

**OPTIMIZATION OF PROCESS PARAMETERS FOR
MECHANIZED PREPARATION OF MAIZE FLOUR
BASED FLATBREAD**

Thesis

**Submitted to the Punjab Agricultural University
in partial fulfillment of the requirements
for the degree of**

**MASTER OF TECHNOLOGY
in
PROCESSING AND FOOD ENGINEERING
(Minor Subject: Mechanical Engineering)**

By

**Prerna Kathuria
(L-2016-AE-205-M)**

**Department of Processing and Food Engineering
College of Agricultural Engineering and Technology
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LUDHIANA-141 004**

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CERTIFICATE – I

This is to certify that the thesis entitled, “**Optimization of process parameters for mechanized preparation of maize flour based flatbread**” submitted for the degree of **M.Tech.** in the subject of **Processing and Food Engineering (Minor subject: Mechanical Engineering)** of Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Prerna Kathuria (L-2016-AE-205-M)** under my supervision and no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigations have been fully acknowledged.

(Dr. Gagandeep Kaur Sidhu)
Major Advisor
Senior Research Engineer
Department of Processing and
Food Engineering
Punjab Agricultural University,
Ludhiana - 141 004, India

CERTIFICATE – II

This is to certify that the thesis entitled, “**Optimization of process parameters for mechanized preparation of maize flour based flatbread**” submitted by **Prerna Kathuria (L-2016-AE-205-M)** to the Punjab Agricultural University, Ludhiana, in the partial fulfilment of the requirements for the degree of **M.Tech.** in the subject of **Processing and Food Engineering (Minor subject: Mechanical Engineering)** has been approved by the student’s Advisory Committee along with External Examiner after an oral examination on the same.

(Dr. Gagandeep Kaur Sidhu)
Major Advisor

(Dr. Sandeep Mann)
External Examiner
Principal Scientist (AS & PE)
CIPHET, Ludhiana

(Dr. Mahesh Kumar)
Head of the Department

(Dr. Gurinder Kaur Sangha)
Dean, Post-Graduate Studies

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Place:

Date:

(Prerna Kathuria)

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Name of the Student and Admission No. : Perna Kathuria
L-2016-AE-205-M

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Name and Designation of Major Advisor : Dr. Gagandeep Kaur Sidhu
Senior Retrench Engineering

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Punjab, India

ABSTRACT

The present study was done to optimize the process parameters for mechanized preparation of maize flour based flatbreads. The whole maize kernels were procured from the farms of Punjab Agricultural University, Ludhiana. The kernels were cleaned, processed into flour and sieved into fine and very fine flour particles. Maize flour was blended with wheat and gram flour in the blending percentage of 20, 30 and 40. Flour samples were tested for physico-chemical properties like moisture content, protein content, crude fat, ash content, crude fiber, carbohydrates, titrable acidity, color, swelling power, water holding capacity and oil holding capacity. The blending percentage of gram flour and wheat flour had a significant effect on protein content, crude fat, crude fiber, carbohydrates, titrable acidity, color value, swelling power, water holding capacity and oil holding capacity. The optimization of process parameters was done using Box-Behnken design using Response Surface Methodology (RSM). The three independent variables set were resting time of dough (0, 10 and 20 min), blending percentage of flour (20, 30 and 40%) and temperature of water to knead the dough (18°, 27° and 36°C). Optimum conditions obtained were 12.45 min resting time, 38.90% blending percentage and 31.47°C water temperature for blending with gram flour and for wheat flour blending, optimum conditions obtained were 20 min resting time, 20% blending percentage and 29.68°C water temperature respectively. Moisture content of flatbread decreases linearly with storage period in both the storage conditions respectively. Browning index increases linearly with storage period but the increase was more prominent in gram flour flatbread. After considering all the parameters, it was found that gram flour blended flatbreads were more acceptable than wheat flour blended.

Keywords: Blending, maize, moisture content, optimization

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ਮੌਜੂਦਾ ਅਧਿਐਨ, ਯਾਂਤ੍ਰਿਕ ਵਿਧੀ ਨਾਲ ਮੱਕੀ ਦੇ ਅੱਟੇ ਤੋਂ ਫਲੈਟ ਬ੍ਰੈੱਡ ਬਨਾਉਣ ਲਈ ਮਾਪਦੰਡਾਂ ਦਾ ਅਨੁਕੂਲਨ ਕਰਨ ਲਈ ਕੀਤਾ ਗਿਆ। ਪੰਜਾਬ ਐਗਰੀਕਲਚਰਲ ਯੂਨੀਵਰਸਿਟੀ, ਲੁਧਿਆਣਾ ਦੇ ਖੇਤਾਂ ਤੋਂ ਮੱਕੀ ਦੇ ਦਾਣੇ ਲਏ ਗਏ। ਦਾਣਿਆਂ ਨੂੰ ਸਾਫ ਕਰਕੇ ਆਟਾ ਤਿਆਰ ਕੀਤਾ ਗਿਆ ਅਤੇ ਇਸਨੂੰ ਛਾਣ ਕੇ ਬਹੁਤ ਹੀ ਮਹੀਨ ਆਟਾ ਬਣਾਇਆ ਗਿਆ। ਮੱਕੀ ਦੇ ਆਟੇ ਨੂੰ ਕਣਕ ਅਤੇ ਛੋਲਿਆਂ ਦੇ ਆਟੇ ਵਿੱਚ 20, 30 ਅਤੇ 40 ਪ੍ਰਤੀਸ਼ਤ ਪੱਧਰ ਤੱਕ ਰਲਾਇਆ ਗਿਆ। ਭੌਤਿਕ-ਰਸਾਇਣਕ ਗੁਣਾਂ ਜਿਵੇਂ ਕਿ ਨਮੀ ਦੀ ਮਾਤਰਾ, ਪ੍ਰੋਟੀਨ ਦੀ ਮਾਤਰਾ, ਕਰੂਡ ਫੈਟ, ਐਸ਼ ਦੀ ਮਾਤਰਾ, ਕਰੂਡ ਰੇਸ਼ਾ, ਖਟਾਸ, ਰੰਗ, ਫੁੱਲਣ ਦੀ ਸਮਰੱਥਾ, ਪਾਣੀ ਅਤੇ ਤੇਲ ਨੂੰ ਸਮਾ ਕੇ ਰੱਖ ਸਕਣ ਦੀ ਸਮਰੱਥਾ ਦੇ ਅਧਾਰ ਤੇ ਇਹਨਾਂ ਨਮੂਨਿਆਂ ਦੀ ਜਾਂਚ ਕੀਤੀ ਗਈ। ਛੋਲਿਆਂ ਅਤੇ ਕਣਕ ਦੇ ਆਟੇ ਦੀ ਬਲੈਂਡਿੰਗ ਪ੍ਰਤੀਸ਼ਤਤਾ ਦਾ ਨਮੀ ਦੀ ਮਾਤਰਾ, ਪ੍ਰੋਟੀਨ ਦੀ ਮਾਤਰਾ, ਕਰੂਡ ਫੈਟ, ਐਸ਼ ਦੀ ਮਾਤਰਾ, ਕਰੂਡ ਰੇਸ਼ਾ, ਖਟਾਸ, ਰੰਗ, ਫੁੱਲਣ ਦੀ ਸਮਰੱਥਾ, ਪਾਣੀ ਅਤੇ ਤੇਲ ਨੂੰ ਸਮਾ ਕੇ ਰੱਖ ਸਕਣ ਦੀ ਸਮਰੱਥਾ ਉਪਰ ਅਰਥਪੂਰਨ ਪ੍ਰਭਾਵ ਪਿਆ। ਰਿਸਪੋਂਸ ਸਰਫੇਸ ਮੈਥੋਡੋਲੋਜੀ (ਆਰ ਐਸ ਐਮ) ਦੀ ਵਰਤੋਂ ਕਰਕੇ ਬੇਕਸ-ਬੈਂਚਕਨ ਡਿਜ਼ਾਈਨ ਨਾਲ ਪ੍ਰੋਸੈਸਿੰਗ ਮਾਪਦੰਡਾਂ ਦਾ ਅਨੁਕੂਲਨ ਕੀਤਾ ਗਿਆ। ਤਿੰਨ ਅਜ਼ਾਦ ਵੇਰੀਏਬਲ ਭਾਵ ਗੁੰਨੇ ਹੋਏ ਆਟੇ ਦੇ ਪਏ ਰਹਿਣ ਦੇ ਸਮੇਂ (ਰੈਸਟਿੰਟ ਸਮਾਂ) (0, 10 ਅਤੇ 20 ਮਿੰਟ), ਆਟੇ ਦੀ ਬਲੈਂਡਿੰਗ ਪ੍ਰਤੀਸ਼ਤਤਾ (20, 30 ਅਤੇ 40%) ਅਤੇ ਆਟੇ ਨੂੰ ਗੁੰਨਣ ਲਈ ਵਰਤੇ ਗਏ ਪਾਣੀ ਦੇ ਤਾਪਮਾਨ (18°, 27° ਅਤੇ 36°C) ਨੂੰ ਨਿਰਧਾਰਤ ਕੀਤਾ ਗਿਆ। ਛੋਲਿਆਂ ਦੇ ਆਟੇ ਲਈ 12.45 ਮਿੰਟ ਰੈਸਟਿੰਟ ਸਮਾਂ, 38.90% ਬਲੈਂਡਿੰਗ ਪ੍ਰਤੀਸ਼ਤਤਾ ਅਤੇ ਆਟੇ ਨੂੰ ਗੁੰਨਣ ਲਈ ਵਰਤੇ ਗਏ ਪਾਣੀ ਦੇ 31.47°C ਤਾਪਮਾਨ ਅਤੇ ਕਣਕ ਦੇ ਆਟੇ ਲਈ 20 ਮਿੰਟ ਰੈਸਟਿੰਟ ਸਮਾਂ, 20% ਬਲੈਂਡਿੰਗ ਪ੍ਰਤੀਸ਼ਤਤਾ ਅਤੇ ਆਟੇ ਨੂੰ ਗੁੰਨਣ ਲਈ ਵਰਤੇ ਗਏ ਪਾਣੀ ਦੇ 29.68°C ਤਾਪਮਾਨ ਸਭ ਤੋਂ ਵਧੀਆ ਮਾਪਦੰਡ ਸਨ। ਭੰਡਾਰਨ ਦੇ ਦੋਨਾਂ ਹਲਾਤਾਂ ਅਧੀਨ ਭੰਡਾਰਨ ਸਮੇਂ ਦੇ ਵਧਣ ਨਾਲ ਫਲੈਟ ਬ੍ਰੈੱਡ ਵਿੱਚ ਨਮੀ ਦੀ ਮਾਤਰਾ ਵਿੱਚ ਇਕਸਾਰ ਕਮੀ ਦਰਜ ਕੀਤੀ ਗਈ। ਭੰਡਾਰਨ ਸਮੇਂ ਦੇ ਵਧਣ ਨਾਲ ਭੂਰੇ ਹੋਣ ਦੀ ਦਰ ਵਿੱਚ ਇਕਸਾਰ ਵਾਧਾ ਹੋਇਆ ਪਰ ਛੋਲਿਆਂ ਦੇ ਆਟੇ ਤੋਂ ਬਣੀ ਬ੍ਰੈੱਡ ਵਿੱਚ ਇਹ ਵਾਧਾ ਜ਼ਿਆਦਾ ਸੀ। ਸਾਰੇ ਮਾਪਦੰਡਾਂ ਨੂੰ ਧਿਆਨ ਵਿੱਚ ਰੱਖਦੇ ਹੋਏ, ਇਹ ਸਿੱਟਾ ਕੱਢਿਆ ਗਿਆ ਕਿ ਕਣਕ ਦੇ ਆਟੇ ਦੇ ਮੁਕਾਬਲੇ ਛੋਲਿਆਂ ਦੇ ਆਟੇ ਨੂੰ ਮੱਕੀ ਵਿੱਚ ਰਲਾ ਕੇ ਬਣਾਈ ਕੀਤੀ ਗਈ ਬ੍ਰੈੱਡ ਨੂੰ ਵਧੇਰੇ ਪਸੰਦ ਕੀਤਾ ਗਿਆ।

