10.1
Calcium (mg)	31	11
Iron (mg)	2.8	15.2
Energy (Kcal)	331	307

Source: Nutritive value of Indian foods, NIN, 2007

Kulkarni *et al.,* (1992) reported the proximate composition of the five millets: Italian, kodo, proso, little, and barnyard. The maximum moisture cotent was found in little millet (11.58 g/100 g), followed by proso millet (10.61 g/100 g), kodo millet (10.1 g/100 g), and barnyard millet (9.89 g/100 g). Small millet had the more protein content (9.70%). The fat content of millets varied from 2.64 to 4.91 per cent. The millets with the highest fat content was barnyard, followed by small, kodo, italian, and proso. When compared to other small millets, kodo millet had more crude fibre. Little millet came second with 6.33%, followed by proso millet, barnyard millet, 5.51%, and Italian millet, 4.51%. Millets had ash content in the range of 2.83 to 4.20 %.

Pawar and Pawar (2006) studied on foxtail millet grains. Foxtail millet grains were soaked in distilled water (1:5 w/v) for 12 h at room temperature. The effects of removal of polyphenols and phytates on the in-vitro protein digestibility (IVPD) and availability of iron and zinc were measured after subjecting the grains to 3 different pre-processing techniques dehulling; dehulled and soaked; dehulled, soaked and cooked in distilled water. The results showed that polyphenols and phytates decreased significantly up to 50.92 and 49.89% respectively. The in-vitro protein digestibility (IVPD), however, increased up to 38.71%. The iron and zinc contents decreased up to 18.79% and 18.61% respectively, but the ionisable iron and zinc increased up to 55.45 and 80.18% respectively. This indicated the suitability of simple processing techniques for improvement of availability of nutrients from foxtail millet

Choudhury *et al*., (2011) studied the nutritional value of Assamese native millets. Two regional types of foxtail millet were used to standardise the popping and malting processes for value addition. In popped samples, the crude fat and crude fibre contents of both the yellow and purple kinds of millet were much lower than present in raw millets, although the carbohydrate and energy values were significantly higher. Compared to raw millet in both kinds, malted samples' crude protein and lipid contents were considerably lower, while their carbohydrate contents were higher. Yellow popped sample had the highest starch digestibility (42.4%) whereas yellow malted sample had the lowest starch digestibility (21.8%). Protein digestibility ranged from lowest (2.4%) in yellow malted samples to highest (13.2%) in purple popped samples.

Ugare *et al.,* (2014) evaluated the nutritional profile, glycemic index, and health advantages of eating barnyard millet in type II diabetes. The millet has 398 kcal/100g, 10.5% protein, 3.6% fat, and 68.8% carbohydrate. The amount of dietary fibre in all forms, including soluble (4.2%) and insoluble (8.4%) fractions, was high (12.6%). Both the dehulled (50.0) and the dehulled and heat-treated (41.7) grains had low glycemic indices.

Uma *et al.,* (2014) reported that foxtail millet had a high protein content (12.3 g/100g), high level of dietary fibre (14 g/100g), and good amount of carbohydrate content (60 g/100g). Additionally, it has a lot of phyto-chemicals (3 g/100g) and minerals.

Doddamani and Yenagi (2018) compared the nutrition composition of pre-treated foxtail millet rice and raw foxtail millet grains. Pre-treatments were given to the millet grains in different combination such as roasting, cooking, drying and roasting. Pre-treatment reduced the moisture, protein, fat content of millet grains. More reduction was observed in cooked, dried and roasted grains and minimum reduction was observed in roasted grains. There was no significant difference observed in ash content. Carbohydrate content increased more in cooked, dried and roasted grains (62.14 g/100g) than roasted grains (56.77 g/100g). Roasting increased insoluble dietary fibre (12.95 g/100g) and total dietary fibre (13.60 g/100g) whereas it decreased in cooked, dried and roasted grains (11.05 and 10.70 g/100g). Pre-treatments did not affect the iron, zinc and manganese content of grains whereas it decreased the calcium content and increased the copper content. More reduction in calcium was observed in cooked, dried and roasted grains (28.50 mg/100g) than roasted grains (31.84 mg/100g). It was concluded that pre-treatment reduced the nutrients like protein, mineral composition and phyto chemicals however there was an effective improvement in the dietary fibre composition and resistant starch which delays the gastric emptying and slows down the digestion.

Singh *et al.*, (2022) reported that barnyard millet had protein, carbohydrates, fibre, and also high concentration of minerals, including iron and zinc. Although it has agronomic and nutritional advantages, barnyard millet is still a less used crop. It contains mineral matter (3.8–4.5 g/100g), calcium (11-27.1 mg/100g), phosphorous (280–340 mg/100g), iron (15–19.5 mg/100g), carbohydrates (55–65.5 g/100g), fat (2–

4 g/100g), crude fibre (9.5–14 g/100 g), protein (6–13 g/100g) and starch (51-62%). Starch is the main source of energy. Starch is made up of the two polymeric molecules amylose and amylopectin. Amylose makes up 20.0% of starch. About 65% of the carbohydrate in the grain of barnyard millet is found as dietary fibre and non-starchy polysaccharides.

2.2 Products from Foxtail Millet

Garwadhiremath (2011) prepared muffins made from foxtail millet and assessed their nutritional content. The muffins were standardised for foxtail millet flour, refined wheat flour, sugar, fat, egg, and baking powder by adjusting quantity, and organoleptically assessed for acceptance of suitable proportion by semi-trained panellists. Dehydrated papaya powder was also added in various amounts to the developed muffins. The millet muffins were compared with muffins made from refined wheat flour. The foxtail millet flour could be added to the conventional recipe of muffins at a ratio of 50% and with a 5% reduction in fat, and then further supplemented with 10 g of papaya powder. The moisture content, protein, fat, ash, crude fibre, and carbohydrate contents of muffin of a refined flour were 24.95, 12.87, 24.80, 0.67, 0.11 and 56.12 per cent, respectively. The protein, crude fibre, and mineral contents of foxtail millet muffins were found to be higher than those made with refined wheat flour, increasing by 12.5, 90, and 28% respectively. The copper, zinc, and iron content were also increased by 34.5, 24.5, and 49.9 percent, respectively. The addition of dehydrated papaya powder in the foxtail millet muffin fruther enhanced the copper, zinc, and iron by 30, 5, and 41%, respectively. Breakfast muffins made with refined wheat flour had a total carotene level of 124.60 g/100 g; however, when foxtail millet flour and papaya powder were added, the amount of carotene jumped by 93% to 291.36 g/100 g. The muffin with foxtail millet had a four-day shelf life.

Meghana *et al.*, (2012) used low-transfat butter to make biscuits with foxtail millet. For savoury biscuits, ingredients including cumin seeds, bishop's weed seeds, and ginger were used. Coriander leaves, green chilies, and salt were used to enhance flavour and taste. It was reported that foxtail millet might be replace up to 40% of refined wheat flour to attain acceptable sensory features with increase in fibre and minerals content. The millet savoury biscuits were found to have 3.5 and 1.5 times more fibre and minerals than control biscuits, indicating that they are suitable for diabetics.

It was reported that textural properties did not vary significantly and were acceptable by the sensory evaluation panel.

Sambavi *et al*., (2015) combined of foxtail millet and wheat flour in the ratios of 60:40, 50:50, and 55:45 to create three different varieties of cookies. The sensory assessment revealed that the samples of 55:45, foxtail millet: wheat flour were well and they had moisture content of 4.6%, carbohydrate content of 55.7%, protein content of 13.1%, fibre content of 0.7%, and an ash content of 1.0%.

Murthy *et al*., (2016) developed complementary foods using malted foxtail millet and wheat flours, skim milk powder, sugar, ghee, and whey protein concentrate. Malted wheat and foxtail millet flours were combined in various ratios to make 70 parts, to which 30 parts of skim milk powder and 7 per cent ghee were added. The levels of foxtail millet flour and wheat flour were taken at the following proportions 30:40, 35:35, 20:50 and 10:60, whey protein concentrate at 1, 2 and 3% levels and sugar at 10, 12 and 14% in order to enhance the taste. The study found that foxtail millet and wheat malt mixes could be used to produce complementary foods.

Dhumketi *et al*., (2017) evaluated the suitability of foxtail millet semolina and soy grits for the formulation of instant upma mix. Instant upma mix was prepared using foxtail millet along with soya grits. The mixture made with 75% foxtail millet, 20% wheat semolina and 5% soy grits was well accepted. In formulations Protein ranges from 11.20 to 12.90%, fat ranges from 6.38 to 8.14%, fibre ranges from 1.15 to 7.47%, ash ranges from 2.00 to 3.80%, and the energy ranges from 245.62 to 256.90 Kcal/100 g and between 37.50 and 40.60% of moisture. The L* value decreased as the amount of foxtail millet semolina increased.

Kadam *et al*., (2018) developed foxtail millet based extruded products and evaluated quality. Five treatments containing various ratios of rice, maize flour and foxtail millet flour 50:50:0, 47.50:47.50:5, 45:45:10, 42.5:42.5:15, and 40:40:20 were taken. The moisture content (max. 4.79% and min. 3.62%), ash content (max. 0.55% and min. 1.42%), and crude fibre (max. 2.35% and min. 1.32%) increased with an increase in the foxtail millet proportion, protein and fat content increased gradually with foxtail millet content. The sample with (42.5:42.5:15) millet ratio was found to be the most ideal treatment for the inclusion of foxtail millet-based extruded products.

2.3 Products from Barnyard Millet

Anju *et al.*, (2010) prepared of low glycaemic index biscuits using foxtail millet and barnyard millet. The biscuits were made using 45% millet flour and 55% refined wheat flour. The biscuits developed from both types of millet flour can be successfully stored for 60 days at room temperature in a thermally sealed single polyethylene bag. The lowest GI was 50.8 for the biscuits made with foxtail millet flour, compared to 68 for those made with barnyard millet flour and refined wheat flour.

Agrawal *et al.*, (2013) developed the vermicelli by incorporating refined wheat flour and replaced with barnyard millet flour and defatted soy flour. Blends in the ratio of 90:00:10, 70:20:10, 45:45:10 and 20:70:10 were evaluated for organoleptic score and nutritional quality. Blends of 45:45:10 was superior than those made from control (100 % wheat flour) and the selected vermicelli had (blends 45:45:10) was moisture 8.10 per cent, protein 15.23 per cent, total carbohydrate 68.40 per cent, crude fat 2.58 per cent, crude fibre 3.5 per cent and ash 2.20 per cent.

Salunke *et al.*, (2019) prepared cookies from barnyard millet with different ratios of wheat flour and maida. Cookies made with MWF50 (50 per cent maida and 50 per cent wheat flour), MBF70 (30 per cent maida and 70 per cent barnyard millet flour), and WBF80 (20 per cent wheat and 80 per cent barnyard millet flour). Cookies (MWF50) had moisture content of 4.0 %, protein 11.55%, crude fat 26.30%, crude fibre 1.10%, carbohydrates 71.65%, calcium 35.50 mg/100 g, phosphorous 238 mg/100g and iron 3.80 mg/100g. Chemical composition of the fresh cookies (MBF70) had moisture content 3.10 %, protein 7.64%, crude fat 26.81%, crude fibre 6.95%, carbohydrates 68.02%, calcium 20.90mg/100g, phosphorous 232 mg/100g and iron 4.31mg/100g. Chemical composition of the fresh cookies (WBF80) prepared from 20% wheat flour and 80% barnyard millet flour had moisture content 3.0 %, protein 7.38%, crude fat 27.10%, crude fibre 8.22%, carbohydrates 66.28%, calcium 30.60mg/100g, phosphorous 295 mg/100g and iron 4.98 mg/100g. The overall Sensory score was above 7 and this score was increased with barnyard millet flour.

Goel *et al.*, (2021) made vermicelli from barnyard millet flour (BMF) and rice flour (RF) along with malt flour from whole green gram, carrot powder, fenugreek powder and xanthan gum (XG). The vermicelli produced by combining 64.25% barnyard millet, 22.3% rice flour, and 2.36% XG can completely replace refined wheat flour. The moisture, protein, ash, fat and carbohydrate content in optimized product was found to be 6.40%, 10.07%, 1.44%, 1.72% and 80.31% respectively. Barnyard millet was used to boost the amount of iron (3.81 mg/100g) and beta carotene (10.39 g/100g).

2.4 Development of Biscuits

Awasthi *et al*., (2000) demonstrated the utilisation of dairy by-products to make protein-rich biscuits. Biscuits made from soy flour and chhena whey (50%) and skim milk powder (50%) were blended separately, combined, and compared with biscuits made from wheat flour. The amount of protein (13.12%), ash (1.50%), and crude fibre (0.46%) in biscuits made by using soy flour and skim milk powder were higher than those made with regular flour (5.92, 0.57, and 0.14 g/100g, respectively). Compared to control and biscuits made with skim milk powder, biscuits made with chhena whey and soya flour had higher percentage of calcium, phosphorus, iron, and reducing and non-reducing sugars.

Devi *et al.*, (2000) prepared four different varieties of biscuits: nankatai, melting moments, tricolour, and salt biscuits with green gram dhal. The salt cookies had the highest levels of moisture (5.83%), total minerals (11.20%), and fibre (5.81%). The largest levels of protein (20.28%) and fat (52.27%). The tricolour biscuits had the highest iron content (0.94mg/100g), whereas nankatai had the highest calcium content (66.10mg/100g) and carbohydrate (30.36%). Salt biscuits were highest in vitro protein digestibility (64.71%).

Akubor (2003) developed biscuits from cowpea and plantain flour blends (60:30). The blend flour was incorporated with wheat flour at different levels ranging from 10 to 60 per cent. It was indicated that at all levels of wheat flour substitution thickness and diameter of cookies were not affected. The biscuit thickness ranged from 3.60 to 3.80 cm, weight from 7.10 to 8.20 g and spread ratio from 3.10 to 3.40. The sensory scores for colour, flavour and texture of the blended biscuit (85:25) were comparable with those of 100 per cent wheat flour biscuits. The protein content of the cowpea plantain flour and wheat flour biscuits ranged between 15.20 to 18.96 per cent, the values increased with increased levels of inclusion of cowpea flour in the blends.

Sindhuja *et al.*, (2005) reported that increasing the amount of amaranth flour in cookies (0 to 30%) decreased the spread ratio from 7.82 to 6.50 and raised the thickness from 10.9 to 11.5 mm. The breaking strength increased from 3.39 to 4.94 kg. the addition of lecithin (0.25%) and glycerol monostereate (0.25%) led to higher spread (8.49) and lower breaking strength (3.81 kg) for the cookies.

Mridula and Gupta (2008) developed high fibre biscuits by adding 10% to 50% pearl millet flour to wheat flour and fortifying with 5% defatted soy flour. The biscuits thickness and spread ratio decreased as pearl millet flour increased. Pearl millet flour mixes had high fibre content and weak dough strength. Pearl millet flour biscuits (50%) recorded higher crude fibre (1.08%), fat (24.16%) and ash (1.41%) than the control biscuits (0.36, 22.10 and 1.15% of crude fibre, fat and ash, respectively). However, protein content of Pearl millet biscuits was less (6.53%) than control biscuits (7.11%).

Masur *et al.*, (2009) developed high protein biscuits using bengal gram flour (10 to 25%). The biscuits' thickness (5.83 mm) and diameter (58.80 mm) remained unaltered up to 20% of bengal gram flour, however the spread ratio and spread factor decreased at that level. The sensory quality of biscuits prepared with 16% fat and 13 ml water received the highest scores for flavour, texture, and overall acceptance. In comparison to control biscuits (4.98, 0.41, and 0.14% of protein, fat, and crude fibre, respectively), the biscuits with the highest protein content (20% bengal gram dhal flour incorporation) had higher levels of protein (5.59%), fat (0.85%), and crude fibre (0.50%). The quality of cookies may be improved by using cereal, millet, and pulse flours singly or in combination.

Srivastava *et al.*, (2010) prepared biscuits by incorporating virgin coconut meal (VCM) into refined wheat flour at 5-25 % level. In comparison to the control (product made entirely of refined wheat flour), blended biscuits included more protein and fibre. The hardness and toughness of the dough increased with the addition of VCM, while the stickiness and adhesiveness values reduced. As the concentration of VCM was raised, the values of L^* decreased while a^* and b^* increased. 15% VCM biscuits were the most palatable by sensory analysis. Differential Scanning Calorimeter (DSC) analysis showed, the onset (To) decreased while the end set (Tc) and enthalpy of gelatinization (H) increased with VCM.

Surekha *et al.,* (2013) assessed the nutritional value and acceptance of barnyard cookies. The basic cookies made with 100% barnyard millet flour were acceptable. The mean scores ranged from 3.97 to 4.20, with taste receiving the lowest rating (3.97) and colour receiving the highest rating (4.20). No statistically significant differences were found between the cookies made with the various types of sago flour and barnyard millet.

Patil *et al.*, (2014) developed fasting biscuits by blending varied amounts of sago, peanut, banana, potato, foxtail millet, and barnyard millet. Sugar and flavour and colouring additions were properly combined. Hydrogenated oil was used. The biscuits were made by rolling, dicing, and baking at 150 to 180°C for 20 minutes. With an acceptable consumer index of 8.32, biscuits made from 100g sago, 50g peanuts, 30g cooked potato mash, and 20g barnyard millet showed good sensory and textural qualities.

Kaur *et al.*, (2020) made finger millet biscuits. The cultivar GPHCPB-149 was used for calcium supplementation in biscuits at varied amounts, i.e., 0, 25, 50, and 75%. Increased finger millet incorporation in biscuits boosted the calcium and crude fibre contents. Finger millet flour could be used with wheat flour up to 50% for making biscuits.

Biradar *et al.*, (2021) prepared cookies with 80% little millet flour and 20% wheat flour. The chookies were packed in LDPE and PP and kept at room temperature (30–40˚C) for 90 days. Results showed that the best acceptability up to the 90^{th} day was associated with moisture content of 4.26 per cent, protein content of 8.40 per cent, crude fat content of 29.10 per cent, crude fibre content of 6.46 per cent, carbohydrate content of 67.48 per cent, and iron level of 8.42 mg per 100g. All the physio-chemical characteristics showed that cookies made with 20% wheat and 80% tiny millet flour performed better in LDPE than PP.

2.5 Health Benefits of Millets

Devi *et al.*, (2011) reported the characteristics of the dietary fibre and polyphenols in finger millet. In proso millet flours and brans, it was discovered that hydrocarbons, sterol esters, triacylglycerols, diacylglycerols, and free fatty acids were present in the free lipids. Proso millet is a good source of B vitamins, including folic acid and vitamin B6.

Ugare *et al.*, (2014) reported that barnyard millet as hardest and can growing challenging agro-climatic conditions. A superior grain in terms of nutrition, barnyard millet contains good levels of macro-nutrients and dietary fibre. It is a significant grain with excellent sensory and cooking attributes, in the diet therapy for diabetics. After a

28-day dietary intervention, the dehulled and roasted grains had a beneficial effect on the blood sugar and serum lipid levels of both diabetic and non-diabetic individuals.

Roy (2017) concluded that little millets be nutrient-dense and provide number of health advantages. Little millet helps manage blood sugar levels. It decreased triglyceride levels, higher HDL cholesterol, and lower LDL/VLDL cholesterol levels. When compared with rice, it has a lower glycemic index, which means that blood sugar levels rise gradually after eating. It is good in diabetes management and digestive issues, lowers the chance of heart attack and encourages the growth of body tissue and energy metabolism.

Sharma and Niranjan (2018) reported that foxtail millet as one of the oldest cultivated crops, grown in the arid and semi-arid regions of Asia and Africa, as well as in some other economically developed countries of the world. Various food products can be prepared using processed whole grain flours for example breads, cookies and porridge. Foxtail millet contains significant levels of protein, fiber, mineral and phyto-chemicals. Anti-nutrients such as phytic acid and tannin present in this millet can be reduced to negligible levels by using suitable processing methods. The millet is also reported to possess hypolipidemic, low-glycemic index and antioxidant characteristics. Physicochemical and health-functional properties of foxtail millet and the processing technologies employed to improve these properties and develop more palatable food products.

Ambati *et al.*, (2019) studied to help the people to recognize the importance of food and to introduce the millets as a nutritious food and the various health benefits of millets as a nutritious food source. Millets offer a rich combination of fiber, protein, calcium, iron, and antioxidants, making them a valuable addition to balanced diet. Incorporating millets into the daily food consumption can help combat malnutrition, address metabolic disorders, support child growth and development, promote cardiovascular health, and mitigate the risk of various health problems, their good protein content which helps in child growth and development, with calcium content which helps in the bone development in both children and geriatric people, with good iron content helps in ailing of anaemia and with gluten free characteristics helps the celiac disease patients and helps in gluten insensitivity. Phytosterols and policosanols are cardio-protective compounds present in the waxy layers of the millet. If these millets are ground into flour without de-hulling, then one can have multiple benefits

2.6 Textural and Engineering Properties of Biscuits

Senthil *et al.*, (2002) combined defatted soy flour and wheat flour in the following ratios: 65:20, 60:25, 55:30, and 45:40. The farinograph features of flour blends revealed minor increase in water absorption and decrease in dough stability as the fraction of soy flour increased. The protein level gradually increased from 20.75 to 27.50% in fried savoury snacks. The boost in protein content in the fried sweet snack was from 15.75 to 21.75% when the per cent of soya flour was increased from 20% to 40% in the blend. There was no discernible difference across the samples acceptance. No significant difference was discovered in the sweet snack's colour and appearance, texture, scent, or taste, regardless of the soya flour content. The force needed to compress a piece of fried food by 50% was used to gauge its hardness. The amount of soy flour increased the texture's hardness values.