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CHAPTER 1

INTRODUCTION

Maize (*Zea mays* L) is one of the most flexible emerging crops having wider adaptability under diverse agro-climatic conditions. Universally, maize is known as queen of cereals as it has the highest genetic yield capability among the cereals. The crop was introduced to Europe in the sixteenth century, from where it spread to Africa and Asia. It is now one of the most extensively grown crops around the world in both temperate and tropical regions. Maize, which is the only food cereal crop that can be grown in different seasons requires moderate climate for growth. It grows well in loamy soils but surplus or poor rains adversely affect yields as well as quality (Ranum 2014). There are six major varieties commercially grown speciality maize for human consumption including flint, floury, dent, pop, waxy and sweet corn (Suleiman *et al* 2013).

Maize has the highest production among all the cereal crops throughout the world. United States is the largest originator and the end user of corn in the world. It is estimated that the universal production of corn is around 980 million metric tons every year out of which 40% production comes from United States. The area under the crop worldwide is estimated to be 817 million hectares and the yield is estimated as 717 million metric tonnes (FAO 2009). India ranks among the world's 10 highest maize producing countries and produces about 23 million metric tonnes of maize from 9.4 million hectares area (FICCI 2015). In Punjab, the maize production was about 6.1 lakh metric tonnes under the crop area of about 1.65 lakh hectares (Agriculture database 2019).

Maize grains have a highly nutritive value and contain vitamin K (0.0005 mg), vitamin E (0.11 mg), vitamin C (0.12 mg), vitamin B1 or thiamine (0.42 mg), vitamin B2 or riboflavin (0.10 mg), vitamin B3 or niacin (1.9 mg), vitamin B5 or pantothenic acid (1.036 mg), vitamin B6 or pyridoxine (0.071 mg), potassium (286 mg), folic acid (0.054 mg), magnesium (139 mg) (Shah *et al* 2015) and are rich in starch, protein, fibre, fat, sugar and minerals. The nutritional content of maize can vary due to the variety, location and the practice followed for its production. For PMH 1 variety, the protein content varies from 6-11 gm, carbohydrate 70-80 gm and crude fat 2-5 gm per 100 gm. (Rafiq *et al* 2010). Virtually every part of maize has economic value and grains are used as food for human beings, fermented to produce a wide range of food and beverages, fed to livestock and industrial uses in the production of starch, oil, sugar, cellulose and ethanol. Leaves stalk and tassels can be fed to livestock either as green manure in the form of fodder and dried as stover. The grain provides number of industrial products such as corn syrup, ethanol and transformation into plastics and fabrics (Ram and Mishra 2010).

Maize is an eloquent source of food for a large segment of the world's population and serves as a mechanism for vitamin and mineral insufficiency intervention. There are diverse industrial procedures which bring ample changes in maize products to satisfy desire and usage of the consumer. Several outputs of the industrial dry maize milling processes may be produced provincially at a small extent as well as in the home. The dry milling process is a less versatile and a less capital intensive process (Sidhu *et al* 2016 (a); Sidhu *et al* 2016 (b)). The quality of flour can be improved by slightly reducing the speed of grinding or by decreasing the throughput, or else, the flour is less homogeneous and warmer. The speed of milling considerably affects the quality and storability of flour. The corn grits, meal and flour have an extended shelf life and they can be conveyed and traded very easily (Gwirtz 2014).

Reduced product stability, mainly due to fat content, results in the need for persistent processing of maize at the household or at small-scale industry level. The maize flour is baked into roti or chapatti. Excellent dough with good elastic properties can be made from maize flour of dehulled grains. Maize is also processed into semolina (sooji) and it also serves as the replacement of wheat semolina in various food preparations. The grain may be dried up, ground to flour and cooked into porridge. It can also be consumed in roasted form or in boiled form on the cob itself.

Maize flour is frequently used in various pharmaceutical and food formulations all over the world. It is used either in their pure form or in the form of their blends with other seed flours such as groundnut and soy bean (Akupapunam and Darbe 1994; Akubor *et al* 2000). Its industrial and food application significantly depends on functional characteristics. Functional properties such as water absorption, oil absorption, gelation, foaming and emulsifying capacities are the intrinsic physicochemical properties which illustrate the structural behaviour of the food systems. The investigations about the functional properties of seed flours provide an advanced knowledge for their use in the preparation of different pharmaceutical and food products. Any change in these properties during processing, transport and storage may significantly influence the nutritional and consumptional importance of the food materials. The factors which affect the functional properties of food materials during storage and processing should be optimized to improve the functional characterization of the food materials.

Maize flour commonly known as 'Atta' in Indian subcontinent is a product obtained by grinding. Generally whole maize flour is used to make 'chapatti', an Indian flatbread. Whole grain flours are prepared by a variety of techniques and with different particle size. About one third of the maize production is imbibed in the form of flat breads which are consumed basically in the northern states of India. Chapatti is substantially a flat piece of dough, round in shape, which is properly cooked or baked. Chapatti is the staple diet of a

large segment of people residing in Indian subcontinent. Maize flat bread along with ‘sarson ka saag’ is a well liked and most common winter dish in Punjab. Maize flat breads are generally prepared with hands. This process is highly time consuming and requires a lot of practical expertise owing to lower gluten content and lower binding properties. There is an increasing demands for ready to eat and easy to carry foods due to rise in working urban class. Thus, a need arises for mechanized preparation of maize flat breads for marketing in unit packs.

There is limited documented knowledge available for the mechanized preparation of maize flour based flat breads using the ‘Roti maker machine’. This machine is basically used for preparing wheat flour flatbread at the domestic and industrial level, but not for maize flour flatbreads. This study focuses on preparation of maize flour based flat breads with the help of roti maker in order to meet the current market needs and to reduce the time consuming and laborious process of manual flat bread preparation. Objectives related to this study were as follows:

- (i) To study the effect of different process parameters on the quality of maize flour based flat bread using existing ‘Roti Maker Machine’.
- (ii) To optimize the process parameters for preparation of maize flour based flat bread.
- (iii) To evaluate the effect of packaging material on the quality of flat bread during storage.

CHAPTER II

REVIEW OF LITERATURE

The relevant research work carried out so far on present investigation entitled “Optimization of process parameters for mechanised preparation of maize flour based flatbread”, has been reviewed as under:

2.1 Flour Processing and Quality assessment of blends

Mojisola and Lateef (2005) examined the useful properties of three different flours and two interfusions of maize meal and soybean flour in the ratios of 9:1 and 8:2 (maize: soybean). The properties that were examined constituted the amylase content, bulk density, swelling ability, water absorption capability and viscoelastic properties. The impact of different flour samples was evaluated on sour maize bread by baking bread samples with different flours with the help of mixed starter culture of lactobacillus planter. Each sample differed notably in their functional properties. Remarkable positive correlations existed among the functional properties of the flours. The maize meal and the soy flour blends did not differentiate significantly from each other in functional properties apart from the amylase content.

Mestres *et al* (2009) presented a study that aimed to propose a comprehensive appropriate technological package for small-scale processing of maize flour, which meets consumer demand for quality and achieves extended shelf life. One traditional soft cultivar was processed by the conventional method (direct grinding with disc mill) and was compared with flours obtained under various degerming and grinding intensities; two types of grinder (disc mill and hammer mill, already present on the market) were tested in parallel. Consumer satisfaction scores were registered for the different products after increasing storage duration (0 to 6 months). It was shown that combining degerming and hammer milling produce high quality flour from hard grains, which can be stored up to 6 months without significant deterioration. In parallel, physicochemical and rheological characterizations showed that the main reaction occurring during storage is lipid degradation, which slightly increased fat acidity, hence decreasing taste and elasticity acceptability of the paste.

Hadnadev and Torbica (2011) stated the aptness of alternative crops like rice, corn, soya and buckwheat for the production of quality bread. Their rheological properties were examined and were compared with the properties of the wheat flour, which served as a yardstick. According to the results obtained, flours from different raw materials presented profiles which greatly varied from wheat flour profile. Samples of rice and buckwheat flour exhibited almost a similar rheological behavior as that of wheat flour. However, there is no tested material which mimics the wheat flour dough properties, thus concluding that their

mixtures would exhibit the optimal rheological properties. Although it was quite a challenging task to mimic wheat flour's unique bread making properties but it was possible to create products having almost a similar rheological behavior as that of wheat flour dough with improved functional properties.

Bareh *et al* (2011) aimed on substituting a part of gelatinized corn flour (GCF) with Triticale flour (TF) and both of them in Tortilla bread, as an attempt to solve the problem shortage in wheat production. Chemical, rheological, Diffraction Scanning Colorimeter (DSC), Starch crystalline, functional compounds of GCF, TF and their mixtures by FT-IR, colour parameters, staling, baking quality and sensory properties of Tortilla bread were evaluated. The incorporation of TF and GCF into Tortilla bread improved protein, fat, fibre, ash, total carbohydrate and minerals (Mg, Ca, P, K, Na, Cu and Fe). Blending TF with GCF gave lower rheological parameters, and lightness of bread was reduced. Sensory properties of aroma, rollability, firmness and dryness were not significantly affected, but a significant difference was observed in taste, colour and overall acceptability at different replacement levels. The results also, showed that amide I fragments were assigned to absorption bands in the region of 1642-1653 cm^{-1} and bands of carboxyl group of protein were exhibited at the region of 3407-3426 cm^{-1} . Triticale and corn flour were characterized with specific fingerprints at 1242 cm^{-1} (N-H in plane, C=N stretching), 1016-1020 per cm (C-C stretching of carbohydrate) and 849-861 cm^{-1} (C-C stretching of pyranose ring, C-O-H and O-C-H deformation) and C=O stretching of ester at 1742-1743 per cm respectively. Generally, TF supplementation with GCF (50:50 percentage) not significantly affected the technological quality of tortilla bread and improved its nutritional values.

Saleh and Brennan (2012) studied the relationships between bread making quality, kernel properties (physical and chemical) and dough rheology were investigated using flours from six genotypes of Syrian wheat lines, comprising both commercially grown cultivars and advanced breeding lines. Grain samples were evaluated for virtuousness, test weight, 1000-kernel weight and then milled and tested for protein content, ash, and water content. Dough rheology of the samples was studied by the determination of the mixing time, stability, weakness, resistance and the extensibility of the dough. Loaf baking quality was evaluated by the measurement of the specific weight, resilience and firmness in addition to the sensory analysis. A comparative study between the six Syrian wheat genotypes and two English flour samples was conducted. Significant differences were observed among Syrian genotypes in virtuousness (69.3 %–95.0 %), 1000-kernel weight (35.2–46.9 g) and the test weight (82.2–88.0 kg/hL). All samples exhibited high falling numbers (346 to 417 s for the Syrian samples and 285 and 305 s for the English flours). A significant positive correlation was exhibited between the protein content of the flour and its absorption of water ($r = 0.84$), as well as with

the virtuousness of the kernel ($r = 0.54$). Protein content was also correlated with dough stability ($r = 0.86$), extensibility ($r = 0.8$), and negatively correlated with dough weakness ($r = -0.69$).

Aziah *et al* (2012) studied dough mixing and thermal properties including the pasting profiles of various commercial wheat flour (WF)-banana pseudo stem flour (BP)-hydrocolloid blends were determined using a farinograph, differential scanning calorimetry (DSC) and a rapid visco analyser (RVA). The prepared blends were WF, WF substituted with 10% BP (10 BP) and 10 BP with added 0.8% w/w (flour weight basis) xanthan gum (XG) or sodium carboxymethylcellulose (CMC) (10 BPX and 10 BPC, respectively). The dough of 10BP and the dough containing XG or CMC reduced stability and breakdown time compared with the WF dough. All dough containing BP demonstrated greater water absorption and mixing tolerance index values than the WF dough. The substitution of 10% BP into WF and the addition of hydrocolloids did not significantly affect the conclusion temperature (T_c) of the mixture, but did increase the onset temperature (T_o), peak temperature (T_p) and decreased the gelatinisation enthalpy change (ΔH_g) of the blends. Samples of 10 BP, 10 BPX and 10 BPC significantly decreased ($p < 0.05$) the breakdown, final viscosity and setback of the mixtures. These are vital characteristics to understand prior to the development of new formulation for low-calorie, wheat-based products.