Tiwari *et al.*, (2003) studied the effect of convective mass transfer coefficient during drying of jaggery in a controlled environment. The jaggery was dried in an even-span greenhouse with a roof using natural and induced convection at atmospheric pressure until there was essentially no mass variation. The floor area was 1.2×0.8 m^2 for a given size of greenhouse, it was discovered that the convective mass transfer coefficient strongly depends on the mass of jaggery, temperatures, and relative humidity.

Tyagi *et al.,* (2007) evaluated nutritional, sensory and textural characteristics of defatted mustard flour fortified biscuits to optimize the mustard flour supplement in the blend for making biscuits. The wheat flour was replaced by defatted mustard flour at 5, 10, 15 and 20% incorporation levels in biscuit preparation. The protein content of mustard flour biscuits increased nearly 2.5 times, coupled with reduction in fat and an increase in fiber content. Sensory evaluation revealed that the sample containing 15% defatted mustard flour scored highest. Textural characteristics of all dough and biscuits up to 15% supplement of defatted mustard flour were similar. The study revealed that incorporation of 15% defatted mustard flour gave desirable results in terms of nutritional, sensory and textural attributes of mustard fortified biscuits.

Darshan (2009) studied the textural characteristics of carrot-fortified soy biscuits and three distinct mixtures of maida, soy flour, and carrot powder were made: 60% maida, 30% soy flour, and 10% carrot powder (A1), 60% maida, 20% soy flour, and 20% carrot powder (A2), and 60% maida, 10% soy flour, and 30% carrot powder (A3). The combination of soy flour and carrot powder significantly influenced the hardness and fracturability of biscuits. The hardness of the biscuit decreased with increase of carrot powder content from 0 to 30 per cent. The biscuits produced with equal parts soy flour and carrot powder showed better crispness.

Agu and Okali (2014) conducted experiment on partial replacement of wheat flour with beniseed and unripe plantain flours mixed in the proportion of 100:0:0, 80:10:10, 70:20:10, 60:30:10, and 50:40:10 % of wheat, beniseed, and unripe plantain, respectively. The physical properties ranged from 6.80 g to 8.30 g for weight, spread ratio 6.93–7.38, and break strength 500–690g. There was no significant difference in taste, crispness, flavour and texture of the biscuits while significant differences existed in colour and overall acceptability. The proximate composition of the biscuits ranged from 1.84 % to 2.55 % for moisture, protein 8.03–9.26 %, fat 30.07–35.81%, ash 2.94–3.68 %, crude fibre 0.47– 0.80 %, carbohydrate 48.74–55.96 %, and energy 526.53–554.21 kcal/100 g. The microbial count of the best biscuits after 20 days of storage was 4.0×10^3 cfu/g for bacteria and mould contained 5.0×10^4 cfu/g.

Rao (2017) developed biscuits with 5%, 10%, and 15% SP and tested there for sorption behaviour, nutritional value, and textural and sensory quality. Moisture sorption isotherm of SP indicated non-hygroscopic nature with an initial moisture content (IMC) of 8.6%, which equilibrated at 64% relative humidity (RH), whereas, biscuits were hygroscopic with an IMC of 0.94-1.26%, which equilibrated between 5-30% RH for control sample (CB), 5%, 10% and 15% RH for SP supplemented biscuits respectively. The hardness and breaking strengths increased with more SP addition, as evidenced by the texture quality. Sensory tests of biscuits revealed that adding 5% more spinach powder made them more palatable.

CHAPTER III

MATERIALS AND METHODS

This chapter gives complete details about the materials used and procedure adopted to achieve the objectives of the investigation. The process development of biscuits made from foxtail millet and barnyard millet, are also included in description of the experimental setup used, an assessment of the biscuits' textural properties and their nutrient analysis.

3.1 Raw Materials

The raw materials used such as foxtail millet and barnyard millet were procured from the local market of Udaipur, Rajasthan (Plate 3.1 and 3.2). All the raw materials were cleaned properly in order to make them free from dirt and foreign material. The other ingredients such as baking powder, baking soda, milk, butter used in the preparation of biscuits were also be procured from the local market.

Plate 3.1 Foxtail millet

Plate 3.2 Barnyard millet

3.2 Preparation of Flour

The foxtail millet and barnyard millet grains were cleaned to remove dust and other foreign materials. The cleaned foxtail millet and barnyard millet grains were milled separately in flour mill in the Department of Processing and Food Engineering, CTAE Udaipur (Plate 3.3). Flour was sieved using a BS 40 mesh sieve (425µm sieve) opening to obtain fine flour and was stored in the air tight container.

Plate 3.3 Flour mill

Plate 3.4 Foxtail millet flour

Plate 3.5 Barnyard millet flour

3.3 Preparation of Biscuits

The biscuits were prepared as per recipe of Sudha *et al*., 2007 (creaming method). All the ingredients were weighed accurately by using digital weighing balance. The foxtail millet flour, barnyard millet flour and powdered sugar were sieved twice separately to remove the foreign particles. The butter was softened, and powdered sugar were added gradually to butter and creamed till light and fluffy for 10 minutes. Finally, flour was mixed gently and kneaded into smooth dough. The dough was sheeted on biscuit frame to thickness of 0.6 cm using wooden rolling pin. The dough-sheet was cut into round shape using a metallic cutter of 4.5 cm diameter. Biscuits were transferred and systematically arranged on a baking tray about 10 mm apart from each other. The tray was placed into a preheated baking oven at 180^{o}C and baked for 16 minutes. After baking the biscuits were immediately transferred on a cooling rack. The cooled biscuits were packed and stored at ambient temperature and evaluated.

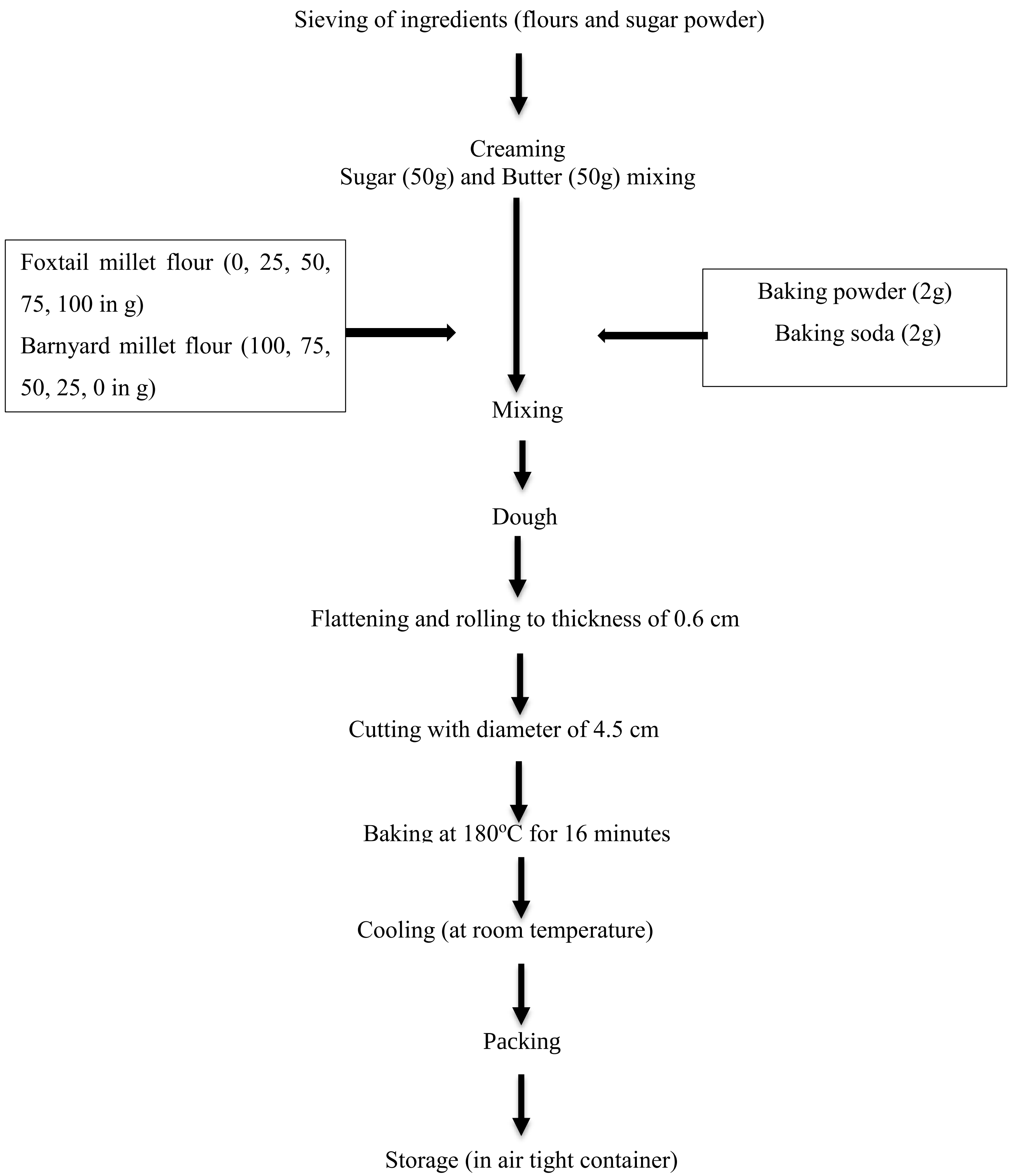


Fig 3.1 Flow chart for foxtail and barnyard millet biscuits preparation

Plate 3. 6 Preparation of biscuits

3.4 Variables:

Variables selected for this study are classified in two major categories such as independent variables and dependent variables.

3.4.1 Independent variables:

Table 3.1 Proportion of foxtail millet and barnyard millet

Sample	Barnyard millet flour (gm)	Foxtail millet flour (gm)
T_1	100	0
T_2	75	25
T_3	50	50
T_4	25	75
T_5	0	100

3.4.2. Dependent variables

3.5. Physical Properties

1. Diameter, mm
2. Thickness, mm
3. Spread ratio
4. Volume, cm^3
5. Density, g/cm^3

3.6 Physio-chemical Analysis

1. Moisture content, (%)
2. Ash, (%)
3. Fibre, (%)
4. Protein, (%)
5. Fat, (%)
6. Carbohydrate, (%)
7. Iron, (mg/100g)
8. Calcium, (mg/100g)
9. Water activity

3.7 Sensory Analysis

1. Color
2. Taste
3. Textur
4. Overall acceptability

3.8 Textural Properties

1. Firmness by Cutting Test (Hardness and work of shear)
2. Firmness by Bending Test (Hardness and fracturability)

3.5. Physical Properties

3.5.1 Diameter

For the determination of the diameter, six biscuits were placed edge to edge. A ruler was used to measure the six biscuits' combined diameter in millimetres. The procedure was thrice, and the average diameter was given in mm (Sindhuri, 2018).

3.5.2 Thickness

To determine the thickness, six biscuits were placed on top of one another. The total height was measured. The measurement was repeated thrice to get an average value, reported in mm.

3.5.3 Spread ratio

Spread ratio was calculated as diameter to thickness ratio (Shrestha and Noomhorm, 2002).

$$\text{Spread ratio} = \frac{\text{Diameter, mm}}{\text{Thickness, mm}}$$

$$\text{Spread factor} = \text{Spread ratio} \times 10$$

3.5.4 Volume

Volume of biscuit was determined by multiplied the area of the biscuit by thickness.

$$\text{Volume} = \frac{d^2 \pi T}{4}$$

T= Average thickness of biscuit, mm

d= Average diameter of biscuit, mm

3.5.5 Density

Density was determined by ratio of weight of volume

$$\text{Density} = \frac{\text{Mass of sample,g}}{\text{Volume of sample,cm}^3}$$

3.6 Physio-chemical Analysis

3.6.1 Moisture content

The moisture content was determined using the hot air oven, which is shown in Plate 3.7. A pre-weighed, dry ceramic crucible containing (5g) of sample was placed in a hot air oven for a period of 4 hours at a temperature of 101-105°C. It was again weighed after cooling in desiccators until the constant weight was obtained. The per cent moisture content was calculated by knowing the difference between initial and final weigh (AOAC, 2005).

$$\text{Moisture content (w}_b\text{, per cent)} = \frac{W_1 - W_2}{W_1} \times 100$$

Where,

MC (w_b) = Moisture content, w_b %

W_1 = Weight of original sample, g

W_2 = Weight of the sample after drying, g

Plate 3.7 Hot air oven

3.6.2 Ash content

The inorganic residue that is left over after burning organic material is known as ash. Total ash was determined using the Muffle Furnace, which is shown in Plate 3.8. A pre-weighed, dry ceramic crucible containing 5g of sample was placed in a muffle furnace for a period of 5 hours at a temperature of 600°C. Then it was quickly cooled in desiccators and weighed and repeated until two consecutive weights were constant. The per cent ash was calculated by knowing the difference between initial and final weigh (AOAC, 2005).

$$\text{Total ash (\%)} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100$$

Plate 3.8 Muffle furnace

3.6.3 Fibre content

One 500 ml beaker was taken, and 200 ml of boiling 0.255 N sulphuric acid (1.25 percent w/v) was added. The weighed sample was transferred into the beaker containing the acid solution. The mixture was boiled for 30 minutes while maintaining the volume constant by adding hot water at frequent intervals. The mixture was stirred with a glass rod to ensure smooth boiling. After 30 minutes of boiling, the mixture was filtered through a muslin cloth to separate the residue. The residue was washed with hot water until it was free from acid. The washed residue was then transferred back to the same beaker. To the beaker, 200 ml of boiling 0.313 N (1.25 percent w/v) NaOH was added. The mixture was boiled for another 30 minutes. After boiling, the mixture was filtered from the beaker into a crucible. The residue in the crucible was dried overnight at a temperature of 80 to 100°C. Once dry, the crucible with the residue was weighed. The crucible with the residue was then placed in a muffle furnace. The residue was ashed at a temperature of 550°C for 3 hours. After ashing, the crucible was removed from the furnace and allowed to cool in a desiccator. The crucible with the ashed residue was weighed. The fibre content in per cent was obtained by using the following formula (AOAC 2005).

$$\text{Crude fibre (\%)} = \frac{(W_2 - W_1) - (W_3 - W_1)}{W} \times 100$$

Where,

W_1= Weight of empty crucible, g

W_2= Weight of crucible with dry residue, g

W_3= Weight of crucible with heated residue, g

W= Weight of sample, g

3.6.4 Protein content

The crude protein content of the samples was estimated according the kjeldahl method (AOAC, 2005) shown in Plate 3.9 procedure and calculated as the product of per cent nitrogen and a multiplication factor.

The temperature of the digestion unit was set to 440^0C and it was turned on. Each sample was weighed into the digestion tubes at a rate of 0.5g. 10 ml of concentrated sulfuric acid was gently placed along the tube's sides after 5g of digestion mixture had been introduced to the tubes. The digestion took place for two hours while the tubes were kept in the digestion unit. After being taken out, the tubes cooled for ten minutes. And while it was still a little warm, 40 ml of distilled water was gently introduced through the sides of the tubes. 25 ml of 4% boric acid and 2 drops of mixed indicator were added to 250 ml conical flask. NaOH (40 ml) was applied to each digestion tube. In the Gerhardt's distillation unit, the digestive tube and conical flask were kept in place, and the distillation process was carried out for three minutes. This was titrated to a permanently pink end point using conventional 0.5N hydrochloride acid. A blank was also fired simultaneously.

The factor 6.25 is the conversion factor of food sample used for calculating crude protein by nitrogen.

$$\text{Nitrogen (\%)} = \frac{(S-B) \times \text{normality of HCl} \times 14.01 \times 100}{W \times 1000}$$

$$\text{Protein\%} = \text{Nitrogen\%} \times 6.25$$

Where,

S= Alkali back titration of sample, ml

B= Alkali back titration of blank, ml

N= Normality of alkali

Plate 3.9 Kjeldahl distillation unit

3.6.5 Fat content

The esters of glycerol are fats and fatty acids. A dry substance is said to contain fat if it has a crude ether extract of actual fats, fatty acids, sterols, chlorophyll, and other pigments like phospholipids and carotenoids. Soxhlet extraction method (Plate 3.10) was used to determine the samples' fat content in accordance with AOAC 2005. Two gram of biscuit sample was weighed accurately and put into a thimble and plugged with cotton.

Then thimble was placed in a Soxhlet apparatus and extracted with anhydrous ether for about 60 min. Once the extraction was complete, the flask was carefully removed from the apparatus. The flask with the residue was transferred into an oven that had been preheated to 100°C. The flask containing the residue was dried for 10-15 minutes. After drying, the flask was removed from the oven, and it was allowed to cool in a desiccator to prevent moisture absorption. Once the flask was cooled, it was weighed accurately using a balance. The fat in percent was obtained by using the following formula

$$\text{Fat (\%)} = \frac{W_4 - W_3}{W_2 - W_1} \times 100$$

W_1= Weight of empty thimble, g

W_2= Weight of thimble + sample, g

W_3= Weight of empty flask, g

W_4= Weight of flask + fat, g

Plate 3.10 Soxhlet apparatus for fat determination

3.6.6 Carbohydrate content

The carbohydrate was estimated by difference as per the procedures outlined by (AOAC, 2005).

Total Carbohydrate = 100 – (%fat + %fibre +% ash + %protein + %moisture)

3.6.7 Iron content

The iron content of the samples was estimated by following the 2, 2 dipyridyl method of AOAC (1998).

3.6.7.1Reagents

1. 2, 2 dipyridyl (Bipyridyl) –100 mg of 2,2 – dipyridyl was dissolved in double distilled water and made upto 100 ml

2. Hydroxylamine hydrochloride – 10g of hydroxylamine hydrochloride was dissolved in double distilled water and diluted to 100ml.

3. Acetate buffer: 8.3g of anhydrous sodium acetate was dissolved in 50 ml of water. To that 12 ml of glacial acetic acid was added and made upto 100 ml.

4. Iron standard solution: 70.2 mg ferrous ammonium sulphate was dissolved in 5 ml of 1:1 HCl solution and made upto 100 ml.

3.6.7.2 Procedure:

Five different test tubes, 0.2 - 1.0 ml (20-100 mg) of standard iron solution and 2.0 ml and 4.0 ml of mineral solution in two separate test tubes was taken. To each test tube, 1.0 ml Hydroxylamine hydrochloride was added and properly mixed, followed by 5.0 ml acetate buffer and 2.0 ml dipyridyl reagent, and the volume was increased to 25 ml by adding the required amount of double distilled water and thoroughly mixing. The sample is kept in flame photometry for direct reading.

3.6.8 Calcium content

The calcium content of the samples was estimated by following the titrimetric procedure of (AOAC, 2005).

3.6.8.1 Reagents / chemicals

1. 0.001N potassium permanganate
2. 0.001N oxalic acid
3. 2N sulphuric acid
4. 0.1% Methyl Red indicator
5. 20% Ammonia solution
6. 10% Acetic acid
7. 6% ammonium oxalate
8. Wang's wash: Mix 7 ml distilled water 32.7 ml ethanol and 2.3 ml ammonia solution were mixed to make Wang's wash solution.

3.6.8.2 Procedure:

A 5ml mineral solution was taken and placed in a 15ml centrifuge tube. Then, 2.0ml of water and a drop of methyl red indicator were added. Drop by drop, ammonium hydroxide was added until the pink color disappeared. After that, acetic acid was added drop by drop until a light pink color appeared. The solution was shaken thoroughly, and then 1.0ml of a 6% ammonium oxalate solution was added. The contents of the tube were mixed well and left undisturbed for one hour. Next, the tube was centrifuged and inverted on a blotting paper for 5 minutes. The resulting precipitate was washed with 4ml of Wang's wash solution and mixed thoroughly. The centrifugation process was repeated. The precipitate was then dissolved in 2ml of 2N sulphuric acid. The solution was heated in a water bath until it reached a temperature of 70-75°C. Subsequently, it was titrated against 0.01N potassium permanganate while still hot, until a light pink colour appeared as the endpoint.