Ozola *et al* (2012) presented a study that said celiac disease is an immune-mediated disease, triggered in genetically susceptible individuals by ingested gluten from wheat, rye, barley and other closely related cereal grains. The only effective treatment is a strict gluten free diet for life. Latvian producers do not offer gluten-free products. In this research, use of extruded maize flour was tested for substituting rice, maize or buckwheat flour in gluten-free bread formulations at different ratios. In addition, the influence of extruded maize flour on the quality parameters of gluten-free bread was investigated. The aim of research was to study the influence of extruded maize flour on gluten-free bread quality. Addition of extruded maize flour affect gluten-free bread crumb colour, structure of crumb, weight loss and dry off bread.

Hussain *et al* (2013) studied the functional properties such as water holding capacity (WHC), oil holding capacity (OHC), least gelation capacity (LGC), emulsifying activity (EA) and foaming capacity (FC) of full fat and defatted maize flour using response-surface methodology. A positive significant linear effect ($p > 0.05$) of concentration of maize flour in the blend on WHC, OHC and EA and a negative linear effect on LGC and FC was observed. Drying temperature had a positive significant linear effect while the quadratic and interaction effects of both variables were found to be non-significant in each case. The optimum conditions of maize concentration in blend (g/100g blend) and drying temperature ($^{\circ}\text{C}$) generated from the statistical model for different functional properties were: WHC; 75 and 125, OHC; 25 and 75, LGC and FC; 75 and 75 and EA; 75 and 125 respectively.

Sumbo and Victor (2014) objected this study to determine the chemical composition; functional properties and amino acids profile of Quality Protein Maize (QPM) and compared with Common Maize (CM). The maize grains and maize meal were assessed for physical properties, proximate composition, mineral, functional properties and amino acid profile using standard methods. The results showed that the proximate composition of QPM 9.72% (protein), 4.85% (fat), 1.50% (ash) and 73.98% (carbohydrate) were within the same range for CM. There was no significant difference ($p > 0.05$) in the proximate composition of the two varieties of maize. The amino acid profile of the QPM was significantly higher ($p < 0.05$) than CM in terms of lysine (2.64 g/100g), isoleucine (2.74 g/100g), phenylalanine (4.20 g/100g). The functional properties of QPM in terms of bulk density, water and oil absorption capacities showed no significantly difference ($p > 0.05$) from CM. However, the final viscosity of QPM (267.75 RVU) was significantly lower ($p < 0.05$) than 458.08 RVU of the CM. QPM can be integrated into the family diet and especially in the weaning food formulation for infant where protein energy malnutrition is a serious problem, due to the higher level of the essential amino acids in the available protein of quality protein maize.

Amir *et al* (2014) examined to investigate the chemical and rheological properties of composite flours prepared by using whole wheat flour (*Triticum aestivum*), whole maize flour (*Zea mays*) and whole sorghum flour (*Sorghum bicolor*). Seven blends were prepared by homogenously mixing maize and sorghum flours with wheat flour in the percentage proportions: 0:100, 10:90, 20:80, 30:70, 15:15:70 (MF: WWF, SF: WWF and MF: SF: WWF) and later used to make cookies. Chemical, rheological properties of the composite flours and sensory characteristics of cookies made from the above combinations were determined. The results of the proximate composition showed that the T3 possesses highest percentage of protein (14.80%), crude fibre (3.19%) and ash (1.79%) while T6 contain maximum value of moisture (10.10%), crude fat (2.268%) and T0 showed maximum NFE (72.09%). Farinogram properties such as dough water absorption, dough development time (DDT), departure time and stability decreased as the amount of substituted sorghum and maize increased whereas arrival time increased. Statistical results revealed that the addition of sorghum, maize and a combination of these whole flours have highly significant effect ($p < 0.01$) on the sensory characteristics of cookies.

Offia and Blessing (2014) studied that walnut (*Juglans regia*) seeds are edible rich source of several essential nutrients, which can be processed into flour for several purposes. Composite flour blends (wheat/walnut flour) in the ratio of 100:0, 90:10, 80:20, 70:30, and 50:50 were produced and analysed for proximate composition, functional properties and pasting properties using standard techniques. Proximate composition results indicated increased level of protein and fat (12.17% - 25.70% and 2.40% - 37.57%) respectively while

carbohydrate decreased (63% - 19.4%) with increasing level of substitution with walnut flour. Functional analysis result indicated a decreasing level of bulk density and water absorption capacity (0.78% - 0.52% and 5.17% - 4.03%) respectively while swelling capacity increased (2.00% - 7.53%) with increasing level of walnut flour substitution. Pasting properties data indicated a decreasing level of pasting viscosity (92.69 - 42.30), trough (59.19 - 39.60) RVU, breakdown (33.55 - 2.92) RVU, final viscosity (252.09 - 95.51) RVU, setback (192.85 - 55.93) RVU with increasing level of walnut flour substitution. Results showed that supplementing wheat flour with walnut flour considerably improved the protein and fat content of the flour; hence, they can find useful application for making of pastries like cakes and other snacks.

Sidhu *et al* (a) (2016) undertook this work to evaluate the effect of milling speed on the quality and shelf life of maize flour. Maize flour was prepared using low speed mini flour mill at 75 and 115 rpm and the results were compared with the flour prepared by commercial flour mill on the basis of recovery, rise in temperature, time taken, particle size distribution and changes in different quality parameters during storage. It was observed that the recovery of flour was highest (95.26%) at 75 rpm speed although the time taken was more i.e. 27.27 minutes, but the rise in temperature during milling was very less (12.24 °C) as compared to commercial mill the temperature rose up to 31.12 °C. The maize flour prepared at low speed was light yellow in color as compared to higher rpm which was dark yellow. The maize flour prepared at 75 rpm can be stored in low density polyethylene LDPE packaging material for two months without change in quality parameters. It was observed that the moisture content, protein content, fat content, alcoholic acidity and carbohydrates was significantly affected by storage time, packaging material and milling speed at $P < 0.05$.

Sidhu *et al* (b) (2016) assessed the effect of milling speeds on shelf-life and proximate composition of pearl millet flour. Pearl millet flour was prepared using low speed m flour mill at 75 and 115 rpm and the results were compared with the flour prepared using commercial flour mill. The performance of flour mill was evaluated on the basis of recovery, rise in temperature, time taken, particle size distribution and different quality parameters. The whole pearl millet flour was packed in high density polyethylene (HDPE), lower density polyethylene (LDPE), plastic jars and stored for 50 days at ambient conditions. The recovery of flour was higher (95.26%) at 75 rpm speed than at 115 rpm although the time taken was more i.e. 25 min. but the rise temperature during milling was very less (13.45 °C) as compared to the commercial mill where the temperature rose up to 36.5 °C. The moisture content and FFA increased significantly ($P < 0.05$), whereas the protein, fat and ash content decreased significantly ($P < 0.05$) with increase in storage time.

Shakpo and Osundahunsi (2016) studied the production of nutritious low cost complementary foods in developing countries. The objective of this study was to examine the complementary effect of cowpea on some quality attributes of maize flour. Flour blends were produced from maize and cowpea flours in the following ratios of maize: cowpea; 90:10, 80:20, 70:30 and 100% maize as control. Physicochemical (proximate, mineral and functional properties) and microbiological analyses were carried out on the flour blends. The proximate result showed that the protein content ranged from 8.85 to 10.52%, total ash, 1.55 to 1.93%; fat content, 10.50 to 11.96%; moisture content, 5.05 to 5.77% and fibre content, 9.88 to 14.43%. The blend with 30% cowpea substitution gave the highest value. It was observed that fat content was not affected by cowpea substitution. Mineral determination showed that potassium, sodium, zinc, and iron contents increased with cowpea substitution in the blends, with 30% cowpea substitution having the highest values. Calcium contents were 3.34, 3.36, 3.39 mg/kg for 10%, 20% and 30% cowpea substitution respectively, whereas calcium was not detected in 100% maize. Functional properties evaluated showed that bulk density ranged from 0.72 to 0.81 g/ml, swelling index, 0.66 to 1.03 ml/g, least gelation, 2.10 to 6.11%, foaming, 7.67 to 15.36%, water absorption, 2.41 to 3.23%, oil absorption 1.24 to 1.45%, emulsion capacity, 8.76 to 37.15% and emulsion stability 7.43 to 14.13%. Microbiological evaluation for the flour blends showed that total viable count ranged from 3.80 to 4.7 x 10³ Cfu/ml, while yeast and mould count ranged from 2.2 to 3.17 x 10³ Sfu/ml for blends. The overall result showed that 20% cowpea substitution is the most adequate percentage to produce an acceptable and nutritious flour blend from maize and cowpea which can be useful for pastries and confectioneries.

Chhabra and Kaur (2018) studied that with passage of time, the demand of gluten free cereals has inclined. Although the maize chapatti is traditional product but their preparation challenges has been overlooked till yet. The maize cultivars i.e PMH1, JL3459 and Buland were milled in atta chakki and their particle size <60, <70 and <80 µm obtained by passing the flour through mesh sieves B1, B2, B3 respectively, and their influence on the composition, pasting properties of flour along with preparation technology and quality of maize chapatti was evaluated. ANOVA indicated that chemical composition in terms of protein, fat, ash, reducing sugar, amylose, beta carotene, neutral detergent fiber and acid detergent fiber was differed insignificantly among the various fractions. Pasting data revealed that finest fraction of maize cultivars had highest pasting and final viscosity. The finest fraction of maize cultivar had better preparation ease in regard to dough handling and rollability.

2.2 Quality assessment of flat bread

Gocmen (2009) stated that the most significant property of flat breads that differ from other loaves is that they have lower specific volumes. In this research paper, a short summary of the main ingredients used in the flat bread manufacture, manufacturing steps of flat bread, some of the flat breads produced globally and the production methods of most common Turkish flat breads are stated

Gurushree (2010) studied the portable and manually operated chapatti press cum vermicelli extruder. This device was designed and manufactured for the manufacture of chapatti and vermicelli. Sensory evaluation for pressed and rolled chapattis showed that quality of chapatties was not skeptically affected as a result of mechanical pressing. The difference in time for making chapattis by manual rolling and machine pressing was 17 seconds per chapatti and it was analytically significant. Combined machine produced more number of chapattis as compared to manual sheeting. There was an observed difference in the thickness and diameter of the two.

Parimala and Sudha (2013) reviewed the traditional flat breads of India like chapatti, poori, tandoori roti, parantha, naan, bhatura, kulcha etc. This review delved over the advancements and enhancement brought about in the storage and large scale production of a few of these breads because of their growing demands in domestic as well as in global markets. This review also indicated the prospects and wide scope available for technological advancements for traditional flat breads.

Yousif (2013) examined the sensory and physical properties of gluten free balady flat bread constituting rice flour, corn and potato starch blends with different levels of hydrocolloids. Conclusions showed that hydrocolloids clearly improved the weight and roundness of gluten free balady flat bread. Bread formulations of four different samples showed lower moisture content after storing them at room temperature for 72 hours with higher moisture retention ability. All the balady flat bread samples were sensory acceptable as they had recorded higher scores in quality characteristics. Samples of bread formulations had lower hardness and remained soft during 72 hours of storage conditions.

Mancebo *et al* (2014) investigated hydrocolloids have as an alternative to gluten for making good quality products for coeliac patients. This study investigated the interactions between hydroxyl propylmethylcellulose (HPMC) (2–4 g/100 g of flour), psyllium (0–4 g/100 g of flour) and water level (90–110 g/100 g of flour) in gluten-free breadmaking. Psyllium incorporation reduced the pasting temperature and compliance values, and increased elastic (G') and viscous (G'') moduli values. In contrast, HPMC addition had no important effects on pasting properties and compliance values, but also increased G' and G''

values. Psyllium inclusion reduced bread specific volume and increased bread hardness, while there were hardly differences in the bread specific volume and hardness between the percentages of HPMC studied. In addition, when the dough hydration level was increased, there was a decrease in the influence of hydrocolloids on dough rheology and specific volume and hardness of breads.

Tadesse and Nigusse (2015) reviewed the nutritional, microbial and sensory qualities of flat bread prepared from blends of maize flour and orange fleshed sweet potato flour. Flat breads were prepared with different ratios of maize and orange fleshed sweet potatoes. The proximate analysis of flour and flat bread was performed. The total bacteria and mold count was done and the sensory acceptability of flat bread was carried out. Based on the results of proximate analysis, the orange fleshed sweet potatoes based flat bread samples were found to be rich in beta carotene and fulfilled 61.63-86% of nutritional and dietary allowance of pre-school children. The total coliform, mold content and the yeast count of the orange fleshed sweet potato incorporated flat breads showed microbiological and sensory acceptability.

Pahwa (2015) reviewed the supplementation of several hydrocolloids having non identical chemical structure and diverse emergence to the flat bread making process. Hydrocolloids have a number of water soluble polysaccharides which provide a range of functional properties to make them suitable for this application. They give a proper texture, moisture control, overall product quality and stability, cost reduction and facilitate processing of flat breads. Hydrocolloids were used for reducing the staling and improving the quality of the fresh product.

Shemwal *et al* (2016) aimed this study to produce complementary food that will meet the nutritional requirement of infants, aged persons, youths, children by addition of nutrient rich flax seed. Efforts were made to prepare rice roti fortified with flax seed flour along with other ingredients. Rice roti fortified with flaxseed at different concentration (0-20%) was subjected for sensory evaluation by a panel of semi trained judges and found that incorporation of flaxseed (10%) was optimum to get well accepted rice roti. Standardized flax seed roti was analyzed for its proximate composition standardized. Sorbic acid was used to enhance the shelf-life of roti. Initially and a regular interval of time samples were analysed for proximate composition, physico-chemical parameters, microbiological and sensory evaluation. It was found that rotis preserved using Sorbic acid remained microbiologically stable even after 1 month of storage studies as compared to roti prepared without using Sorbic acid which get spoiled due to the development of mold growth after 8 days of storage. During storage, there was a slight increase in peroxide value, free fatty acid value, thiobarbituric acid value. There was no significant increase in hardness during storage.

Eshak (2016) aimed of this study to evaluate the effect of two different concentrations of banana peels BP (5% and 10%) as a partial replacement for wheat flour on physicochemical and sensory properties of Egyptian balady flat bread. The peel powder (0.50 mm size) from banana was prepared from their dried peel. The bread was prepared by replacing 5% and 10% of wheat flour with a banana peel. The bread prepared was designated as B1 and B2 respectively. They were tested for moisture, ash, protein, fat, crude fibre as per the standard methods. The physicochemical and sensory parameters of these two test bread were compared with controlled bread 100% wheat flour designated as B0. Results showed that BP flour owed 11.20% crude fibre, which is higher than the wheat flour 1.21%. In addition, BP flour has high potassium, calcium, sodium, iron and manganese compared with wheat flour. The protein and fibre content of B2 and B1 bread were higher (12.52% and 11.79% protein and 2.18% and 1.97% fibre) as compared to the control bread (10.79 proteins and 1.42% fibre). B1 and B2 had the highest K, Na, Ca, Fe, Mg and Zn content compared with controlled bread. The water holding capacity (WHC) and oil holding capacity (OHC) of bread with BP flour were higher as compared to the bread control. The bread prepared by replacing 5% and 10% of BP (B2) is found to be sensorially acceptable. Our results showed that the nutritionally and sensory accepted bread can be prepared by replacing at most 10% of flour.

Shah *et al* (2017) developed maize flat bread supplemented with asparagus bean flour (ABF). Preliminary study was conducted for maximum supplementation of ABF on the basis of sensory attributes and it was found that 15% ABF can be supplemented. Further, a composite flour containing 85% maize flour (MF) and 15% ABF was used for the preparation of flat bread. The effect of baking temperature (200 to 235 °C) and baking time [time 1 (surface 1) and time 2 (surface 2)] (70 to 120 sec) on product responses such as sensory characteristics (overall colour, appearance, flavour, taste, mouth feel, overall acceptability), texture (shear value) and moisture content were studied. Results indicated that baking temperature and baking time had significant ($p < 0.05$) positive effect on sensory characteristics and shear value, while significant ($p < 0.05$) negative effect on moisture content. Numerical optimization resulted in baking temperature 225 °C, baking time 1 (120 sec) for surface 1 and time 2 (116 sec) for surface 2 to develop a flat bread with best quality.