Titre value of 1.0 ml of potassium permanganate = 0.2004 m of calcium

Calcium content (mg/100g) =

$$(\text{Titre value} \times 0.2004) \times \frac{\text{Total volume of mineral solution} \times 100}{\text{Value used for estimation} \times \text{Weight of sample taken}}$$

3.6.9 Water activity

Water activity is a function of moisture content in the food and the temperature (Ratti and Mujumdar, 1996). Bound molecule of water in food can be defined by water activity (Barbosa-Cánovas and Vega-Mercado, 1996):

a. Tightly bound water $a_w < 0.3$
b. Moderately bound water $0.3 < a_w < 0.7$
c. Loosely bound water $a_w > 0.7$
d. Free water $a_w = 1.0$.

The water activity was measured using an Aqua Lab digital water activity meter as shown in Plate 3.1. Biscuits were crushed into small pieces and a representative sample is placed into plastic cups and measured one at a time. Water plays an important role in the stability of fresh, frozen and dried foods. It acts as a solvent for chemical, microbiological and enzymatic reactions. Water activity, a_w, is a measure of the availability of water to paticipate in such reactions. Water in a food will exert a vapour pressure. The extent of this pressure will depend on the amount of water present, temperature and composition of the food. Different food components will lower water vapour pressure to different extents, with salts and sugars being more effective than starches or proteins. Thus, two different foods with similar moisture contents may not necessarily have the same a_w. Water activity can be defined as the ratio of vapour pressure exerted by the food to the saturated vapour pressure of water at the same temperature.

$$a_W = \frac{P_A}{P_{ast}}$$

Whare

a_W = Water activity

P_A = Vapour pressure of water exerted by food

P_{ast} = Saturated vapour pressure of water at the same temperature

Plate 3.11 Water activity meter

3.7 Sensory Evaluation of Biscuits

Sensory analysis provides an understanding of quality of product reformulations. The sensory evaluation of developed biscuits was carried out for many quality criteria such as colour, texture, flavour, appearance, and overall acceptance. The sensory evaluation was carried out by 15 panellists using a numerical sensory card with a 9-point hedonic scale (Amerine *et al*., 2013). All biscuit samples were served to fifteen panellists at a time for evaluation. Panellists were given score sheets and asked to mark the product according to their preferences. The panellists' average scores were computed.

Table 3.2 Score card for sensory evaluation

Quality grade description	Score
Liked extremely	9
Liked very much	8
Liked moderately	7
Liked slightly	6
Neither Liked nor- disliked	5
Disliked slightly	4
Disliked moderately	3
Disliked very much	2
Disliked	1

3.7.1 Colour

One of the most essential aspects in consumer acceptance of products that conveyed feeling to the human eye was colour. Colour was valued by consumers as a form of identity, means of assessing quality, and for its purely aesthetic value. Dried items were often darker in colour, yet this did not always signify superior quality. If a product was too dark, it might have been over-dried. The fact that this property could be visually examined for dryness quality was beneficial.

Hunter Lab Colorimeter was used, and a colour scale representing the relationship of colour index in the present investigation was presented in Plate 3.12 and Plate 3.13. At the light port (3.175 cm dia.), a cylindrical glass sample cup (6.35 cm dia. x 4 cm depth) was installed. The colour values of each sample were evaluated three times. The instrument was initially calibrated using both a black and white plate. The colour values were obtained using the L*, a*, and b* scales. The L* represented the lightness coefficient, ranging from 0 (black) to 100 (white) on a vertical axis. The a* represented purple-red (positive a* value) and blue-green (negative a* value) on a horizontal axis. A second horizontal axis was b*, representing yellow (positive b* value) or blue (negative b* value) colour. This 3D colour system could be seen in Plate 3.13 (Pomeranz and Meloan, 1971).

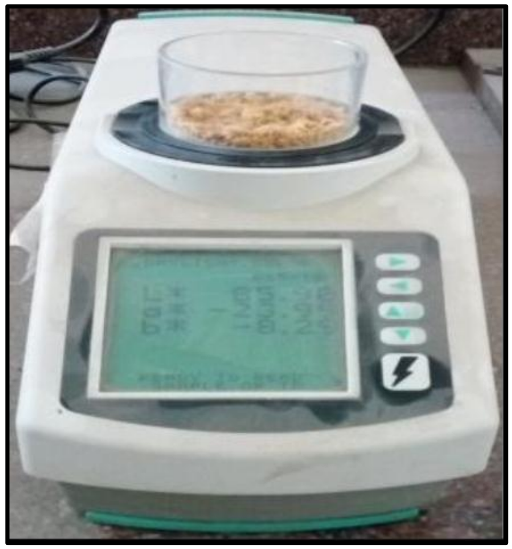


Plate 3.12 Hunter lab colorimeter

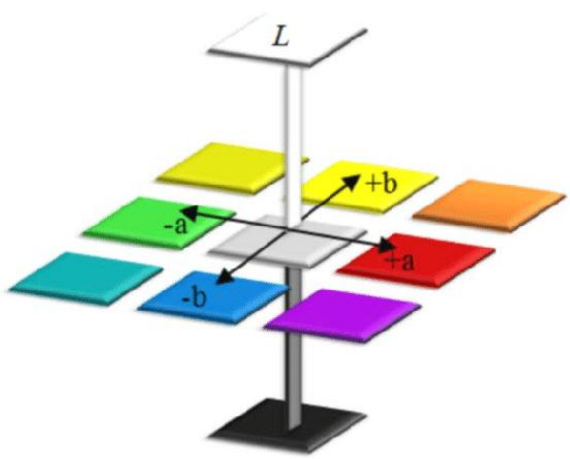


Plate 3.13 Colour scale representing relationship of colour index

3.8 Textural Properties

The arrangement and structure of particles within a substance are referred to as its texture. It is a manifestation of a food's rheological characteristics as well as all other aspects of a food that are sensed by the mouth's kinetic and tactile senses. Processing and handling have a significant impact on shelf life, and customer acceptability of foods, among other things. One of the most difficult aspects of food qualities and parameters influencing meal preference is food texture. Therefore, texture profile analysis was conducted for the developed biscuits.

3.8.1 Texture profile analysis (TPA)

The TA. XT Plus/TA.HD Plus Textural Analyzer, which is used to measure the textural characteristics of biscuits, shown in Plate 3.14, and Appendix D contains a description of its specifications. An array of peripherals, including computer was interfaced to the texture analyzer (TA). The texture analyzer provided three dimensional product analyses by measuring force, distance and time. Forces could be monitored in relation to predetermined distances, and vice versa. The load cell is present inside the probe carriage. Electronic overload protection was built into the TA.HD plus load cell. Mechanical overload affected the TA-XT plus load cell. The analyzer was linked to a computer that recorded the data through software program Stable Micro System Exponents software (Stable Micro Systems).

The results of experiments using various tests that produced a plot of force (kg) vs. time (s) were used to determine the texture of biscuits. Three replications of each combination were taken, and samples were pulled out of their package just before testing. In Table 3.3, various tests, probes, fixtures, and measuring parameters are listed for texture analysis. The samples were physically held against the base plate during testing, and the various experiments were run in accordance with the TA settings listed in Table 3.4. The cutting test, and bending test were conducted by Stable Micro Systems to measure the textural attributes such as hardness, fracturability, and work of shear.

Table 3.3 Different tests and probe/fixtures used in texture analysis of biscuits

Tests	Probe/fixtures	Measuring Parameters
Cutting Test	Blade set with knife	1. Mean first peak force (Hardness) 2. Mean total area (Work of Shear)
Bending Test	Three point bend rig	1. Mean maximum force (Hardness) 2. Mean distance at break (Fracturability)

Plate 3.14 Texture analyzer

Table 3.4 TA Settings used in textural analyzer for performing different tests

TA Settings	Cutting Test	Bending test
Modes	Measure Force in Compression	Measure Force in Compression
Option	Return To Start	Return To Start
Pre- Test Speed	1.5 mm s^{-1}	1.0 mm s^{-1}
Test -speed	2.0 mm s^{-1}	3.0 mm s^{-1}
Post- Test speed	10 mm s^{-1}	10 mm s^{-1}
Trigger Force	Auto - 10g	Auto - 50g
Tare mode	Auto	Auto
Distance	8 mm	8 mm
Data Acquisition Rate	400 pps	400 pps

3.8.2 Determination of firmness of biscuits

Textural properties like firmness, hardness, or softness are all often on the same scale of properties. A product is described as soft if it displays only a minimal amount of resistance to deformation, firm if it shows a moderate amount of resistance to deformation, and hard if it displays a significant amount of resistance to deformation. The most frequently considered factor for selecting biscuit texture is firmness. Depending on the test type used, hardness, fracturability, and work of shear measurements can be used to determine how firm biscuits are (Stable Micro Systems).

The term "firmness" has frequently been used in place of the term "hardness," which is defined as the maximal peak force during the first compression cycle (first bite). Units can be kg, g, or N. Depending on the test, it can either be expressed as initial peak force (kg) or area under the curve (kg m). A characteristic known as brittleness was previously known as fracture-ability. The quickness (i.e., the distance at fracture) with which the meal breaks is a factor that influences fracturability. It can occasionally also be determined by linear distance. Linear Distance function determines the length of a hypothetical line connecting each point in the chosen area.

3.8.3 Cutting test by using blade set

In cutting test, firmness of biscuit was obtained by determining hardness and work of shear. The first peak force provided the hardness (kg), and the work of shear (kg m) was determined by the area under the curve. In this test, extrusion, shearing, and compression forces were all combined. Under predetermined circumstances, a single blade measuring 70 mm in width and 90 mm in length was used to slice or shear through the biscuit sample. As indicated in Plate 3.15, the knife edge was attached to the load cell carrier, lowered into the slotted insert, and the Slotted Insert was fixed to the heavy duty Platform.

A "blank" test run was performed as safety measure after the heavy duty platform was moved to ensure that the blade and slot surfaces were not in contact. After that, the blade was elevated to make room for the sample. Samples were taken out of storage right before testing so they could fit in the middle of the platform beneath the Knife Edge. After then, the sample was allowed to shear by the blade. The dimensions of the samples were held constant for comparison. Fig. 3.2 shows a typical textural profile curve for a single complete run of a biscuit cutting

Plate 3.15 Blade set with knife

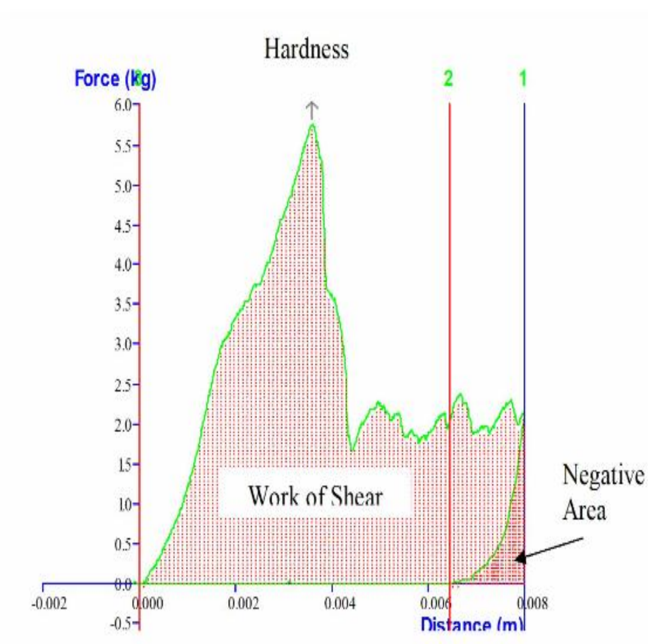


Fig. 3.2 Typical texture profile curve for firmness of biscuits by cutting test

3.8.4 Bending test by using three point bend rig

In bending or snap tests, hardness and fracturability serve as representatives of firmness. Indicators of the product's hardness (kg) and fracturability (mm) are the maximum peak force obtained in the curve and the distances at break. The sample was supported during this test by the two movable supports of the rig base plate that were spaced apart just enough. This gap distance was maintained throughout the comparative process. Once the heavy duty platform is in place, the base plate is fastened. Heavy Duty Platform was secured in place so that the distance between the upper blade and the two lower supports were equal. The sample was positioned in the middle of the supports and bent as indicated in Plate 3.16 using the Three Point Bend Rig, which offers configurable support lengths and widths up to 70 mm and 80 mm, respectively. Fig. 3.3 shows a typical textural profile curve for a biscuit which was obtained from bending test with one full run.

3.8.5 Analysis of data

Texture profile curves were obtained for different composition of biscuits. The textural properties such as hardness, fracturability and work of shear were determined. These data were graphically represented and the results were depicted from the trends obtained.

Plate 3.16 Three point bend rig

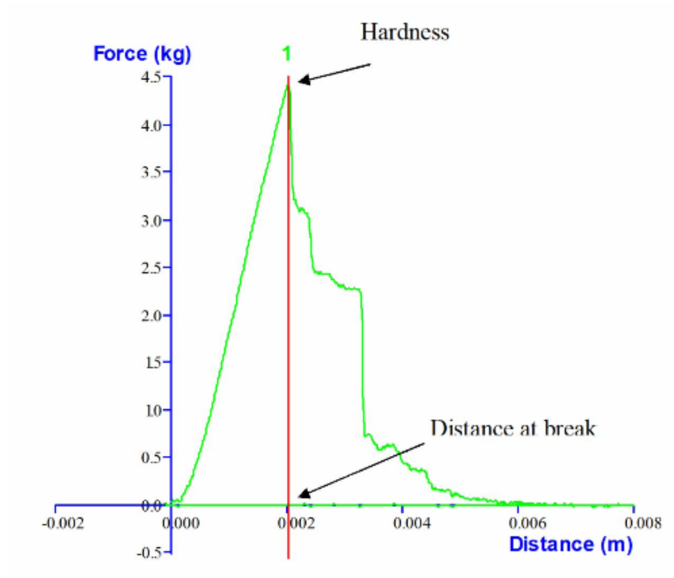


Fig. 3.3 Typical texture profile curve for firmness of biscuits by bending test

CHAPTER IV
RESULTS AND DISCUSSION

The aim of this study was to assess the physical properties, sensory analysis, and textural properties of prepared biscuits. The biscuits were prepared using different proportions of foxtail millet and barnyard millet flours, labelled as T_1 (100% barnyard millet flour), T_2 (75% barnyard millet flour+25% foxtail millet flour), T_3 (50% barnyard millet flour + 50% foxtail millet flour), T_4 (25% barnyard millet flour+75% foxtail millet flour), and T_5 (100% foxtail millet flour). Prepared biscuits were evaluated for textural properties, nutritional and sensory characteristics and results of study are presented in the following sections:

4.1 Physical Properties of Developed Biscuits

Biscuits were prepared using composite mixture of foxtail millet flour and barnyard millet flour. The standard procedure was used for preparation of biscuits as described in Chapter III. The thickness, diameter, mass and other physical properties of biscuits after baking were measured.

The average values of the diameter, thickness, mass, volume and spread ratio of the baked biscuits are presented in Table 4.1. The average diameter and thickness of the unbaked biscuits were 45.00 mm and 6.00 mm, respectively. The diameter of the biscuits after baking were varied from 47.52 mm to 52.64 mm and it increased with increase in proportion of barnyard millet flour. Conversely, the thickness of the biscuits increased after baking and ranged from 6.18 mm to 7.12 mm. Similar results have been reported for physical attributes of flaxseed flour supplemented cookies by Shahzad *et al*., (2006).

The mass of the individual biscuits were 7.14 g, 7.35 g, 7.63 g, 7.90 g, and 8.32 g for compositions T_1, T_2, T_3, T_4, and T_5, respectively, after baking. The spread ratio of the biscuits decreased and varied from 8.52 to 6.65 with increased percentage of foxtail millet in composition. The increase in foxtail millet per cent in composition decreased the diameter of biscuits (52.64 to 47.52 mm). The addition of foxtail millet flour also resulted in decrease in the spread factors of the biscuits. This reduction in spread factor can be attributed to the increased dough viscosity caused by the interaction of free water with hydrophilic sites during dough mixing. Additionally, the density of the individual biscuits were 0.52 g/cm^3, 0.55 g/cm^3, 0.62 g/cm^3, 10.65 g/cm3, and 0.66 g/cm^3 for treatments T_1, T_2, T_3, T_4, and T_5, respectively showing increase in volume with increase in foxtail millet flour content in biscuits.

Table 4.1 Effect of treatments on physical properties of biscuits

Treatment (%)	Diameter (mm)	Thickness (mm)	Spread ratio	Spread factor	Volume (cm^3)	Weight (g)	Density (g/cm^3)
T_1	52.64	6.18	8.52	85.2	13.44	7.14	0.52
T_2	50.31	6.38	7.88	78.8	12.69	7.35	0.55
T_3	49.22	6.65	7.39	73.95	12.65	7.63	0.62
T_4	48.15	6.76	7.12	71.2	12.30	7.90	0.65
T_5	47.52	7.12	6.67	66.7	12.63	8.32	0.66

*Treatment, T_1(100% barnyard millet), T_2 (75% barnyard millet flour+25% foxtail millet flour), T_3 (50% barnyard millet flour + 50% foxtail millet flour), T_4 (25% barnyard millet flour+75% foxtail millet flour), and T_5 (100% foxtail millet flour).

The diameter of developed biscuits were 52.64 mm, 50.31 mm, 49.22 mm, 48.15 mm, and 47.52 mm, respectively for biscuits made from 100% barnyard millet flour (T_1); biscuits made of 75% barnyard millet flour and 25% foxtail millet flour (T_2); 50% barnyard millet flour and 50% foxtail millet flour (T_3); 25% barnyard millet flour and 75% foxtail millet flour (T_4) and 100% foxtail millet flour (T_5) as shown in Fig 4.1. The diameter of the biscuits decreased as the composition of foxtail millet flour increased and varied from 52.64 mm to 47.52 mm. It can be seen from ANOVA (Table 4.2) that the effect of the varying composition of flour is significant at 1% level of significance on diameter of developed biscuits.

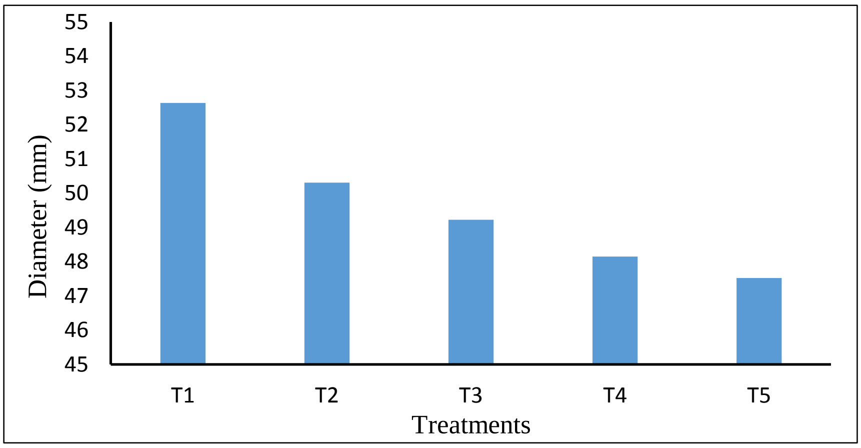


Fig 4.1 Variation in diameter for developed biscuits

Table 4.2 ANOVA showing effect of composition of flour on diameter of developed biscuits

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	48.7911	4	12.198	42552.7	4.2×10^{-21}	5.991
Within Groups	0.0023	10	0.0002			
Total	48.7934	14				

** Significant at 1%, C.V. %= 0.037, SD=1.86

The thickness of developed biscuits were 6.18 mm, 6.38 mm, 6.65 mm, 6.76 mm, and 7.12 mm, respectively for biscuits made from 100% barnyard millet flour (T_1); biscuits made of 75% barnyard millet flour and 25% foxtail millet flour (T_2); 50% barnyard millet flour and 50% foxtail millet flour (T_3); 25% barnyard millet flour and 75% foxtail millet flour (T_4) and 100% foxtail millet flour (T_5) as shown in Fig 4.2. The thickness of the biscuits increased as the composition of foxtail millet flour increased and varied from 6.18 mm to 7.12 mm. The effect of variation in composition of different flour was statistically analysed ANOVA (Table 4.3) shows that composition of flour had significant effect on thickness of developed biscuits at 1 per cent level of significance.

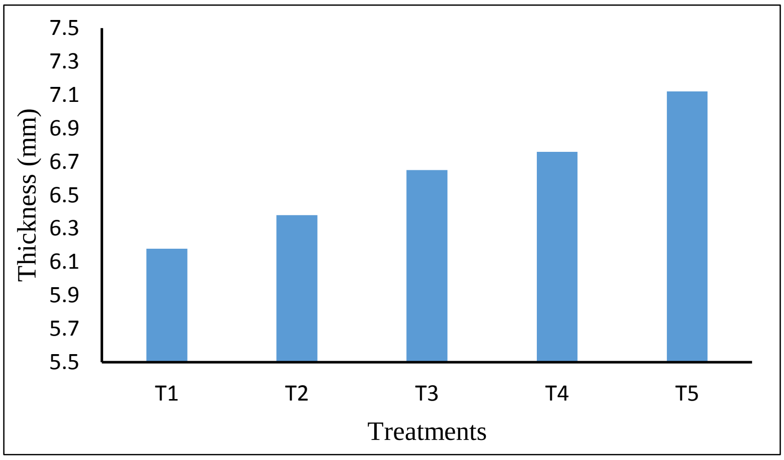


Fig 4.2 Variation in thickness for developed biscuits

Table 4.3 ANOVA showing effect of composition of flour on thickness of developed biscuits

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.6041	4	0.4013	2734.38	3.815×10^{-15}	5.992
Within Groups	0.0014	10	0.0001			
Total	1.6055	14				

** Significant at 1%, C.V. %= 0.037, SD=1.86

The spread ratio of developed biscuits were 8.52, 7.88, 7.39, 7.12 and 6.67, respectively for biscuits made from 100% barnyard millet flour (T_1); biscuits made of 75% barnyard millet flour and 25% foxtail millet flour (T_2); 50% barnyard millet flour and 50% foxtail millet flour (T_3); 25% barnyard millet flour and 75% foxtail millet flour (T_4) and 100% foxtail millet flour (T_5) as shown in Fig 4.3. The spread ratio and spread factor decreased with increase composition of foxtail millet flour and varied from 8.52-6.67 and 85.20-66.7 respectively. The effect of variation in composition of different flour was statistically analysis and developed ANOVA (Table 4.4) shows that composition of flour had significant effect on spread ratio of developed biscuits at 1 per cent level of significance.

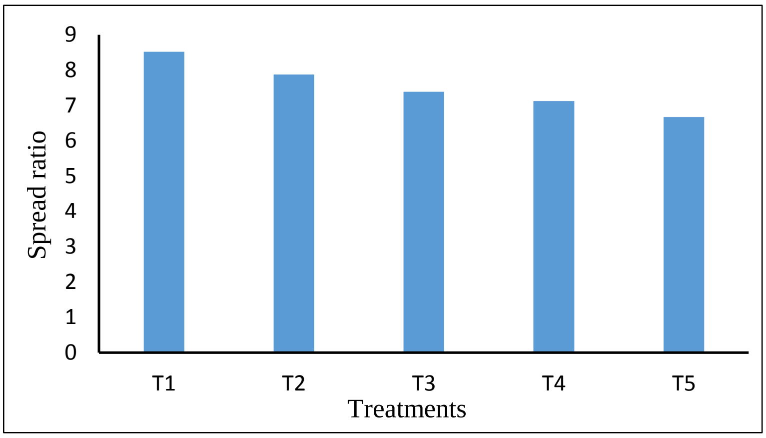


Fig 4.3 Variation in spread ratio for developed biscuits

Table 4.4 ANOVA showing effect of composition of flour on spread ratio of developed biscuits

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4.0553	4	1.0138	5963.765	2.221×10^{-9}	5.1921
Within Groups	0.0005	5	0.0001			
Total	4.0558	9				

** Significant at 1%, C.V. %= 0.055, SD=0.33

The volume of developed biscuits were 13.44 cm^3, 12.69 cm^3, 12.65 cm^3, 12.30 cm^3 and 12.63 cm^3, respectively for biscuits made from 100% barnyard millet flour (T_1); biscuits made of 75% barnyard millet flour and 25% foxtail millet flour (T_2); 50% barnyard millet flour and 50% foxtail millet flour (T_3); 25% barnyard millet flour and 75% foxtail millet flour (T_4) and 100% foxtail millet flour (T_5) as shown in Fig 4.4. The effect of variation in composition of different flour was statistically analysis and ANOVA (Table 4.5) shows that composition of flour had significant effect on volume of developed biscuits at 1 per cent level of significance.

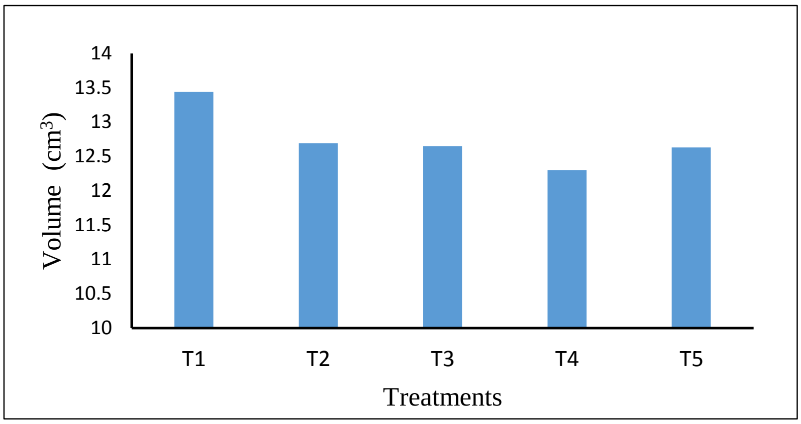


Fig 4.4 Variation in volume for developed biscuits

Table 4.5 ANOVA showing effect of composition of flour on volume of developed biscuits

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.4247	4	0.356185	712.37	4.488×10^{-7}	5.1921
Within Groups	0.0025	5	0.0005			
Total	1.4272	9				

** Significant at 1%, C.V. %= 0.03, SD=0.39

The mass of the individual biscuits were 7.14 g, 7.35 g, 7.63 g, 7.90 g, and 8.32 g for compositions T_1, T_2, T_3, T_4, and T_5, respectively for biscuits made from 100% barnyard millet flour (T_1); biscuits made of 75% barnyard millet flour and 25% foxtail millet flour (T_2); 50% barnyard millet flour and 50% foxtail millet flour (T_3); 25% barnyard millet flour and 75% foxtail millet flour (T_4) and 100% foxtail millet flour (T_5) after baking as shown in Fig 4.5. The effect of variation in composition of different flour was statistically analysis and developed ANOVA (Table 4.6) shows that composition of flour had significant effect on mass of baked biscuits at 1 per cent level of significance.

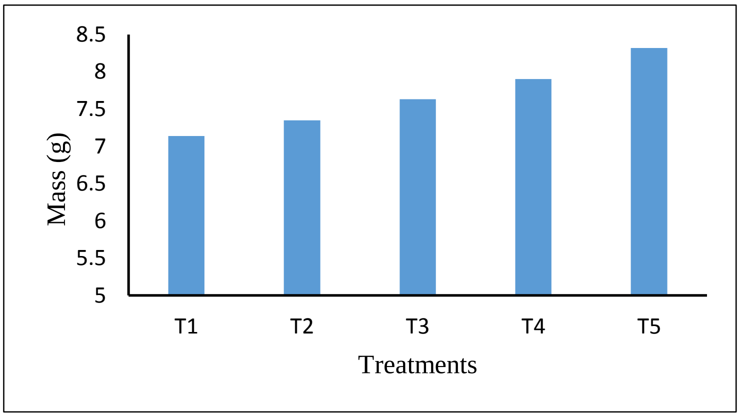


Fig 4.5 Variation in mass for developed biscuits

Table 4.6 ANOVA showing effect of composition of flour on mass of developed *biscuits*

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.7252	4	0.4313	2053.85	3.194×10^{-8}	5.192
Within Groups	0.0010	5	0.0002			
Total	1.7262	9				

** Significant at 1%, C.V. %= 0.55, SD=0.42

The density of developed biscuits were 0.52 g/cm^3, 0.55 g/cm^3, 0.62 g/cm^3, 0.65 g/cm^3 and 0.66 g/cm^3, respectively for biscuits made from 100% barnyard millet flour (T_1); biscuits made of 75% barnyard millet flour and 25% foxtail millet flour (T_2); 50% barnyard millet flour and 50% foxtail millet flour (T_3); 25% barnyard millet flour and 75% foxtail millet flour (T_4) and 100% foxtail millet flour (T_5) as shown in Fig 4.6. The density of biscuit increased as foxtail millet increased and varied from 0.52-0.66 g/ cm$^{3.}$ The effect of variation in composition of different flour was statistically analysis and developed ANOVA (Table 4.7) shows that composition of flour had significant effect on weight of baked biscuits at 1 per cent level of significance

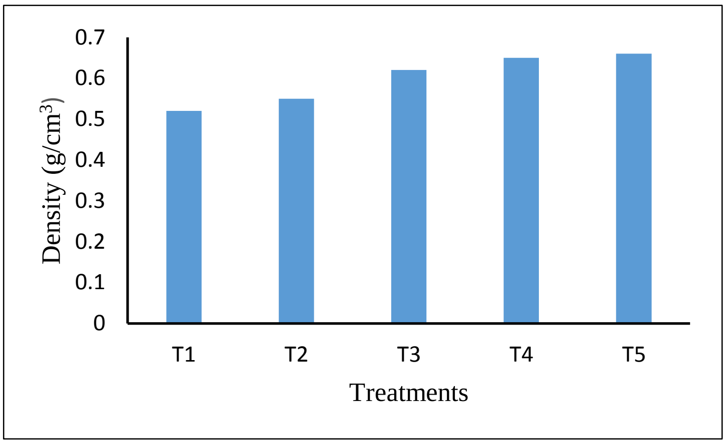


Fig 4.6 Variation in density for developed biscuits

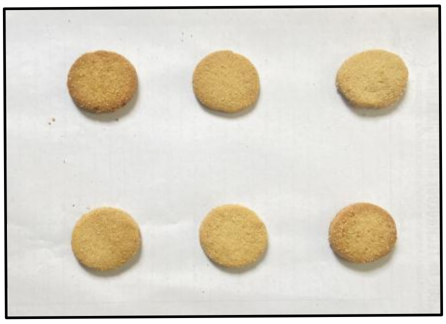
Table 4.7 ANOVA showing effect of composition of flour on density of developed biscuits

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.0388	4	0.0097	54.018	9.788×10^{-7}	3.478
Within Groups	0.0018	10	0.0001			
Total	0.0406	14				

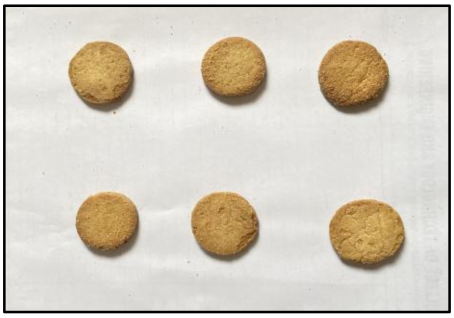
** Significant at 1%, C.V. %= 0.05, SD=0.89

4.2 Prepared Biscuits

The developed biscuits of varying composition of barnyard millet flour and foxtail millet flour are shown in Plate 4.1

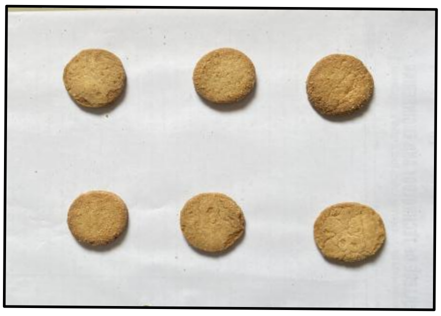


Sample T_1 (100% barnyard millet flour)

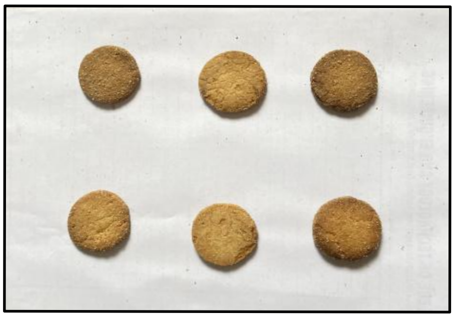


Sample T_2 (75% barnyard millet flour+ 25% foxtail millet flour)

Sample T_3 (50% barnyard millet flour+ 50% foxtail millet flour)



Sample T_4 (25% barnyard millet flour+ 75% foxtail millet flour)



Sample T_5 (100% foxtail millet flour)

Plate 4.1 Samples of prepared biscuits

4.3 Chemical Composition of Developed Biscuits

Biscuits were prepared using composite mixture of foxtail millet flour and barnyard millet flour. The standard procedure was used for chemical analysis of biscuits as described in Chapter III. The carbohydrate content, fat content, protein content, fibre content, calcium content, iron content, moisture content, water activity and ash content were determined for developed biscuit and shown in Table 4.8

Table 4.8 Effect of treatments on chemical composition of developed biscuits

Treatment (%)	Carbohydrate (%)	Fat (%)	Protein (%)	Fibre (%)	Calcium (mg/100)	Iron (mg/100)	Moisture content (%)	Water activity (aw)	Ash (%)
T_1	49.29	26.32	8.81	7.91	18.13	13.53	4.82	0.27	2.83
T_2	48.66	26.93	9.51	7.42	21.64	10.34	5.24	0.25	2.23
T_3	47.41	27.18	10.34	7.17	28.55	8.14	5.62	0.21	2.26
T_4	46.62	27.6	10.58	6.71	32.56	5.36	6.27	0.18	2.09
T_5	45.95	28.12	11.22	6.33	36.28	1.91	6.45	0.17	1.88

*Treatment, T_1(100% barnyard millet), T_2 (75% barnyard millet flour+25% foxtail millet flour), T_3 (50% barnyard millet flour + 50% foxtail millet flour), T_4 (25% barnyard millet flour+75% foxtail millet flour), and T_5 (100% foxtail millet flour).

The carbohydrate content of biscuits developed by various composition of barnyard millet and foxtail millet are shown in Table 4.8. It can be seen that values of carbohydrate content in biscuits varied with variation in composition of both flours in biscuits. The carbohydrate contents of biscuits were 49.49%, 48.66%, 47.41%, 46.62%, and 45.95%, respectively for biscuits made from 100% barnyard millet flour (T_1); biscuits made of 75% barnyard millet flour and 25% foxtail millet flour (T_2); 50% barnyard millet flour and 50% foxtail millet flour (T_3); 25% barnyard millet flour and 75% foxtail millet flour (T_4) and 100% foxtail millet flour (T_5) as shown in Fig. 4.7. The effect of variation in composition of different flour was statistically analysis and developed ANOVA (Table 4.9) shows that composition of flour had significant effect on carbohydrate content of developed biscuits at 1 percent level of significance. Similar results were also reported by Salunke *et al.*, 2019 for nutritional quality of barnyard millet cookies.

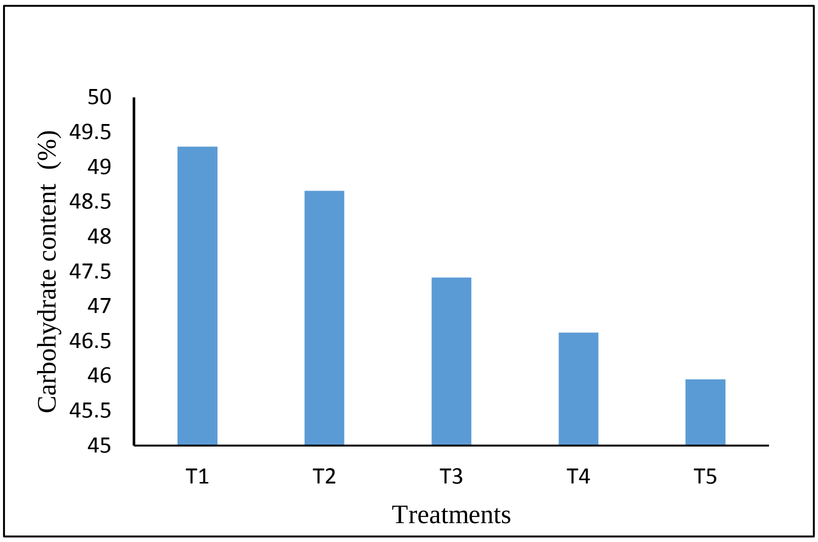


Fig 4.7 Variation in carbohydrate content for developed biscuits

Table 4.9 ANOVA showing effect of composition of flour on carbohydrate content of developed biscuits

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	23.1174	4	5.7793	518.7947	1.52×10^{-11}	3.4780
Within Groups	0.1114	10	0.0111			
Total	23.2288	14				

** Significant at 1%, C.V. %= 0.02, SD=1.28

The fat content of biscuits developed by various composition of barnyard millet and foxtail millet are shown in Table 4.8. It can be seen that values of fat content varied with variation in composition of both flours in biscuits. The fat contents of biscuits were 26.32%, 26.93%, 27.18%, 27.60% and 28.12%, respectively for biscuits made from 100% barnyard millet flour (T_1); biscuits made of 75% barnyard millet flour and 25% foxtail millet flour (T_2); 50% barnyard millet flour and 50% foxtail millet flour (T_3); 25% barnyard millet flour and 75% foxtail millet flour (T_4) and 100% foxtail millet flour (T_5) as shown in Fig. 4.8. The effect of variation in composition of different flour was statistically analysis and developed ANOVA (Table 4.10) shows that composition of flour had significant effect on fat content of developed biscuits at 1 percent level of significance. Similar results were also reported by Mridula and Gupta 2008 for the biscuit developed by pearl millet flour and soy flour.

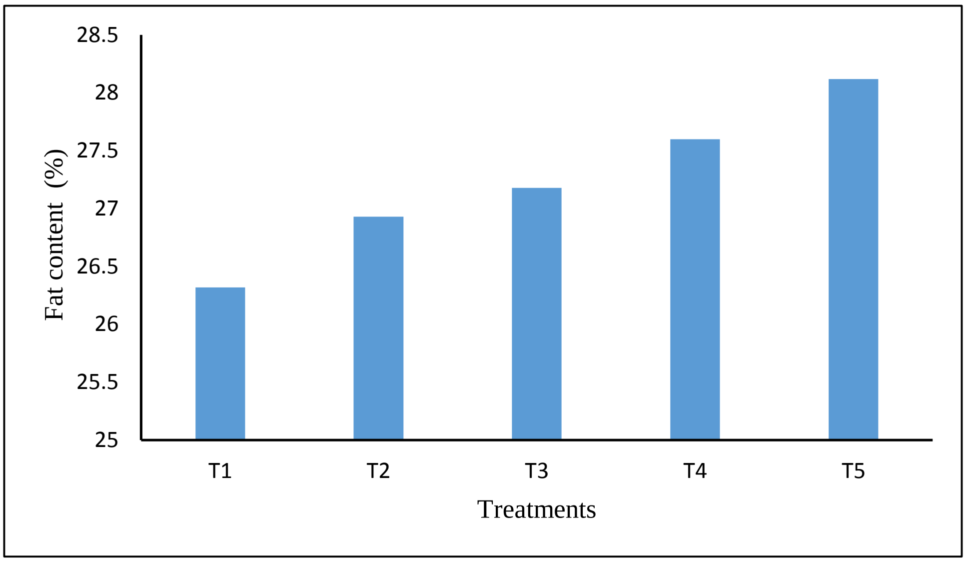


Fig 4.8 Variation in fat content for developed biscuits

Table 4.10 ANOVA showing effect of composition of flour on fat content of developed biscuits

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5.7273	4	1.4318	789.6176	1.87×10^{-12}	3.47805
Within Groups	0.0181	10	0.0018			
Total	5.7454	14				

** Significant at 1%, C.V. %= 0.02, SD=0.64

The protein contents were 8.81%, 9.51%, 10.34%, 10.58% and 11.22%, respectively in biscuits made from 100% barnyard millet flour (T_1); biscuits made of 75% barnyard millet flour and 25% foxtail millet flour (T_2); 50% barnyard millet flour and 50% foxtail millet flour (T_3); 25% barnyard millet flour and 75% foxtail millet flour (T_4) and 100% foxtail millet flour (T_5) as shown in Fig 4.9. T_5 had the highest protein content among all treatments, reaching 11.21%. Foxtail millet had a higher protein content (12.3%) compared to barnyard millet (10.2%). As a result, the protein content of the biscuits increased as the proportion of foxtail millet flour increased in the blends from sample T_1 to T_5. The substitution of barnyard millet flour with foxtail millet flour resulted in an overall increase in protein content in the biscuits. The obtained results were similar to the findings reported by Sambavi *et al*., (2015) for cookies made from foxtail millet flour. The various composition of millets had significant effect on protein content at 1% level of significance as shown in Table 4.11

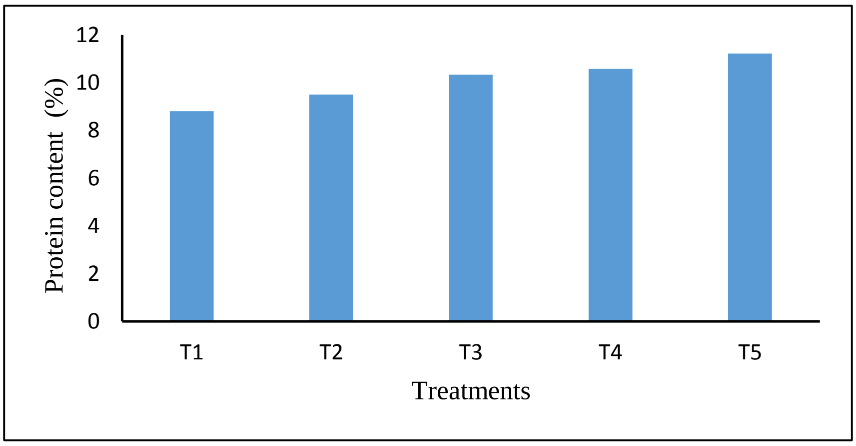


Fig 4.9 Variation in protein content for developed biscuits

Table 4.11 ANOVA showing effect of composition of flour on protein content of developed biscuits

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	10.6421	4	2.6605	2089.437	1.46×10^{-14}	3.4780
Within Groups	0.0127	10	0.0012			
Total	10.6548	14				

** Significant at 1%, C.V. %= 0.08, SD=0.87

The fibre content of biscuits developed by various composition of barnyard millet and foxtail millet are shown in Table 4.8. It can be seen that values of fibre content in biscuits varied with variation in composition of both flours in biscuits. The fibre contents of biscuits were 7.91%, 7.42%, 7.17%, 6.71% and 6.33%, respectively in biscuits made from 100% barnyard millet flour (T_1); biscuits made of 75% barnyard millet flour and 25% foxtail millet flour (T_2); 50% barnyard millet flour and 50% foxtail millet flour (T_3); 25% barnyard millet flour and 75% foxtail millet flour (T_4) and 100% foxtail millet flour (T_5) as shown in Fig. 4.10 The effect of variation in composition of different flour was statistically analysis and developed ANOVA (Table 4.12) shows that composition of flour had significant effect on fibre content of developed biscuits at 1 percent level of significance. Similar results were also reported by Biradar *et al.,* 2021 for cookies made from little millet flour and wheat flour.