2.3 Packaging and Storage

Rao *et al* (1986) studied the tearing resistance tester and Warner Bratzler shear press to evaluate, objectively, the quality changes in chapatti during storage. Tearing strength, indicative of development of brittleness, decreased markedly from 72.5 to 31.0 g and only slightly during three days' storage when chapatti was packed in polyethylene pouches and in

waxed paper, respectively. Warner Bratzler shear value served as an index of texture and decreased by 21 and 46% for chapattis packed in waxed paper and polyethylene pouches, respectively. A simple pliability tester was devised to measure chapatti pliability. When chapattis were packed in waxed paper, pliability decreased from 2.3 to 1.2 cm, but increased from 2.1 to 4.4 cm when packed in polyethylene pouches. Although no significant difference was observed in salt-soluble proteins and ether extractives during storage, starch was found to be affected significantly. This was indicated by decreases in water retention capacity, falling number, enzyme-susceptible starch, and soluble starch. Furthermore, both amylose and amylopectin were found to decrease, possibly contributing thereby to staling of chapatti. Although heat treatment of chapatti packed in a polyethylene pouch delayed mold attack from three to 90 days, the chapatti had a somewhat cooked flavor and was brittle, as indicated by the marked decrease in shear value. Addition of salt (1.25%), glycerol monostearate (0.5%), sorbic acid (0.2%), and fat (4%) minimized the development of brittleness to some extent.

Friedman (1996) studied the enzymatic and non enzymatic browning reactions of amino acids and proteins with carbohydrates, oxidized lipids, and oxidized phenols cause deterioration of food during storage and processing. The loss in nutritional quality and potentially in safety is attributed to destruction of essential amino acids, decrease in digestibility, inhibition of proteolytic and glycolytic enzymes, interaction with metal ions, and formation of anti nutritional and toxic compounds. Studies in this area include influence of damage to essential amino acids on nutrition and food safety, nutritional damage as a function of processing conditions, and simultaneous formation of deleterious and beneficial compounds. These compounds include kidney-damaging Maillard reaction products, mutagens, carcinogens, antimutagens, antioxidants, antibiotics, and anti allergens. This overview covers the formation, nutrition, and safety of glycated proteins, characterized browning products, and heterocyclic amines. Possible approaches to inhibiting browning reactions and preventing adverse effects of browning during food processing and food consumption, including protection against adverse effects of heterocyclic amines by *N*-acetylcysteine, caffeine, chlorophyll, conjugated linoleic acid, lignin, and tea extracts, are also described. This research subject covers a complex relationship of the chemistry, biology, and pathology of browning products and the impact on human nutrition and health. Future study should differentiate anti nutritional and toxicological relationships, define individual and combined potencies of browning products, and develop means to prevent the formation and to minimize the adverse manifestations of the most anti nutritional and toxic compounds. Such studies should lead to better and safer foods and improved human health.

Majzooobi (2011) reviewed some of the physical characteristics and the manufacture of partly baked flat bread (Barbari). Properties like volume, hardness, color, weight loss and micro structure were studied during the storage of the samples at ambient (25°C) and refrigerated (-18°C) conditions. The partly or the half baked bread had a higher moisture content than the controlled or fully baked bread. And it had a shorter shelf life of 72 hours than that of fully baked breads at the ambient temperature conditions. Full baking of the bread leveled out the effects of staling and thus the quality of the full baked bread was similar to that of the fresh bread. For the refrigerated samples, the peak storage time was of two months. The undesirable effects of freezing during the storage were more for the partly baked bread. Moreover, full baking compensated some of the adverse impacts of freezing and thus the resultant bread had a superior quality than the controlled ones.

Kadam *et al* (2012) studied the effect of packaging materials and storage periods on biochemical qualities of whole and degermed maize flours. The flours were packed in three packaging materials viz. aluminium laminated foil (ALF), high density polyethylene (HDPE) and low density polyethylene (LDPE) and its biochemical qualities were determined at ten days storage interval for 70 days storage. The moisture, fat and FFA were increased whereas protein, total acid and ash contents decreased with increase in storage interval. Maize flour stored in aluminium foil found best followed by HDPE. Biochemical qualities of degermed maize flour showed that it can be stored for longer period as compared to whole maize flour.

Barnwal *et al* (2013) studied the effect of packaging materials and storage periods on biochemical qualities of whole and degermed maize flours. The flours were packed in three different packaging materials viz. aluminium laminated foil (ALF), high density polyethylene (HDPE) and low density polyethylene (LDPE) packages and its biochemical qualities were determined at every ten days storage interval for 70 days. Degermed maize flour was found better in terms of moisture, protein, fat, ash, FFA and alcoholic acidity as compared to the whole maize flour. The moisture, FFA and alcoholic acidity were increased whereas protein, fat and ash contents decreased with increase in storage interval. The moisture, fat, protein, FFA and alcoholic acidity were significantly affected by storage time and packaging material whereas the ash and crude fibre varied non-significantly. Both whole and degermed maize flours, stored in ALF packages, were found best followed by HDPE.

Khan *et al* (2013) examined that chapatti, an unleavened, hot plate baked product was prepared using fresh spinach paste and permitted level of antimycotic agent like sorbic acid. Chapatties were in pack sterilized and finally packed in PFP packaging materials and stored at ambient room temperature conditions. Initially and at a regular interval. Chapatties were evaluated for physico-chemical changes, sensory attributes, colour values, texture profile and

microbiological profile. Chapaties remained stable and acceptable for 12 months of storage studies at ambient room temperature conditions (14-34 °C)

Khan *et al* (2017) analysed that the stuffed parothas are perishable in nature and got spoiled within 24 hrs of their preparation. Armed Forces required food products having a longer shelf life with high nutritive value. Germination results an increase in nutritive value in terms of protein, fibre and minerals. Hence efforts were being made to develop shelf stable stuffed parothas using germinated green gram and permitted level of antimycotic agent with inpack heat treatment. Stuffed parothas were subjected to heat treatment at 90 °C for 2 hrs and stored at ambient temperature conditions (14-34 °C). Shelf-life of stuffed parothas was evaluated chemically, sensorily and microbiologically to assess their shelf-life. After 9 months of storage, peroxide value (PV), thiobarbituric acid value (TBA), free fatty acid value (FFA) and browning index increases significantly ($p \leq 0.05$) from 5.12 to 19.24 meqO₂/Kg fat, 0.087 to 0.142 mg MA/Kg sample, 0.75 to 1.69 % oleic acid and 0.082 to 0.112 respectively. During storage, there was no significant decrease in sorbic acid content was observed. Negative correlation was observed between chemical changes and overall acceptability during storage. During storage, textural and colour values had an impact on sensory scores which decreases significantly ($p \leq 0.05$) from 8.5 to 7.5 on a nine point hedonic scale. Microbiologically stuffed parothas remained stable during entire period of storage. Highly acceptable and nutritious germinated green gram stuffed parothas with longer shelf-life can be prepared using antimycotic agent and in pack heat treatment. The product remains safe chemically and microbiologically up to 9 months of storage at ambient temperature conditions.

CHAPTER III

MATERIAL AND METHOD

The experiments to accomplish the desired objectives were performed in the laboratories of the Department of Processing and Food Engineering, Punjab Agricultural University, Ludhiana. The maize kernels were procured from Punjab Agricultural University farm. The details of material used and methodologies employed for completing various experimental observations have been discussed as under:

3.1 Experimental design and equipments used

The experimental setup used for the study is shown in the Table 3.1 and the important equipments used during study are shown in Table 3.2.