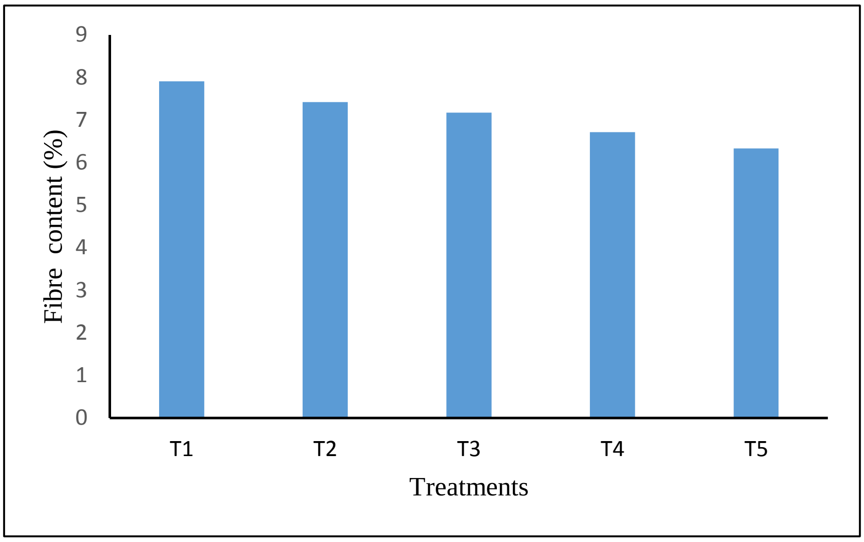


Fig 4.10 Variation in fibre content of developed biscuits

Table 4.12 ANOVA showing effect of composition of flour on fibre content of developed biscuits

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4.5428	4	1.1357	2212.435	1.1×10^{-14}	3.4780
Within Groups	0.0051	10	0.0005			
Total	4.5479	14				

** Significant at 1%, C.V. %= 0.80, SD=0.59

The calcium content of biscuits developed by various composition of barnyard millet and foxtail millet are shown in Table 4.8. It can be seen that values of fibre content in biscuits varied with variation in composition of both flours in biscuits. The calcium contents of biscuits were 18.13 mg/100g, 21.64 mg/100g, 28.55 mg/100g, 32.56 mg/100g, and 36.28 mg/100g, respectively for biscuits made from 100% barnyard millet flour (T_1); biscuits made of 75% barnyard millet flour and 25% foxtail millet flour (T_2); 50% barnyard millet flour and 50% foxtail millet flour (T_3); 25% barnyard millet flour and 75% foxtail millet flour (T_4) and 100% foxtail millet flour (T_5) as shown in Fig. 4.11. The effect of variation in composition of different flour was statistically analysis and developed ANOVA (Table 4.13) shows that composition of flour had significant effect on calcium content of developed biscuits at 1 percent level of significance. Similar type of results were reported by Salunke *et.al.*, (2019) for nutritional quality of barnyard millet cookies.

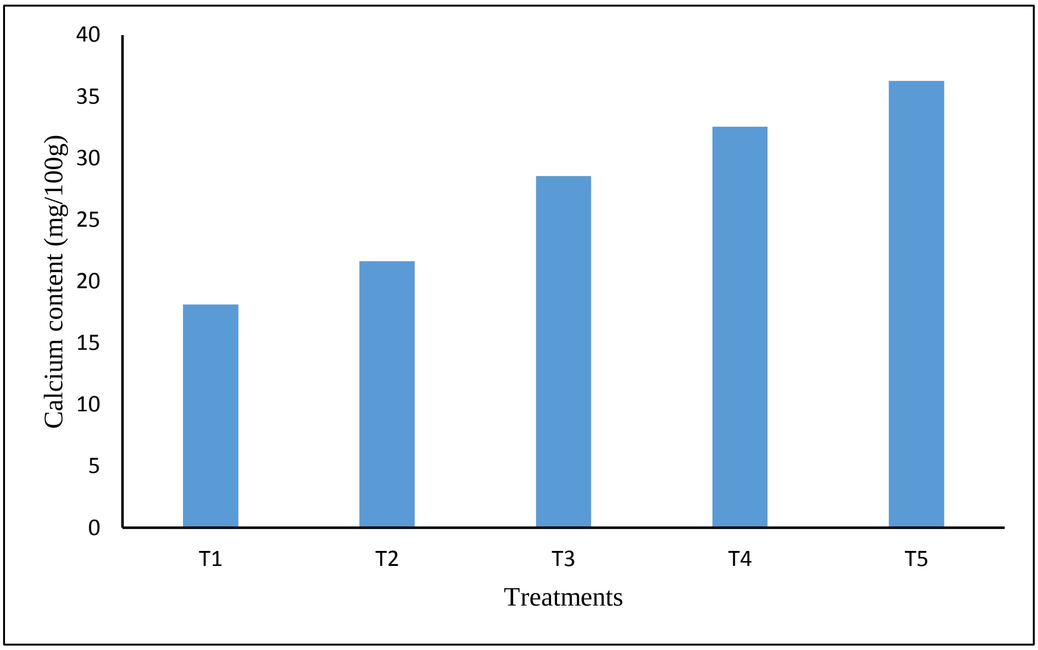


Fig 4.11 Variation in calcium content of developed biscuits

Table 4.13 ANOVA showing effect of composition of flour on calcium content of developed biscuits

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	678.4551	4	169.6138	6655	4.48×10^{-17}	3.4780
Within Groups	0.2548	10	0.025487			
Total	678.7099	14				

** Significant at 1%, C.V. %= 0.25, SD=6.96

The iron content of biscuits developed by various composition of barnyard millet and foxtail millet are shown in Table 4.8. It can be seen iron content in biscuits varied with variation in composition of both flours in biscuits. The iron contents of biscuits were 13.53 mg/100g, 10.34 mg/100g, 18.14 mg/100g, 5.36 mg/100g and 1.91 mg/100g, respectively for biscuits made from 100% barnyard millet flour (T_1); biscuits made of 75% barnyard millet flour and 25% foxtail millet flour (T_2); 50% barnyard millet flour and 50% foxtail millet flour (T_3); 25% barnyard millet flour and 75% foxtail millet flour (T_4) and 100% foxtail millet flour (T_5) as shown in Fig. 4.12 The effect of variation in composition of different flour was statistically analysis and developed ANOVA (Table 4.14) shows that composition of flour had significant effect on iron content of developed biscuits at 1 percent level of significance. Similar type of results were also reported by Thejasri *et al*., (2017) for quinoa and foxtail millet flour.

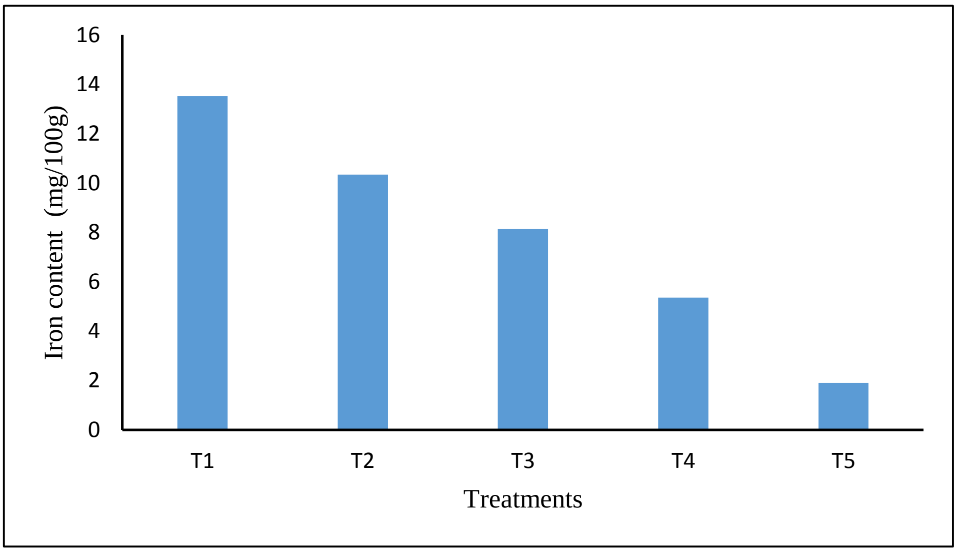


Fig 4.12 Variation in iron content of developed biscuits

Table 4.14 ANOVA showing effect of composition of flour on iron content of developed biscuits

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	239.9963	4	59.99908	145159.1	9.09×10^{-24}	3.47805
Within Groups	0.0041	10	0.000413			
Total	240.0004	14				

** Significant at 1%, C.V. %= 0.52, SD=4.14

The final moisture contents in developed biscuits were determined as described in Section 3.6.1. The moisture contents were 4.82%, 5.24%, 5.62%, 6.27% and 6.45% (db), respectively for biscuits made from 100% barnyard millet flour (T_1); biscuits made of 75% barnyard millet flour and 25% foxtail millet flour (T_2); 50% barnyard millet flour and 50% foxtail millet flour (T_3); 25% barnyard millet flour and 75% foxtail millet flour (T_4) and 100% foxtail millet flour (T_5) shown in Table 4.8 and replication of all treatments are shown in Table A.2 of Appendix A. As the proportion of foxtail millet flour increased in the blends from T_1 to T_5, the final moisture content gradually increased, (4.81% to 6.46%), however biscuits developed by various composition have final moisture content in the permissible limit given by FSSAI. These results were similar to that reported by Selvaraj *et al*., (2002) for storage studies of biscuits prepared by finger millet flour. The standard statistical technique 'Analysis of Variance' (ANOVA) was applied to study the effect of composition on final moisture content of biscuits. It can be seen from ANOVA (Table 4.15) that the varying composition of flour is significant at 1% level of significance on moisture content of baked biscuits.

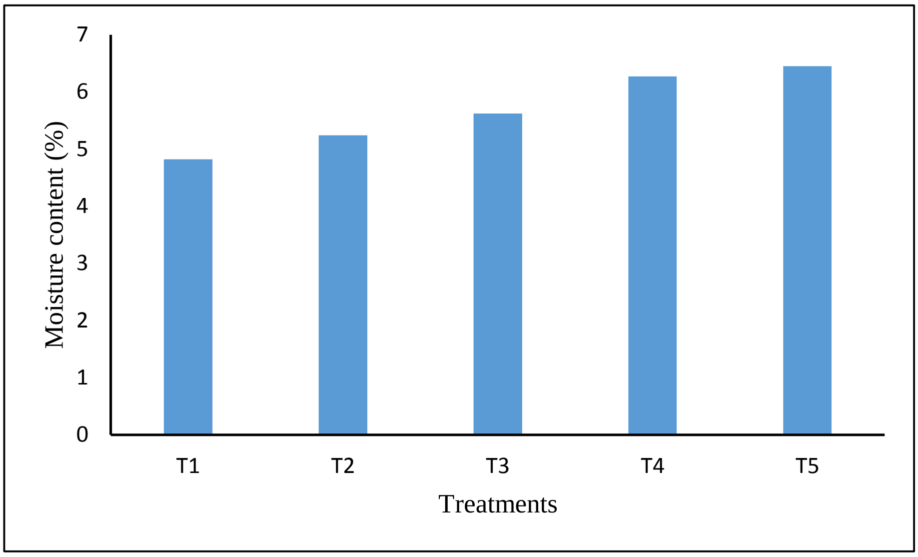


Fig 4.13 Variation in moisture content for developed biscuits

Table 4.15 ANOVA showing effect of composition of flour on moisture content of developed biscuits

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5.6100	4	1.4025	1724.406	3.81×10^{-14}	3.4780
Within Groups	0.0081	10	0.0008			
Total	5.6182	14				

**Significant at 1%, C.V. %= 0.11, SD=0.63

The water activity of biscuits developed by various composition of barnyard millet and foxtail millet are shown in Table 4.8. It can be seen that water activity value of biscuits varied with variation in composition of both flours in biscuits. The water activity of biscuits were 0.27, 0.25, 0.21, 0.18 and 0.17, respectively for biscuits made from 100% barnyard millet flour (T_1); biscuits made of 75% barnyard millet flour and 25% foxtail millet flour (T_2); 50% barnyard millet flour and 50% foxtail millet flour (T_3); 25% barnyard millet flour and 75% foxtail millet flour (T_4) and 100% foxtail millet flour (T_5) as shown in Fig. 4.14 The effect of variation in composition of different flour was statistically analysis and developed ANOVA (Table 4.16) shows that composition of flour had significant effect on water activity of developed biscuits at 1 percent level of significance. Similar type of results were also reported by Thejasri *et al*., (2017) for quinoa and foxtail millet flour. This range ensured that the samples were safe from microbial growth and enzymatic reactions ($a_w < 0.3$), which was consistent with the findings of Cervenka *et. al.,* (2006) regarding the water activity of biscuits.

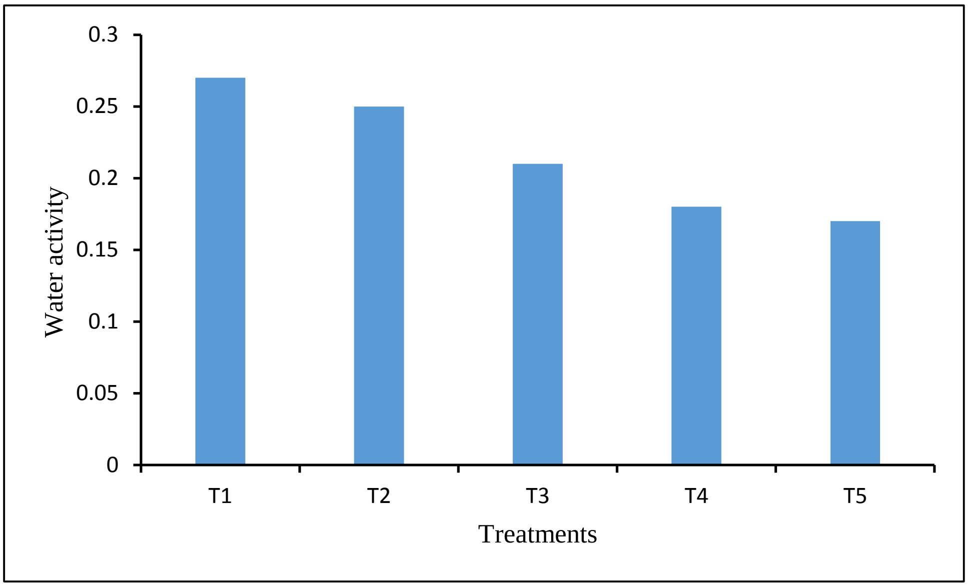


Fig 4.14 Variation in water activity for developed biscuits

Table 4.16 ANOVA showing effect of composition of flour on water activity of developed biscuits

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.0256	4	0.0064	21.8181	6.3×10^{-5}	3.47805
Within Groups	0.0029	10	0.0002			
Total	0.0285	14				

** Significant at 1%, C.V. %= 0.20, SD=0.04

The ash content of biscuits developed by various composition of barnyard millet and foxtail millet are shown in Table 4.8. It can be seen that values of ash contents in biscuits varied with variation in composition of both flours in biscuits. The ash contents of biscuits were 2.83%, 2,23%, 2.26%, 2.09% and 1.88 respectively for biscuits made from 100% barnyard millet flour (T_1); biscuits made of 75% barnyard millet flour and 25% foxtail millet flour (T_2); 50% barnyard millet flour and 50% foxtail millet flour (T_3); 25% barnyard millet flour and 75% foxtail millet flour (T_4) and 100% foxtail millet flour (T_5) as shown in Fig. 4.15. The effect of variation in composition of different flour was statistically analysis and developed ANOVA (Table 4.17) shows that composition of flour had significant effect on ash content of developed biscuits at 1 percent level of significance. Similar results were also reported by Anju and Sarita (2010) for foxtail and barnyard millet biscuits.

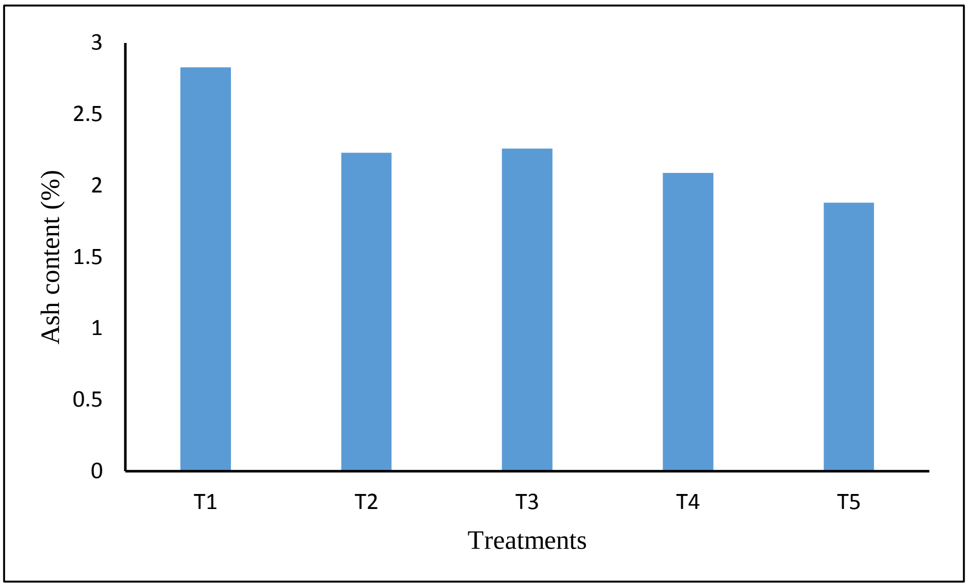


Fig 4.15 Variation in ash content for developed biscuits

Table 4.17 ANOVA showing effect of composition of flour on ash content of developed biscuits

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.4737	4	0.368427	327.0059	1.5×10^{-10}	3.47805
Within Groups	0.0112	10	0.001127			
Total	1.4849	14				

** Significant at 1%, C.V. %= 0.14, SD=0.32

4.4 Sensory Evaluation of Developed Biscuits

The sensory evaluation of developed biscuits was conducted on the basis of colour, texture, taste, appearance and overall acceptability. There were five samples of biscuits of different compositions. The quality was judged by a fifteen member's consumer panel as shown in Plate 4.2. The food products were rated on a nine-point hedonic scale as described in Chapter III. The average values of scores for various sensory parameters judged by panellist is in shown in Table (4.18). It can be seen that all the samples of biscuits developed by various combination of barnyard millet flour and foxtail millet flour scored more than 7.41 showing good acceptability from consumer panel. Further, the T_3 sample of biscuits developed by 50 % barnyard millet flour and 50% foxtail millet flour scored highest value of overall acceptability of 8.07 score. It can be observed that the maximum scores of colour (8.00), texture (8.06), taste (8.20) appearance (8.13), and overall acceptability (8.07) were obtained for the composition of T_3. It was observed that the combination T_3 containing 50% foxtail millet flour and 50% barnyard millet flour was most accepted by the panel. Minimum score of colour, taste and texture were obtained by biscuits prepared from 100% foxtail millet flour. However, these sample also had the values more than 7.41 showing liked moderately. Similar results were also reported by Patil *et. al*., (2014) for biscuits made from potato, foxtail and barnyard millet flour.

Table 4.18 Effect of treatment on sensory analysis of biscuits

Treatment	Average score of sensory analysis				
	Colour	Taste	Texture	Appearance	Overall acceptability
T_1	7.93	7.53	7.87	7.93	7.73
T_2	7.73	7.67	7.73	7.87	7.67
T_3	8.0	8.2	8.06	8.13	8.07
T_4	7.67	7.8	7.67	7.8	7.67
T_5	7.60	7.41	7.62	7.6	7.41

*Treatment, T_1(100% barnyard millet), T_2 (75% barnyard millet flour+25% foxtail millet flour), T_3 (50% barnyard millet flour + 50% foxtail millet flour), T_4 (25% barnyard millet flour+75% foxtail millet flour), and T_5 (100% foxtail millet flour).

Plate 4.2 Sensory analysis

4.4.1 Colour

Fig 4.16 shows the average sensory score for the colour of the biscuits of various proportions. The sensory score for colour were 7.93, 7.73, 8.00, 7.67 and 7.60 respectively for biscuits made from 100% barnyard millet flour (T_1); biscuits made of 75% barnyard millet flour and 25% foxtail millet flour (T_2); 50% barnyard millet flour and 50% foxtail millet flour (T_3); 25% barnyard millet flour and 75% foxtail millet flour (T_4) and 100% foxtail millet flour (T_5). The sample (T_3) 50% barnyard millet flour and 50% foxtail millet flour receive the highest sensory score of 8.00 for colour indicating the favourable combination among all the different biscuits blends. It can be seen from ANOVA in Table 4.19 the effect on colour of developed biscuit was found to be significant at 1 per cent level of significance.

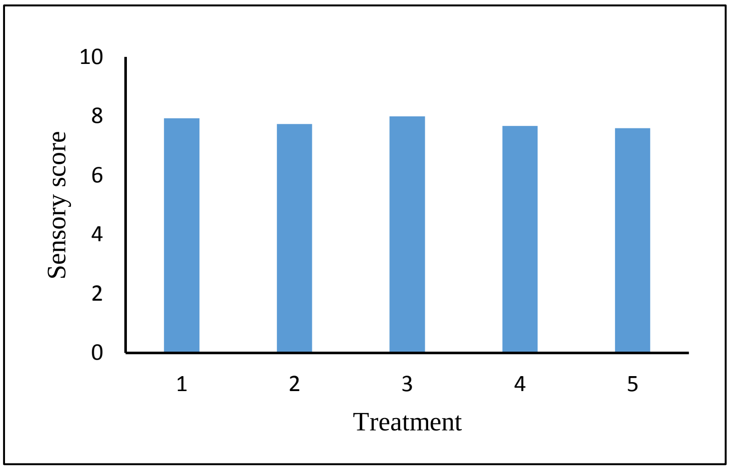


Fig 4.16 Variation in colour for developed biscuits

Table 4.19 ANOVA showing effect of composition of flour on colour of developed biscuits

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.6	4	0.4	0.3977	0.0046	2.5026
Within Groups	70.4	70	1.0057			
Total	72	74				

** Significant at 1%, C.V. %= 0.12, SD=0.98

4.4.2 Taste

The sensory score for taste were 7.53, 7.67, 8.20, 7.80 and 7.41 respectively for biscuits made from 100% barnyard millet flour (T_1); biscuits made of 75% barnyard millet flour and 25% foxtail millet flour (T_2); 50% barnyard millet flour and 50% foxtail millet flour (T_3); 25% barnyard millet flour and 75% foxtail millet flour (T_4) and 100% foxtail millet flour (T_5) as shown in Fig 4.17. The sample (T_3) 50% barnyard millet flour and 50% foxtail millet flour receive the highest sensory score of 8.20 for taste indicating the favourable combination among all the different biscuits blends. It can be seen from ANOVA in Table 4.20 the effect on taste of developed biscuit was found to be significant at 1 per cent level of significance.

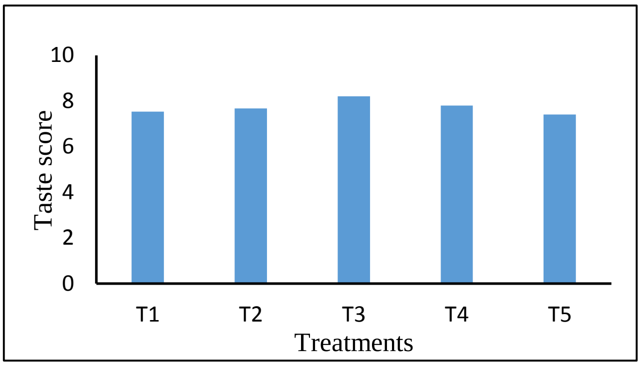


Fig 4.17 Variation in taste for developed biscuits

Table 4.20 ANOVA showing effect of composition of flour on taste of developed biscuits

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5.6533	4	1.4133	1.5588	0.0014	2.5026
Within Groups	63.4666	70	0.9066			
Total	69.1199	74				

** Significant at 1%, C.V. %= 0.12, SD=0.96

4.4.3 Texture

The sensory score for texture were 7.87, 7.73, 8.06, 7.67 and 7.62 respectively for biscuits made from 100% barnyard millet flour (T_1); biscuits made of 75% barnyard millet flour and 25% foxtail millet flour (T_2); 50% barnyard millet flour and 50% foxtail millet flour (T_3); 25% barnyard millet flour and 75% foxtail millet flour (T_4) and 100% foxtail millet flour (T_5) as shown in Fig 4.18. Texture of the biscuits prepared from 50% foxtail millet flour and 50% barnyard millet flour got highest (8.06) score while lowest score (7.62) was obtained for the biscuits prepared from 100% foxtail millet flour with respect to the texture, judges have accepted biscuits prepared from all the treatments of the composite flours. It can be seen from ANOVA in Table 4.21 the effect on texture of developed biscuit was found to be significant at 1 per cent level of significance.

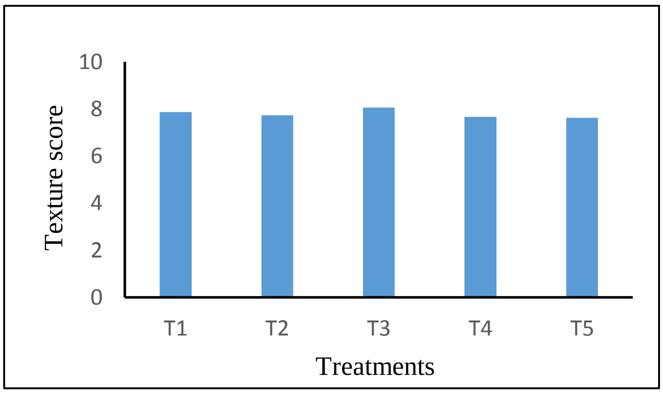


Fig 4.18 Variation in texture for developed biscuits

Table 4.21 ANOVA showing effect of composition of flour on texture of developed biscuits

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4.7466	4	1.1866	1.3143	0.0015	2.5026
Within Groups	63.2	70	0.9028			
Total	67.9466	74				

** Significant at 1%, C.V. %= 0.12, SD=0.95

4.4.4 Appearance

The average sensory scores for the appearance of developed biscuits with different combination were 7.87, 7.73, 8.06, 7.67 and 7.62 respectively for biscuits made from 100% barnyard millet flour (T_1); biscuits made of 75% barnyard millet flour and 25% foxtail millet flour (T_2); 50% barnyard millet flour and 50% foxtail millet flour (T_3); 25% barnyard millet flour and 75% foxtail millet flour (T_4) and 100% foxtail millet flour (T_5) as shown in Fig 4.19 The highest (8.06) value for the appearance score of the biscuits was found for 50% foxtail millet flour and 50% barnyard millet flour. It can be seen from ANOVA in Table 4.22 the effect on appearance of developed biscuit was found to be significant at 1 per cent level of significance.

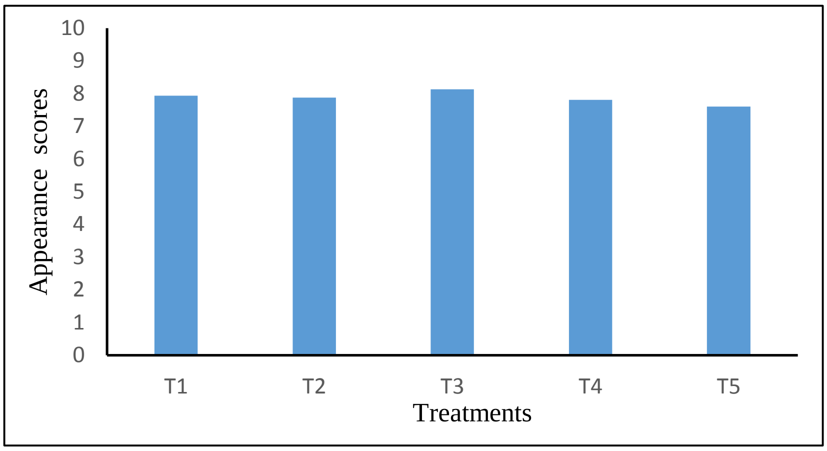


Fig 4.19 Variation in appearance for developed biscuits

Table 4.22 ANOVA showing effect of composition of flour on appearance of developed biscuits

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.2666	4	0.5666	0.9355	0.0035	2.5026
Within Groups	42.4	70	0.6057			
Total	44.6666	74				

** Significant at 1%, C.V. %= 0.098, SD=0.76

4.4.5 Overall acceptability

The sensory score for overall acceptability were 7.73, 7.67, 8.07,7.67 and 7.41 respectively for biscuits made from 100% barnyard millet flour (T_1); biscuits made of 75% barnyard millet flour and 25% foxtail millet flour (T_2); 50% barnyard millet flour and 50% foxtail millet flour (T_3); 25% barnyard millet flour and 75% foxtail millet flour (T_4) and 100% foxtail millet flour (T_5) as shown in Fig 4.20. The overall acceptability scale was given based on colour, taste and texture. The maximum Overall acceptability score (8.07) was obtained by biscuits prepared from 50% foxtail millet flour and 50% barnyard millet flour, while minimum scores (7.54) were scored by the biscuits prepared from 100% foxtail millet. The standard statistical analysis was conducted by ANOVA to see the effect of composition of flours at 1 % level of significance on overall acceptability as shown in Table 4.23.

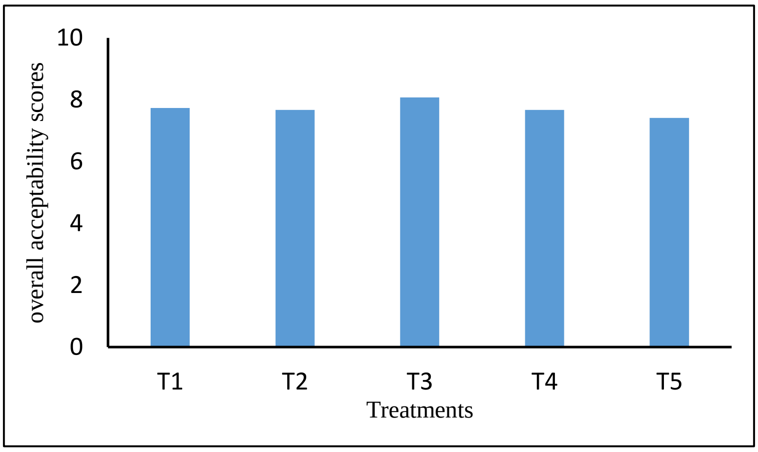


Fig 4.20 Variation in overall acceptability for developed biscuits

Table 4.23 ANOVA showing effect of composition of flour on overall acceptability of developed biscuits

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.4133	4	0.8533	1.4883	0.0045	2.5026
Within Groups	40.1331	70	0.5733			
Total	43.5464	74				

** Significant at 1%, C.V. %= 0.09, SD=0.76

4.5 Colour

Colour is often used as an indication of quality and freshness for food products. Hence, it has become important for food processors to be able to evaluate and grade their products based on colour. Colour values were measured using Hunter lab colorimeter, which were relative to the absolute values of perfect diffuser as measured under the same geometric conditions. The specifications of Hunter lab Colorimeter are shown in Table C.1 of Appendix C.

4.5.1 Colour L*, a* and b* values

Colour measurements of biscuits prepared by different amount of foxtail millet and barnyard millet were carried out by Hunter Lab colorimeter. The instrument described the colour in three value namely "L^*", "a^*" and "b^*". Colour value "L^*" indicates lightness/darkness (100-0), it distinguishes light colour from dark or white from black. Colour value "a^*" indicate the redness with positive value and greenness with negative value and colour value "b^*" described the shade of yellow varying to blue colour (from positive value to negative value). The biscuit colour is an important factor for initial acceptability of food products by consumers.

Table 4.24 Effect of treatment on colour analysis of biscuits

Samples	L^*	a^*	b^*
T_1	64.92	9.22	22.14
T_2	60.19	7.74	20.53
T_3	58.31	8.67	19.11
T_4	55.81	3.97	16.85
T_5	52.12	3.47	14.54

*Treatment, T_1(100% barnyard millet), T_2 (75% barnyard millet flour+25% foxtail millet flour), T_3 (50% barnyard millet flour + 50% foxtail millet flour), T_4 (25% barnyard millet flour+75% foxtail millet flour), and T_5 (100% foxtail millet flour).

4.5.2 Colour value L*

Colour value L* were found as 64.92, 60.19, 58.31, 55.81 and 52.12 for samples respectively for biscuits made from 100% barnyard millet flour (T_1); biscuits made of 75% barnyard millet flour and 25% foxtail millet flour (T_2); 50% barnyard millet flour and 50% foxtail millet flour (T_3); 25% barnyard millet flour and 75% foxtail millet flour (T_4) and 100% foxtail millet flour (T_5). Fig 4.21 shows L^* values of biscuits and it can be seen that colour L^*value decreased as the amount of foxtail millet flour increased in biscuits. Colour L^* value was found to have decreased by increasing the levels of foxtail millet flour. Colour "L^*" value indicates lightness (maximum value is 100) and it decreased because of colour of foxtail millet flour. The colour L^* values decreased from 64.90 to 52.12 as the amount of foxtail millet flour increased in the biscuit samples. It can be seen in ANOVA (Table 4.25) that composition of flour has significant effect on colour values "L^*" at 1 per cent level of significance.

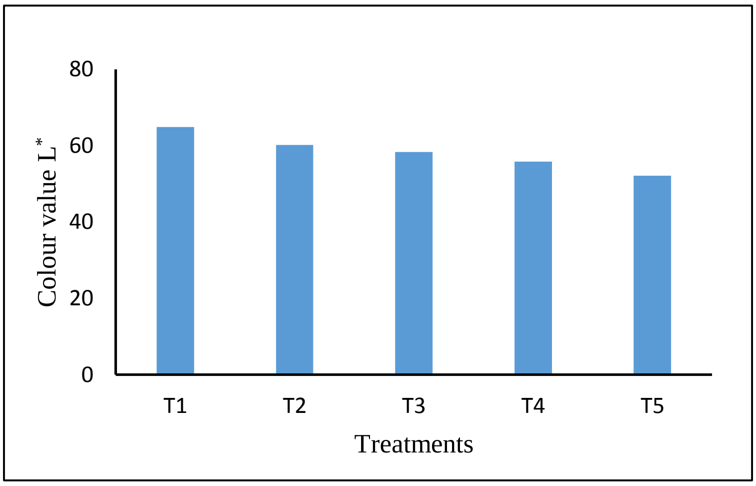


Fig 4.21 Variation in colour value $L^*$for developed biscuits

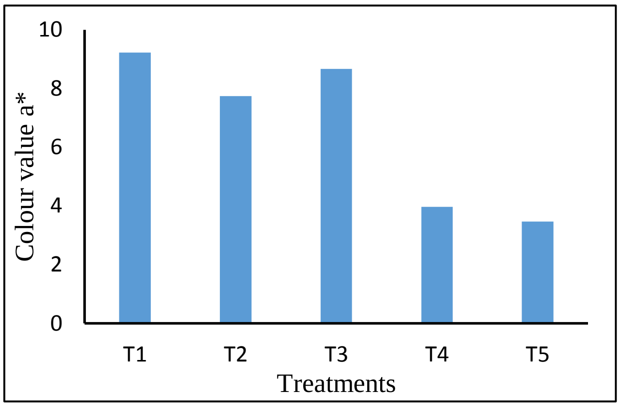
Table 4.25 ANOVA showing effect of composition of flour on colour L* value of developed biscuits

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	275.5637	4	68.89093	100326.6	5.76E-23	3.4780
Within Groups	0.0068	10	0.000687			
Total	275.5705	14				

** Significant at 1%, C.V. %= 0.076, SD=4.4

4.5.3 Colour value a*

The colour values "a^*" were found as 9.21, 7.76, 8.68, 3.97. and 3.47 for biscuit samples respectively for biscuits made from 100% barnyard millet flour (T_1); biscuits made of 75% barnyard millet flour and 25% foxtail millet flour (T_2); 50% barnyard millet flour and 50% foxtail millet flour (T_3); 25% barnyard millet flour and 75% foxtail millet flour (T_4) and 100% foxtail millet flour (T_5) shown in Table 4.24. Colour value "a^*" indicate the redness with positive value and greenness with negative value as shown in Fig. 4.22. It can be seen that colour a^*value decreased as the amount of foxtail millet flour increased in biscuits. The statistical analysis by ANOVA was used (Table 4.26) to see the effect of different combinations on colour value a* at 1 per cent level of significance.



4.22 Variation in colour value a* for developed biscuits

Table 4.26 ANOVA showing effect of composition of flour on colour a* value of developed biscuits

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	52.5477	4	13.13694	46917.65	2.58E-21	3.4780
Within Groups	0.0028	10	0.00028			
Total	52.5505	14				

** Significant at 1%, C.V. %= 0.26, SD=1.91

4.5.4 Colour value b*

The colour value "b*" were 22.13, 20.55, 19.11, 16.87 and 14.55 for biscuits made from 100% barnyard millet flour (T_1); biscuits made of 75% barnyard millet flour and 25% foxtail millet flour (T_2); 50% barnyard millet flour and 50% foxtail millet flour (T_3); 25% barnyard millet flour and 75% foxtail millet flour (T_4) and 100% foxtail millet flour (T_5) as shown in Table 4.24. Numerically the value of "b*" decreased from T_1 to T_5 due to browning of sugar to produce brown pigments during baking. It can be seen in ANOVA (Table 4.27) that composition of flour has significant effect on colour values "b*" at 1 per cent level of significance

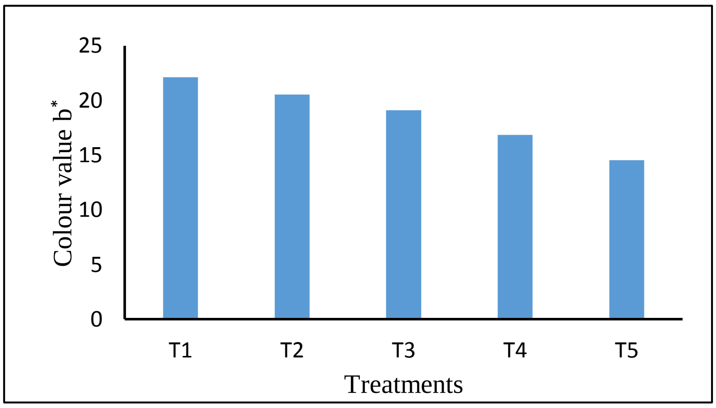


Fig 4.23 Variation in colour value b* for developed biscuits

Table 4.27 ANOVA showing effect of composition of flour on colour b* value of developed biscuits

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	108.2788	4	27.06971	72508.15	2.92E-22	3.47805
Within Groups	0.0037	10	0.000373			
Total	108.2825	14				

** Significant at 1%, C.V. %= 0.14, SD=2.7

4.6 Textural Properties of Biscuits

4.6.1 Firmness

Firmness, hardness, and softness are textural properties that were evaluated during the analysis, as they represent different levels of resistance to rupture in a product. A soft product exhibits slight resistance to break, while a firm product is moderately resistant, and hardness indicates substantial resistance. Firmness is a commonly assessed characteristic when determining the texture of biscuits. Textural analysis, conducted using a texture analyzer (Stable Micro Systems) allowed for the measurement of hardness, fracturability, and work of shear to obtain information about the firmness of the biscuits.