Table 3.1 Design of experiment

Sr. No.	Heading	Description
1	Variety	Maize PMH 1
2	Treatment	Cleaning, grinding and sieving of maize kernels. The whole maize flour was divided into coarse, fine and very fine flour. The blended flour was prepared by adding substitution of wheat flour (20, 30 and 40%) and gram flour (20, 30 and 40%)
3	Preparation of dough	The dough was prepared by varying temperature of water and particle size of flour using dough maker machine.
4	Preparation of maize flour flatbread	Maize flour flatbread was prepared for all the flour samples using 'Roti making machine'.
5	Design of experiment	Box-Behnken design using Response Surface Methodology (RSM)
6	Primary observations	Efficiency of milling machine, particle size distribution, uniformity index, recovery of different sized flour, proximate composition of whole maize and blended flour viz. protein content, moisture content, fat content, titrable acidity, free fatty acid, ash content, carbohydrates, swelling power, water holding and oil holding capacity and morphological properties of flour.
7	Secondary observations	Colour of dough, texture of dough, flatbread colour, texture and sensory and microbial evaluation of flatbread.
8	Quality test	Flatbread quality parameters during storage in HDPE packaging material and in refrigerated and ambient conditions.
9	Analysis	Statistical analysis using Design Expert10 7.0 software

Table 3.2 List of equipments used during research

Sr. No.	Name of equipment	Description	Application
1	Universal weighing balance	5 Kg capacity with least count of 0.05 g.	Weighing of samples
2	Hot air oven	Model SNW-143, Range 0-250 ^o C	Drying of samples
3	Muffle furnace	Industrial furnace (SVSW MAKE)	Determination of ash content
4	Hunter Colorimeter	Miniscan XE plus hunter lab colorimeter	Colour (L, a, b values)
5	Burr mill	Jas-GM-1302BL, 2 Hp, 1.75 Kw, 25-30 Kg grinding capacity per hour	Grinding of maize kernels
6	Ro-Tap shaker	VEW, 1440 rpm, 0.25 Hp, 50 Hz	Sieving of flour
7	Electronic UV spectrophotometer	Digital spectronic	Determination of protein content
8	Mini centrifuge machine	REMI R8C Laboratory centrifuge	Protein content
9	Vernier calliper	Digital	Thickness of flatbread
10	Texture analyser	Instron, TA-XT2	Determination of texture dough and flatbread
11	Dough maker machine	Havels Dough maker	Dough preparation
12	Roti maker machine	Prestige Roti Maker PRM 1.0, 230 volts/900 watts	Flatbread preparation
13	Electronic orbital shaker	230 VAC 50 Hz, 200 rpm, 250 Kg	Determination of free fatty acid
14	Soxhlet apparatus	Kjeltech fat analyser	Determination of fat content
15	Hot air oven	Model SNW-143, Range 0-250 ^o C	Determination of moisture content
16	Thermometer	Mercury thermometer	Determination of temperature
17	Precision weighing balance	AND electronic balance FX-320	Weighing of samples
18	Scanning electron microscope	Hitachi, S-3400N	Determination of morphological characteristics

3.2 Procurement and preparation of sample

Commercially available PMH 1 variety of maize kernels was procured from the seed farm of Punjab Agricultural University, Ludhiana. The moisture content of the maize kernels was determined using standard method (AOAC 2000). Cleaned and healthy grains were selected for the study.



Fig 3.1 Maize kernels of PMH1 variety

3.2.1 Grinding of maize kernels

The burr mill was used to grind the maize kernels as shown in Fig 3.2. The clearance between the two stones of burr mill was set and grains were fed to the mill through the hopper. A batch of 5 kg was used at a time for grinding the kernels into fine particles. The time taken for grinding of one batch of maize kernels was recorded.



Fig. 3.2 Mini burr mill

3.2.2 Sieve analysis

After grinding the maize kernels, the sieve analysis was done using tyler sieve set at Ro-Tap shaker. The fineness modulus, uniformity index and average particle size were determined by using increasingly small screens, to give a series of particles classified into size ranges i.e. sieve analysis. In sieve analysis, the material was shaken above a mesh screen; particles of smaller size than the mesh openings can pass through under the force of gravity. Standard sieve sizes have been evolved, covering a range from 5.6 mm aperture down to about 0.180 mm aperture i.e. 5.6 mm, 2.8 mm, 1.4 mm, 0.710 mm, 0.355 mm, 0.180 mm and pan. A logical base for a sieve series was that each sieve size having fixed relation to the next larger and to the next smaller i.e. 2:1 and this has been chosen for the standard series of sieves, the Tyler sieve series. Calculation of fineness modulus, uniformity index and average particle size is described below:

$$\text{Fineness modulus} = \text{Total fineness number} \div 100$$

$$\text{Uniformity Index for Fineness number} = \frac{x}{10} : \frac{y}{10} : \frac{z}{10}$$

$$\text{Average Particle size} = 0.0104 \times 2^{\text{FM}} \text{ mm}$$

Where,

x= sum of coarser sized particle

y= sum of medium sized particles

z= sum of fine sized particles

FM= Fineness modulus

3.2.3 Blending of whole maize flour

The maize flour was divided into three parts i.e. coarse (5.6 mm – 1.4 mm), fine (0.7 mm – 0.355 mm) and very fine particles (0.180 mm). For the purpose of flatbread preparation, the flour size selected was 180 μm (very fine particles) and 355 μm (fine particles). The flour was then blended with gram flour and whole wheat flour. The blending was done with flour mixer. The different combination of flours and their labelling symbols are depicted in the Table 3.3. Atta samples obtained from different combinations were labelled as Atta A, B, C, D, E, F, G, H, I, J, K, L, M and N respectively as presented in Table 3.3.

Table 3.3 Depiction of different combinations of maize flour (*atta*) samples

Flour sample	Composition
A	Very fine whole maize flour
B	Very fine flour + 20% wheat flour
C	Very fine flour + 30% wheat flour
D	Very fine flour + 40% wheat flour
E	Very fine flour + 20% gram flour
F	Very fine flour + 30% gram flour
G	Very fine flour + 40% gram flour
H	Fine whole maize flour
I	Fine flour + 20% wheat flour
J	Fine flour + 30% wheat flour
K	Fine flour + 40% wheat flour
L	Fine flour + 20% gram flour
M	Fine flour + 30% gram flour
N	Fine flour + 40% gram flour

3.3 Determination of physico-chemical properties of whole and blended maize flour

The physico-chemical parameters of whole and blended maize flour like moisture content, protein content, crude fat, crude fibre, ash content, carbohydrates, titrable acidity were determined using standard methods as discussed under:

3.3.1 Moisture content of maize flour

The initial moisture content of maize flour samples was measured by standard hot air oven method (AOAC 2000). The flour samples were kept in oven at 130 °C for 4 hr. The loss in weight was noted down and moisture content was determined using the following equation:

$$\text{Moisture content (\% wb)} = \frac{W_1 - W_2}{W_1} \times 100$$

Where,

W_1 = Weight of the sample before drying

W_2 = Weight of the sample after drying

3.3.2 Protein content

Proteins were determined by Lowry *et al* method (1951) as under:

Preparation of chemicals

Reagent A: (2% sodium carbonate in 0.1N sodium hydroxide)- Sodium carbonate 2g was dissolved in 100ml 0.1N sodium hydroxide solution.

Reagent B: (0.5% copper sulphate in 1% sodium potassium tartarate)- Dissolved 1 g of sodium potassium tartarate in 100 ml of distilled water followed by addition of 0.5 g of copper sulphate.

Reagent C: Freshly prepared by mixing reagent A and reagent B in the proportion of 50:1.

Reagent D: Prepared by mixing Folin and Ciocalteu's phenol reagent and distilled water in proportion of 1:1.

Extraction of sample- 0.5 g of maize flour was taken in a test tube and 5 ml of 20 M Tris – HCl buffer containing 0.5% NaCl was added to it. It was centrifuged for 20 min and supernatant was collected.

Estimation of protein: About 0.1ml of supernatant was put in a test tube and 0.5ml volume was made by adding distilled water. 5 ml of reagent C was added to the test tube and vortex it. 0.5 ml of reagent D was added to it after 10 min and again vortexed properly. Absorbance of the colour developed was read at 520 nm using spectrophotometer (Fig.3.3). The concentration of protein was measured by preparing standard curve of Bovine Serum Albumin (BSA) at different concentration ranging from 20-100 µg.