4.6.2 Firmness by cutting test

In the cutting test, firmness was determined by measuring hardness and work of shear. Hardness (kg) was obtained from the first peak force, while the area under the curve represented the work of shear (kg.m) measured by the texture analyzer. These values were obtained for samples prepared from different blend levels of the T_1 to T_5 combinations. During the shearing process, various comparative major peaks were observed at specific depths as the blade cut through the samples. Table 4.28 presents the mean values of hardness and work of shear for biscuit samples with different proportions of foxtail millet flour and barnyard millet flour. The hardness and work of shear values for each replication can be found in the Table.D.1 Appendix D

It is evident from the Table 4.28, that the hardness of the biscuits increased with foxtail millet flour content in the blend. The hardness values obtained for the various biscuit blends at the first peak ranged from 4.86 kg to 6.32 kg shown in Fig 4.24. The shear force and work of shear required to cut the samples also increased as the proportion of foxtail millet flour ranged from 0.015 kg.m to 0.027 kg.m shown in Fig 4.25. Biscuits T_1 and T_2 had low values hardness (cutting or shearing force) compared to T_3, T_4, and T_5. The texture of biscuits T_1 and T_2 may be considered as soft compared to other formulation of biscuits. T_3 may be firm, and T_4 and T_5 may be considered hard as comparatively. It is cleared that less force and work were required to shear the biscuit samples containing a higher percentage of barnyard millet flour. However, T_3 biscuits having equal proportions of foxtail millet and barnyard millet flour (50%;50%) shows better firmness comparable to other combinations. The graphical representations of variation in hardness of biscuits are shown in Fig 4.26.

Table 4.28 Hardness and work of shear of biscuit samples for cutting test

Treatments	Firmness	
	Hardness (kg) ('Mean First Peak Force')	Work of shear (kg.m) ('Mean Total Area')
T_1	3.56	0.015
T_2	4.92	0.018
T_3	5.45	0.021
T_4	6.19	0.024
T_5	6.32	0.027

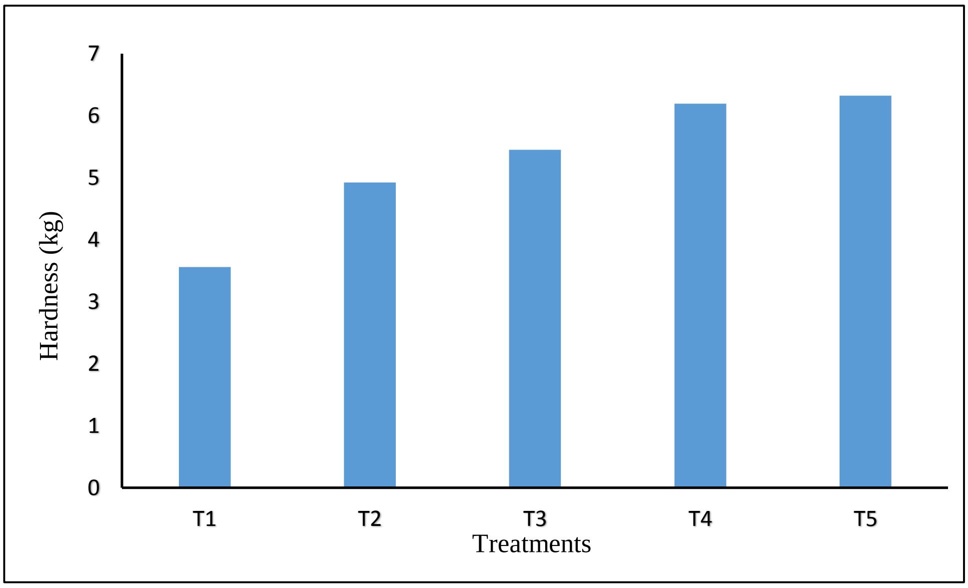


Fig. 4.24 Variation in hardness of developed biscuits

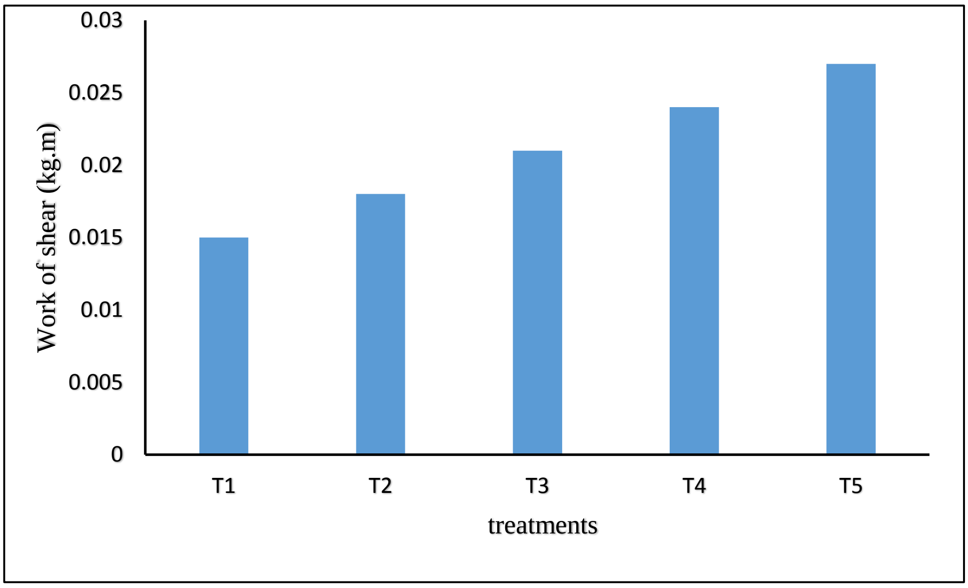


Fig. 4.25 Variation in work of shear of developed biscuits

ANOVA was used to see the effect of different combinations used for preparing biscuit on texture. It can be seen in ANOVA (Table 4.29 and 4.30) composition had significant textural properties at 1 % level of significance.

Table 4.29 ANOVA showing effect of composition of flour on hardness of developed biscuits

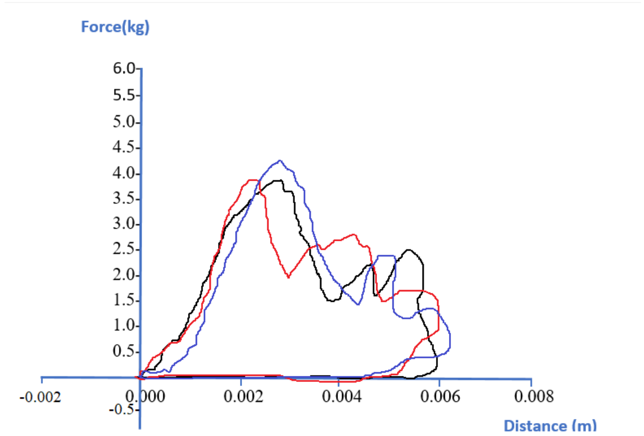
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	15.4389	4	3.859	13464.16	1.32×10^{-18}	3.4780
Within Groups	0.0028	10	0.0002			
Total	15.4417	14				

** Significant at 1%, C.V. %= 0.19, SD=1.4

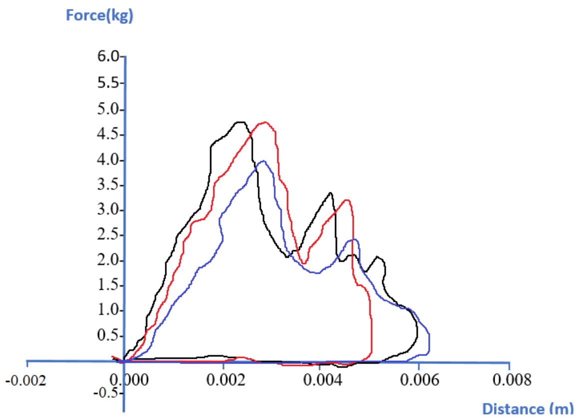
Table 4.30 ANOVA showing effect of composition of flour on work of shear of developed biscuits

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.000322	4	8.04E-05	80.4	1.46×10^{-7}	3.47805
Within Groups	0.00001	10	0.000001			
Total	0.000332	14				

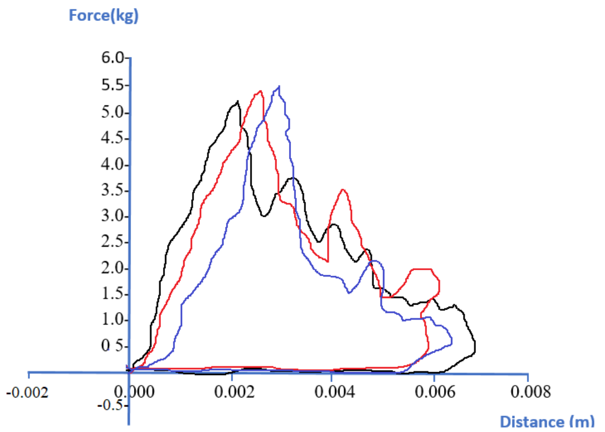
** Significant at 1%, C.V. %= 0.22, SD=0.004



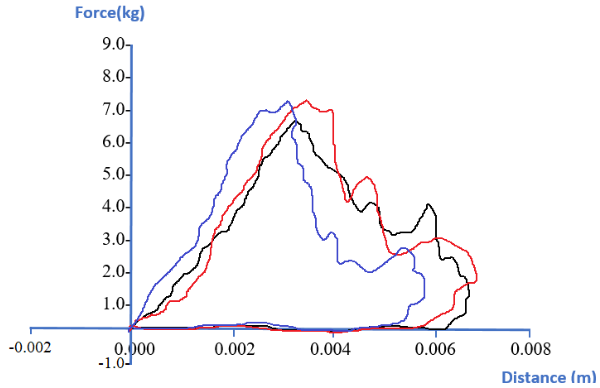
Sample T1



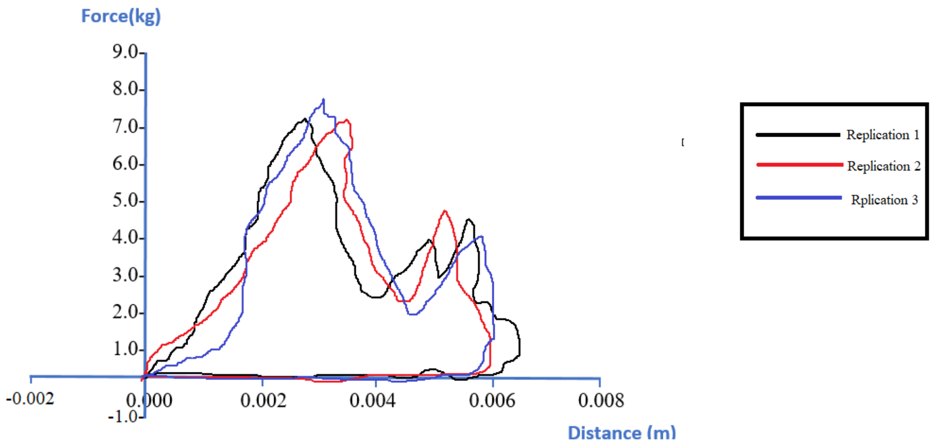
Sample T2



Sample T3



Sample T4



Sample T5

Fig 4.26 Variation in cutting strength of texture analysis of developed biscuits

4.6.3 Firmness by bending test

In the bending or snap test, the firmness of the biscuits were determined by measuring hardness and fracturability. Hardness was represented by the maximum peak force obtained in the curve, measured in kilograms (kg), while fracturability was determined by the distance at which the biscuit broke, measured in millimetres (mm). As the force applied increased, the biscuits fractured and cut into two pieces, with the maximum force indicated the "hardness" of the sample. The distance at the point of break represented the sample's resistance to bend and was related to its "fracturability. Table 4.31 shows the average hardness and fracturability values of biscuit samples with different proportions of foxtail millet flour and barnyard millet flour.

Table 4.31 Hardness and fracturability of biscuit samples for bending test

Treatments	Firmness	
	Hardness (kg) ('Mean Maximum Force')	**Fracturability (mm) ('Mean Distance at Break')**
T_1	1.64	3.12
T_2	1.87	3.06
T_3	1.91	2.93
T_4	2.15	2.63
T_5	2.35	2.84

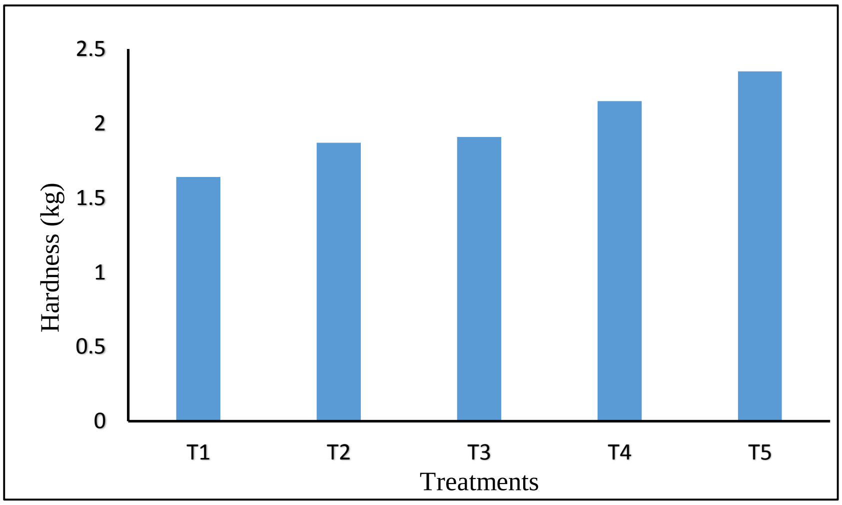


Fig. 4.27 Variation in hardness of developed biscuits

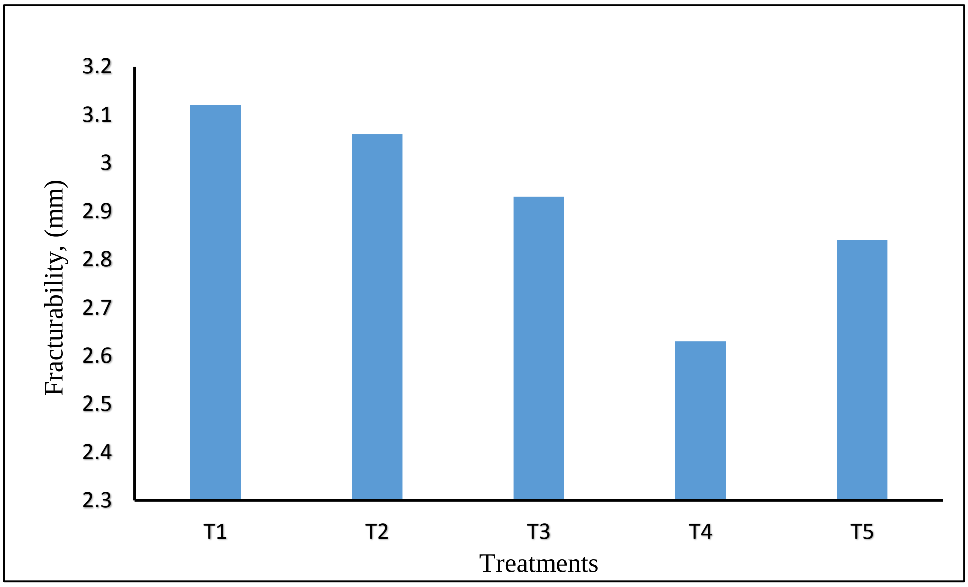


Fig. 4.28 Variation in fracturability of developed biscuits

Anlaysis of varience was used to see the effect of different treatment (T_1 to T_5) on textural properties at 1 % level of significance as shown in table (Table 4.32 to 4.33).

Table 4.32 ANOVA showing effect of composition of flour on hardness of developed biscuits

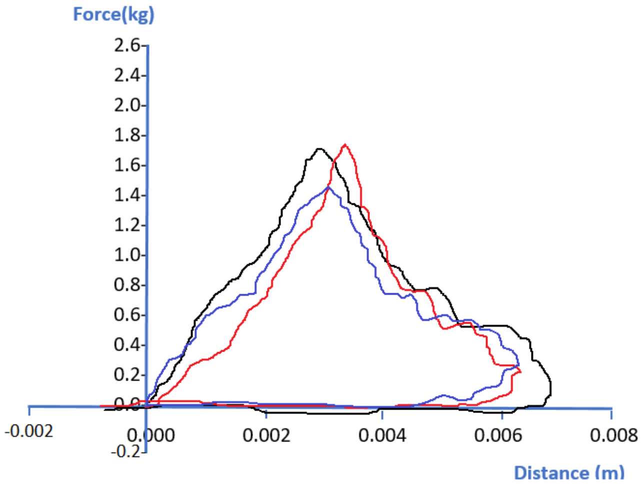
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.8940	4	0.223523	657.4216	4.67×10^{-12}	3.47805
Within Groups	0.0034	10	0.00034			
Total	0.8974	14				

** Significant at 1%, C.V. %= 0.12, SD=0.25

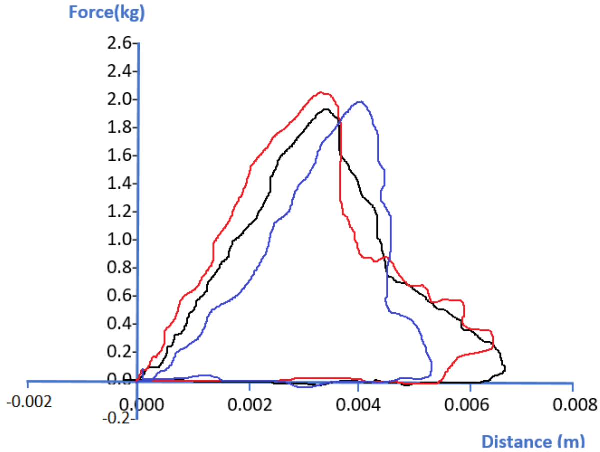
Table 4.33 ANOVA showing effect of composition of flour on fracturability of biscuits

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.458693	4	0.114673	296.569	2.43×10^{-10}	3.47805
Within Groups	0.003867	10	0.000387			
Total	0.46256	14				

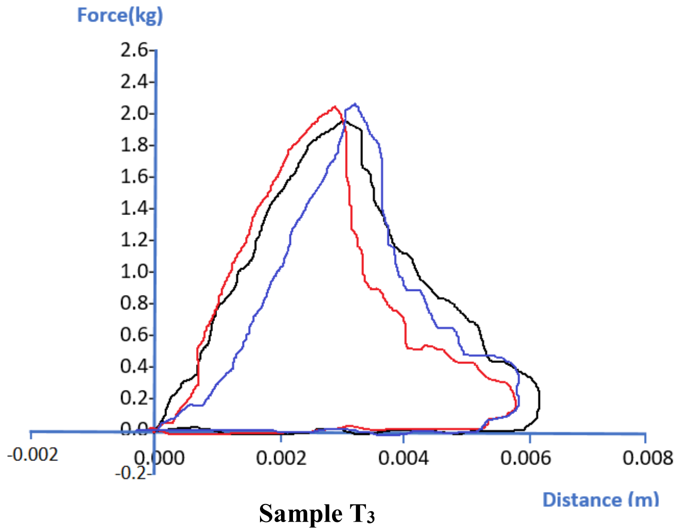
** Significant at 1%, C.V. %= 0.06, SD=0.18



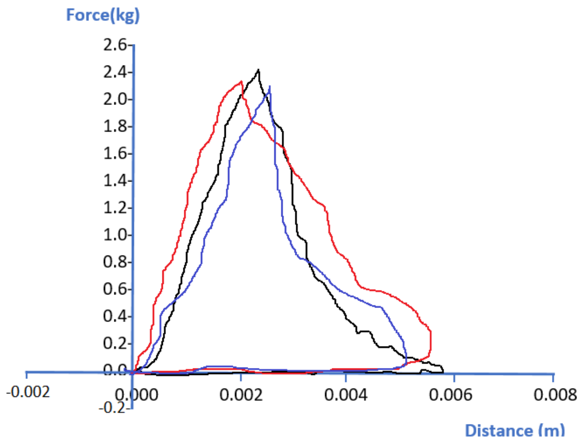
Sample T_1



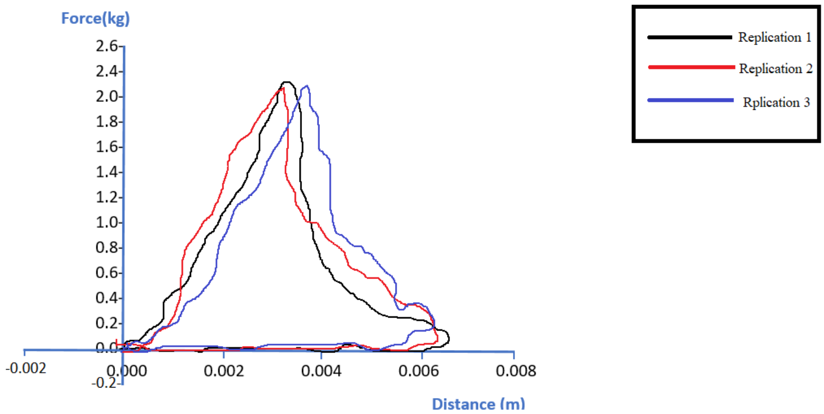
Sample T_2



Sample T_3



Sample T_4



Sample T_5

Fig 4.29 Variation in bending tests of texture analysis of developed biscuits

It can be observed that biscuit samples with a higher percentage of foxtail millet flour showed more hardness. In the bending test, the hardness values for the various biscuit blends ranged from 1.64 kg to 2.35 kg shown in Fig 4.27. As the proportion of foxtail millet flour increased from 0% to 100%, the hardness values also increased and it was in range of 1.64 kg to 2.35 kg. It was noted that the hardness of the biscuits decreased with an increase in the percentage of barnyard millet flour, and the biscuit prepared with 50% foxtail millet flour and 50% barnyard millet flour had a hardness value of 1.91 kg. The graphical representations of result of bending tests of texture analysis are shown in Fig 4.29

Sample T_4 showed a high fracturability as it broke at a very short distance of 2.63 mm compared to other combinations. On the other hand, the biscuit sample T_1, which had a higher proportion of barnyard millet flour, fractured at the maximum distance of 3.12 mm, indicating less crispiness. Therefore, a higher percentage of barnyard millet flour affected the texture of the biscuits, reducing and less crispiness.

CHAPTER V

SUMMARY AND CONCLUSIONS

Millets are traditional small grains, grown and consumed in the Indian subcontinent from the past 5000 years. They are rainfed, hardy grains which have low requirements of water and fertilizers when compared to other cereals. Millet are more nutritious than other cereals. Millets have played a significant role as a staple meal, especially in Asia and Africa.

Foxtail millet is one of the World's oldest cultivated crops. Although foxtail millet has been identified as minor millet in terms of worldwide production, but it is the sixth highest yielding grain. Foxtail millet comprises a wide range of health- benefiting components that not only make it a valuable source but also unique among the cereal category for the particular balance of nutrients it contains. The main components of foxtail millet are starch, protein, dietary fibre, fat, vitamins and minerals.

Barnyard millet contains decent amount of protein, has good proportions of soluble and insoluble fibre and easy to digest. The low and slowly digesting carbohydrate content of barnyard millet makes it a gift from nature for today's sedentary life style.

India is considered as the third largest producer of biscuits after USA and China. Bakery industry is the rapidly growing in our country. It is the largest industries with annual turnover of about INR 30 Billion. Biscuits have low moisture, good shelf life and due to increase consumer demands for convenient and nutritious food products. The consumers demand has increased for the quality food products with taste, safety, convenience and nutrition.

The biscuits were prepared by using traditional creamy method. Biscuits from blend of foxtail millet flour and barnyard millet flour were prepared by mixing in different proportions viz. T_1 (100% barnyard millet flour), T_2 (75% barnyard millet flour + 25% foxtail millet flour), T_3 (50% barnyard millet flour + 50% foxtail millet flour), T_4 (25% barnyard millet flour + 75% foxtail millet flour), and T_5 (100% foxtail millet flour). The developed biscuits had undergone to the physical, chemical and sensory analysis. The properties like diameter, thickness, spread ratio, volume, density, carbohydrate, fat, protein, fibre, calcium, iron, water activity, moisture content, ash, color and texture were determined for prepared biscuit. The effect of various composition of barnyard millet flour and foxtail millet flour on various physical and nutritional properties were statistically analysed by one way ANOVA test.

The following are significant finding based on present study:

1) The diameter of the biscuits decreased as the composition of foxtail millet flour increased and varied from 52.64 mm to 47.52 mm. Conversely, the thickness of the biscuits increased with higher foxtail millet flour content, with 100% foxtail millet flour biscuit having the highest thickness for 7.12 mm and 100% barnyard millet biscuit having the lowest thickness of 6.18 mm.

2) The spread ratio and spread factor decreased with increase foxtail millet flour in composition and varied from 8.52-6.67 and 85.2-66.7.

3) The volume of individual biscuit was in the range of 13.44- 12.30 cm^3 and density of biscuit increased as foxtail millet increased and varied from 0.52-0.66 g/ cm^3

4) The carbohydrate content of biscuit was maximum for (T_1) 100% barnyard millet flour biscuit of (49.29 %) and minimum for (T_5), 100% foxtail millet flour of (45.49 %), it decreased as decreased in fibre content and increase in protein and fat content

5) The fat content of biscuit was found highest for (T_5),100% foxtail millet flour biscuit (28.12%) and lowest was for (T_1) 100% barnyard millet flour biscuit (26.32%) and increased with foxtail millet flour content.

6) The protein content of combination was found highest for 100% foxtail millet flour biscuit (11.22%) and minimum for 100% barnyard millet flour biscuit (8.81%) and the proportion of foxtail millet flour increased in the blends from T_1 to T_5, the protein content of the biscuits also increased.

7) The crude fibre content of biscuits was in the range of 6.33- 7.91 g/100g. The fibre content was found highest for (T_1), 100% barnyard millet flour biscuit of (7.91) and minimum for (T_5), 100% foxtail millet flour of (6.33%). There was a decrease in fibre content as the proportion of foxtail millet flour increased.

8) The calcium content of biscuits varied from 18.13 - 36.28 mg/100g, increase was observed with an increase in the per cent of foxtail millet flour in biscuits

9) The iron content of biscuits varied from 13.53 - 1.91 mg/100g and decreased with the amount of foxtail millet flour in biscuits.

10) The water activity varied from 0.27-0.17% for all samples of developed biscuits.

11) The maximum and minimum moisture content of biscuits were found to be 6.45% (db) for 100% foxtail millet flour biscuits and 4.82% (db) for 100% barnyard millet biscuits.

12) The ash content was in the range of 1.88 to 2.85% for all samples.

13) The L* colour values of the biscuit decreased with increase foxtail millet flour content in biscuits. The maximum value was found for sample (T_1) made with 100% barnyard millet flour (64.92). and minimum for (T_5) 100% foxtail millet flour biscuit (52.12). The a * colour value was minimum for the (T_5), 100% foxtail millet flour biscuits which is (3.47) and maximum for (T_1) 100% barnyard millet flour biscuit (9.22). The b* colour value was in the range of 22.14-14.54 and decreased with increase foxtail millet flour.

14) The sensory evaluation done by panellists had given 8.07 for overall acceptability for biscuits prepared from 50% foxtail and 50% barnyard millet flour respectively for colour, taste, flavour, texture, appearance and overall acceptability.

15) The hardness values of cutting test for all samples of biscuits obtained at initial peak were in the range of 3.56-6.32 kg. The work of shear increased with increase foxtail millet flour and was in the range of 0.015-0.027 kg.m.

16) The hardness scores recorded for the various composition of biscuit of the bending test were in the range of 1.64 to 2.35 kg. Sample T_4 made from 25% barnyard millet flour + 75% foxtail millet flour, breaks at a very short distance at 2.63 mm and has high fracturability compared to other combinations.

Conclusions

1) The diameter, spread ratio, spread factor and density decreased with increase in proportion of foxtail millet flour. The moisture content, fat content, protein content and calcium content increased with increase foxtail millet flour. Carbohydrate content, fibre content and iron content decreased with increase foxtail millet flour.
2) Proportions of foxtail millet flour affected the colour, texture, taste and overall acceptability of biscuits. The scores for appearance was almost same for all treatments. The composition 50% foxtail millet flour and 50% barnyard millet flour i.e. T_3 was best for colour, texture, taste, appearance and overall acceptability.

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SUGGESTIONS FOR FUTURE WORK

1. Heat and mass transfer coefficients of biscuits during baking may be evaluated.
2. Storage study of developed biscuits may be conducted.

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ABSTRACT

India is considered the third largest biscuit producer after the United States and China. The biscuits represent a fast-growing segment of the baking industry in India. The biscuits were developed using foxtail millet and barnyard millet flour.

Biscuits from blend of foxtail millet flour and barnyard millet flour were prepared by mixing in different proportions viz. T_1 (100% barnyard millet flour), T_2 (75% barnyard millet flour+25% foxtail millet flour), T_3 (50% barnyard millet flour+50% foxtail millet flour), T_4 (25% barnyard millet flour+75% foxtail millet flour), and T_5 (100% foxtail millet flour). The biscuits were baked at 180^{o}C for 16 min. The developed biscuits were subjected to physical, textural analyses and sensory analyses. The results revealed that biscuits have diameter (52.64- 47.52 mm), thickness (6.18- 7.12 mm), spread ratio (8.52- 6.67), spread factor (85.2- 67.7) and volume (13.44-12.30 cm^3), density (0.52- 0.66 g/ cm^3) and weight of sample (18.40- 16.74 g).

The diameter, spread ratio, spread factor and density decreased with increase in proportion of foxtail millet flour. The moisture content, fat content, protein content and calcium content increased with increase foxtail millet flour. Carbohydrate content, fibre content and iron content decreased with increase foxtail millet flour. Biscuits have amount of carbohydrate content (49.29%- 45.95 %), fat content (26.32%- 28.12 %), protein content (8.81%-11.22%), calcium content (18.13 mg/100 g - 36.28 mg/100 g), iron content (13.53 mg/100 g - 1.91 mg/100 g) and ash content (1.88-2.83). Proportions of foxtail millet flour affected the colour, texture, taste and overall acceptability of biscuits. The scores for appearance was almost same for all treatments. The composition 50% foxtail millet flour and 50% barnyard millet flour i.e. T_3 was best for colour, texture, taste, appearance and overall acceptability.

संक्षेप

संयुक्त राज्य अमेरिका और चीन के बाद भारत को तीसरा सबसे बड़ा बिस्किट उत्पादक माना जाता है। बिस्कुट भारत में बेकिंग उद्योग के तेजी से बढ़ते क्षेत्र का प्रतिनिधित्व करते हैं। बिस्कुट कंगनी और सांवा के आटे का उपयोग करके विकसित किए गए थे।

कांगनी का आटा और सांवा आटा के मिश्रण से बने बिस्कुट थे अलग-अलग अनुपात में मिलाकर तैयार किया जाता है। T_1 (100% सांवा का आटा), T_2 (75% सांवा का आटा + 25% कांगनी का आटा), T_3 (50% सांवा का आटा + 50% कांगनी का आटा), T_4 (25% सांवा का आटा + 75% कांगनी का आटा), और T_5 (100% कांगनी का आटा)। बिस्कुट को 180°C पर 16 मिनट तक बेक किया गया। विकसित बिस्कुट का भौतिक, बनावटी विश्लेषण और संवेदीकरण किया गया विश्लेषण करता है. परिणामों से पता चला कि बिस्कुट का व्यास (52.64- 47.52 मिमी), मोटाई (6.18- 7.12 मिमी), फैलाव अनुपात (8.52- 6.67), फैलाव कारक (85.2- 67.7) और आयतन (13.44- 12.30 सेमी^{3}), घनत्व (0.52- 0.66 ग्राम/ सेमी^{3}) और नमूने का वजन (18.40- 16.74 ग्राम) है।
कांगनी के आटे के अनुपात में वृद्धि के साथ व्यास, प्रसार अनुपात, प्रसार कारक और घनत्व में कमी आई है। कंगनी के आटे में वृद्धि के साथ नमी की मात्रा, वसा की मात्रा, प्रोटीन की मात्रा और कैल्शियम की मात्रा बढ़ गई। कांगनी के आटे में वृद्धि के साथ कार्बोहाइड्रेट सामग्री, फाइबर सामग्री और लौह सामग्री कम हो गई। बिस्कुट में कार्बोहाइड्रेट की मात्रा (49.29%-45.95%), वसा की मात्रा (26.32%-28.12%), प्रोटीन की मात्रा (8.81%-11.22%), कैल्शियम की मात्रा (18.13 मिलीग्राम/100 ग्राम - 36.28 मिलीग्राम/100 ग्राम), लौह की मात्रा (13.53 मिलीग्राम/100 ग्राम - 1.91 मिलीग्राम/100 ग्राम) और राख की मात्रा (1.88-2.83). कांगनी के आटे के अनुपात ने बिस्कुट के रंग, बनावट, स्वाद और समग्र स्वीकार्यता को प्रभावित किया। सभी उपचारों के लिए उपस्थिति का स्कोर लगभग समान था। 50% सांवा का आटा और 50% कांगनी का आटा यानी T_3 की संरचना रंग, बनावट, स्वाद, उपस्थिति और समग्र स्वीकार्यता के लिए सर्वोत्तम थी।

APPENDIX –A

Table A-1 Physical properties of prepared biscuits

Treatment		Diameter (mm)	Thickness (mm)	Spread ratio	Spread factor	Volume (cm3)	Weight (g)	Density (g/cm3)
T1	**1**	52.61	6.17	8.53	85.3	13.41	7.13	0.53
	2	52.65	6.19	8.51	85.1	13.47	7.13	0.53
	3	52.63	6.17	8.53	85.3	13.42	7.15	0.53
T2	**1**	50.31	6.36	7.91	79.1	12.64	7.35	0.58
	2	50.33	6.38	7.89	78.9	12.69	7.34	0.58
	3	50.29	6.39	7.87	78.7	12.69	7.36	0.58
T3	**1**	49.25	6.65	7.41	74.1	12.66	7.61	0.60
	2	49.21	6.65	7.40	74	12.64	7.63	0.60
	3	49.23	6.66	7.39	73.9	12.67	7.63	0.60
T4	**1**	48.13	6.74	7.14	71.4	12.26	7.91	0.65
	2	48.15	6.75	7.13	71.3	12.28	7.89	0.64
	3	48.15	6.77	7.11	71.1	12.32	7.92	0.64
T4	**1**	47.52	7.14	6.66	66.6	12.66	8.29	0.65
	2	47.53	7.12	6.68	66.8	12.63	8.31	0.66
	3	47.51	7.13	6.66	66.6	12.63	8.33	0.66

APPENDIX –A

Table A-2 Physio-chemical analysis of prepared biscuits

Treatment		Carbohydrate (%)	Fat (%)	Protein (%)	Fibre (%)	Calcium (mg/100g)	Iron (mg/100g)	Moisture content (%)	Water activity	Ash (%)
T1	1	49.3	26.33	8.8	7.9	18.14	13.51	4.85	0.25	2.82
	2	49.33	26.35	8.82	7.9	18.12	13.54	4.78	0.29	2.82
	3	49.26	26.3	8.82	7.94	18.1	13.54	4.83	0.29	2.85
T2	1	48.76	26.9	9.45	7.41	21.59	10.36	5.27	0.26	2.21
	2	48.67	26.91	9.52	7.43	21.67	10.31	5.21	0.25	2.26
	3	48.56	26.98	9.56	7.42	21.68	10.35	5.24	0.24	2.24
T3	1	47.39	27.16	10.37	7.18	28.56	8.15	5.59	0.19	2.31
	2	47.46	27.22	10.31	7.15	28.53	8.15	5.65	0.23	2.21
	3	47.38	27.18	10.35	7.2	28.57	8.13	5.63	0.21	2.26
T4	1	46.48	27.58	10.55	6.68	32.56	5.37	6.28	0.18	2.06
	2	46.7	27.59	10.58	6.74	32.57	5.35	6.3	0.18	2.09
	3	46.68	27.63	10.61	6.71	32.57	5.38	6.25	0.17	2.12
T5	1	46.09	28.13	11.18	6.31	36.61	1.88	6.45	0.17	1.86
	2	46.01	28.11	11.25	6.33	35.91	1.93	6.42	0.15	1.88
	3	45.77	28.24	11.23	6.35	36.33	1.92	6.45	0.19	1.93

APPENDIX - B

Table B-1 Sensory score for developed foxtail millet and barnyard millet biscuits

Name of judge:
Date:

Scale:

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

Product	Quality characteristics				
	Colour	Taste	Texture	Appearance	Overall acceptability
T1					
T2					
T3					
T4					
T5					

Signature:

APPENDIX - B

Table B-2 Score of sensory evaluation of prepared biscuits

Sensory Attributes	Treatment	No. of Panellists Score														
Test	T1	8	7	8	8	7	7	8	9	7	6	8	6	8	9	7
	T2	7	8	7	8	7	8	9	7	8	8	6	8	7	9	8
	T3	8	9	9	8	7	8	9	9	7	8	8	9	7	8	9
	T4	6	7	8	9	9	8	7	9	8	8	9	6	7	9	7
	T5	8	9	8	6	7	6	7	8	9	6	8	9	6	7	7
Colour	T1	9	7	9	7	9	7	9	6	9	8	7	9	7	9	7
	T2	8	8	9	6	6	9	6	8	7	7	8	9	8	9	8
	T3	8	8	9	9	9	8	7	8	7	6	8	9	7	8	9
	T4	8	8	7	8	6	8	7	8	9	7	7	9	6	8	9
	T5	8	9	8	7	8	8	9	7	7	7	6	8	8	6	8
Texture	T1	8	7	8	8	7	8	9	8	7	7	9	8	7	8	9
	T2	8	9	8	9	6	8	7	7	8	9	6	7	8	7	7
	T3	9	8	9	8	9	8	9	7	9	7	9	8	8	6	7
	T4	7	8	8	8	9	8	6	7	7	8	6	8	7	7	9
	T5	6	6	7	8	6	8	6	7	8	6	9	8	8	9	8
Apperance	T1	8	7	8	9	8	9	8	7	8	8	7	8	7	8	9
	T2	7	8	9	8	9	8	7	8	7	8	7	8	9	8	7
	T3	9	8	9	8	7	8	9	8	8	8	7	7	9	9	8
	T4	7	9	8	9	8	8	6	8	8	8	7	7	9	8	7
	T5	7	8	9	8	6	7	8	9	8	7	8	7	7	8	7
Overall	T1	8	7	8	9	8	7	8	7	8	9	8	7	8	8	6
	T2	7	8	7	8	7	7	8	7	9	8	8	7	8	8	8
	T3	8	7	8	7	8	8	9	9	8	9	8	9	8	7	8
	T4	8	7	7	7	8	9	6	7	8	9	6	9	8	8	8
	T5	8	7	8	7	8	7	8	8	7	7	8	7	6	7	8

APPENDIX –C

Table C-1 Specifications of hunter lab colorimeter

S. No.	Particulars	details
1.	Manufacturer's Name	Hunter Associates Laboratory, Inc.
2.	Product Name	Colourflex
3.	Model	CFLX-DIEF, CLFX-45
4.	Illumination and viewing i) Source ii) Source UV iii) Integrating Sphere	Dual beam Xenon flash lamp Nominal match to D65 63.5 mm diameter, high efficiency, white coating
5.	Port diameters/view diameters i) 45/0 model ii) Diffuse/8o	31.8 mm/25.4 mm 14.9 mm/8.0 mm

Table C-2 Color analysis of prepared biscuits

Treatment		L*	a*	b*
T1	1	64.9	9.21	22.13
	2	64.94	9.23	22.15
	3	64.92	9.22	22.15
T2	1	60.18	7.76	20.55
	2	60.2	7.73	20.53
	3	60.2	7.74	20.52
T3	1	58.31	8.68	19.09
	2	58.35	8.69	19.11
	3	58.26	8.65	19.13
T4	1	55.81	3.97	16.87
	2	55.78	3.95	16.85
	3	55.83	3.99	16.83
T5	1	52.1	3.47	14.55
	2	52.12	3.45	14.51
	3	52.13	3.48	14.56

APPENDIX –D

Table D-1 Specifications of texture analyzer

Main supply

APPENDIX -D SPECIFICATIONS OF TEXTURE ANALYZER

The TA-XT plus / TA-HD plus has an IEC style main inlet and requires a mains supply of frequency and voltage that fall within the following limits:-

Table-1 Manual of TA.HD plus Texture Analyzer

Mains Supply Requirements	
Supply Voltage	100v A.C. to 240v A.C.
Supply Frequency	47 Hz to 63 Hz
SupplyV.A.	120VA (TA.XT plus) 250 VA (TA.HD plus)

Only three pin mains plugs should be used for safety reasons

The main inlet on the TA-XT plus /TA-HD plus contains two 200 mm mains fuse, one fuse in the live circuit and the other in the neutral circuit. Both fuses must be fitted and working for the texture analyzer to operate.

Fuse Rating

These main fuses must be 1.6 amp anti-surge cartridge fuses, e.g. 1.6A (T) for TA-XT plus and 10A (T) for TA-HD plus. The TA-XT plus / TA-HD plus are factory fitted with fuses of type BEL 5TT(P)1.6A and 10A(T) respectively, which carry safety agency approvals from underwriters Laboratories, UL listed file number E20624 and CSA certified file number LR39772.

APPENDIX - D

Table D-2 Texture Analyzer readings for various combinations of biscuits

Treatment		Test			
		Cutting		Bending	
		Hardness (kg)	work of shear, (kg m)	hardness (kg)	Fracturability, (mm)
T1	1	3.56	0.015	1.63	3.12
	2	3.52	0.014	1.65	3.14
	3	3.54	0.015	1.64	3.11
T2	1	4.9	0.018	1.89	3.08
	2	4.92	0.019	1.85	3.06
	3	4.92	0.017	1.87	3.05
T3	1	5.42	0.021	1.91	2.96
	2	5.45	0.02	1.88	2.9
	3	5.44	0.022	1.92	2.92
T4	1	6.19	0.024	2.16	2.63
	2	6.18	0.024	2.14	2.65
	3	6.19	0.023	2.16	2.61
T5	1	6.32	0.027	2.32	2.83
	2	6.35	0.028	2.35	2.85
	3	6.37	0.029	2.37	2.83