Fig. 3.3 Spectrophotometer

3.3.3 Crude fat

Moisture free 5 g sample was taken in readymade thimble and oil was extracted in a pre-weighed beaker using petroleum ether in SOCS PLUS (Pelican Equipment Limited, Chennai, India) for 2.5 to 3 hours. The beaker was then dried in a hot air oven to evaporate petroleum ether. Final weight of the beaker was taken and used for the estimation of crude fat content of sample (AOCS 1980). The following equation was used for estimation of crude fat content (%) in the sample:

$$\text{Crude fat (\%)} = \frac{\text{Weight of fat (g)}}{\text{Weight of sample (g)}} \times 100$$

3.3.4 Ash content

Samples (5 g) were taken in triplicate in crucibles. These were burnt on hot plate and then placed in an electric muffle furnace at 600°C for 6 hours. After cooling the crucibles to room temperature, the residue left (ash) in the crucible was weighed (AOCS 1980). The following formula was used to calculate the ash content:

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

3.3.5 Crude fibre

Two grams of moisture and fat free sample was first digested with 200 ml boiling 0.255 N H₂SO₄ for 30 min. After acid digestion the mixture was filtered and washing of residue with hot water was carried out to remove traces of acid. Then alkali digestion was performed with 200 ml of 0.313 N NaOH for 30 min. Again the mixture was filtered and washed with hot water followed by alcohol and ether to remove traces of alkali. The residue was dried and weight was noted down. It was ignited in muffle furnace at 600°C for 3 hours and cooled and weighed. The following equation was used for estimation of crude fibre content (%) in the sample (AOCS 1980):

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

Where,

W = mass of dry sample

W₁ = weight of the crucible and the sample before ashing (g)

W₂ = weight of the crucible and the sample after ashing (g)

3.3.6 Carbohydrates

Carbohydrates were calculated by subtraction method as under:

$$\text{Carbohydrate (\%)} = (100 - (\text{moisture (\%)} + \text{ash (\%)} + \text{fat (\%)} + \text{protein (\%)} + \text{fibre (\%))})$$

3.3.7 Titrable acidity

Titration acidity of reconstituted sample was estimated by diluting the aliquot of the sample with water to a fixed volume and then titrated with 0.1 N NaOH using phenolphthalein as an indicator. Percentage acidity was calculated as the percentage of anhydrous citric acid using following method (Kadam *et al* 2010):

$$\begin{aligned} \text{Total acid (\%)} \\ = \frac{\text{Titre} \times \text{Normality of alkali} \times \text{Volume made up} \times \text{Equivalent weight of acid} \times 100}{\text{Volume of sample taken for estimation} \times \text{volume of sample taken} \times 1000} \end{aligned}$$

3.3.8 Colour measurement

Colour properties of maize flour were measured using Konika Minolta Colour Reader as shown in Fig 3.4. The colour was described by a value of 'L', 'a' and 'b' where L indicates the intensity of colour i.e. lightness which varies from 100 for perfect white to 0 for perfect black and 'a' and 'b' values are chromaticity dimensions which give understandable designations of colour i.e. the value of 'a' measured redness when positive, grey when zero and blueness when negative. The change in colour was calculated from 'L', 'a' and 'b' readings.

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

Where,

ΔL , Δa , and Δb are deviations from L, a, and b values of the fresh sample.



Fig. 3.4 Konika Minolta CR-10 colour reader

3.3.9 Swelling power

One gram of sample was poured into pre-weighed graduated centrifuge tube appropriately labelled. About 10 ml of distilled water was added to the weighed sample in the centrifuge tube and the solution was stirred and placed in a water bath heated at 65°C for 1 h while shaking the sample gently to ensure that the starch granules remained in suspension until gelatinization occurred. The samples were cooled to room temperature under running water and centrifuged for 15 min at 3000 rpm. After centrifuging, the supernatant was decanted from the sediment into a pre-weighed petridish; the supernatant in the petridish was weighed and dried at 105 °C for 1 h (Hirsch and Kokini 2002). The sediment in the tube was weighed and the reading was recorded. The starch swelling power was determined according to the equation below:

$$\text{Swelling power} = \frac{\text{Weight of swollen sediment}}{\text{Weight of the dry starch}}$$

3.3.10 Water holding capacity (WHC) and oil holding capacity (OHC)

The WHC and OHC of the samples were determined by using the methods suggested by Sosulski *et al* (1976). The flour/blend (2 g) was vortexed with distilled water (10 ml) in

pre weighed centrifuge tube for 30 minutes. After standing at room temperature for 30minutes, the sample was centrifuged for 25 min at 3000 rpm. The sediments were weighed after complete removal of the supernatant. For the determination of OHC, the flour/blend (0.5 g) was homogenized with canola oil (5 ml) in pre-weighed centrifuge tube and preceded further as described for WHC. The WHC and OHC (%) were calculated as:

$$\text{WHC (\%)} = \frac{\text{Total water mass}}{\text{Dry matter mass}} \times 100$$

$$\text{OHC (\%)} = \frac{m(\text{oil}) - m(\text{d})}{m(\text{d})} \times 100$$

Where, m (oil) and m (d) are mass of oil and mass of dry material respectively.

3.4 Morphological characteristics of flour

The morphology of whole maize flour was examined using a scanning electron microscope (Hitachi, S-3400N) as shown in Fig. 3.5. Flour sample was initially suspended in acetone to obtain a 1% (w/v) suspension, and was then maintained in an ultrasound for 15 min. A small quantity of each sample was spread directly onto the surface of the stub and dried in an oven at 32°C for 1 h. Subsequently, the sample was sputter coated with gold and examined an acceleration voltage of 15 kV and magnifications of 1500× and 3000×.



Fig. 3.5 Scanning Electron Microscope

3.5 Experimental design for optimization

Design of experiment in the study was done by Box and Behnken method (Matos *et al* 2007) using RSM. Response surface methodology or RSM is the collection of mathematical and statistical techniques that are useful for modelling and analysis of problems in which the response is influenced by several variables. It is reported to be an efficient tool for optimising a process when the independent variable has a joint effect on the responses (Wani and Kumar 2016). Three levels of each three variables were chosen thus providing 17

combination points according to Box and Behnken design. Thus providing the best optimized value out of all the combinations. The parameter values have been shown in Tables 3.4 and 3.5.

3.5.1 Analysis of design

The analysis was done independently for each response variable with the help of response surface methodology (RSM) by using software ‘Design Expert DX10 7.0’ (Trial version 2017). The adequacy of the fitted model was tested through the analysis of variance.

Table 3.4 Level of variables chosen for Box-Behnken design for flatbread preparation

Independent variables	Coded	Levels		
		-1	0	+1
Resting time of dough (min)	A	0	10	20
Blending ratio of flour (%)	B	20	30	40
Temperature of water used for dough kneading (°C)	C	18	27	36

Table 3.5 Experimental combination for response surface analysis for flatbread preparation

Std	Runs	Resting time of dough (min)	Blending ratio of flour (%)	Temperature of water (°C)
1	1	0	20	27
5	2	0	30	18
15	3	10	30	27
9	4	10	20	18
2	5	20	20	27
6	6	20	30	18
7	7	0	30	36
11	8	10	20	36
12	9	10	40	36
4	10	20	40	27
13	11	10	30	27
8	12	20	30	36
3	13	0	40	27
10	14	10	40	18
16	15	10	30	27
14	16	10	30	27
17	17	10	30	27

3.6 Dough preparation

The dough was prepared using dough maker machine as shown in Fig 3.6. About 200 g of flour sample was put in a dough maker and water was added as per the results obtained by the water holding capacity with slight correction to get the desired consistency of dough for 'roti' making. The electrically operated dough maker machine was run at a fixed speed to prepare the maize flour blended dough. The dough was prepared by varying the water temperature i.e. ambient temperature (18°C), lukewarm (27°C) and warm (36°C). Time taken for preparation of dough was noted. Similar procedure was followed for all the 17 *atta* samples.



Fig. 3.6 Dough maker machine

3.7 Evaluation of quality of dough

3.7.1 Texture profile analysis

Textural profile analysis (TPA) of all the dough samples was carried out using texture analyser (Instron, TA-XT2) as shown in Fig. 3.7. The sample was positioned on the base table underneath a 6 mm cylinder probe, which is attached to the texture analyser. At the beginning of the procedure, this probe was positioned 20 mm above the sample with trigger force of 0.10 N. Once the test commenced, the probe descended at a speed of 1 mm per second, and pierced to a depth of 15 mm beyond the sample surface. The trigger load used to instigate data recording once the probe makes contact, was set at 5 grams (Siddiq *et al* 2009).



Fig. 3.7 Universal testing machine for texture analysis

3.7.2 Colour change assessment of dough

Colour properties of dough samples were measured using Konica Minolta CR-10 colour reader. The colour was described by a value of 'L', 'a' and 'b' where L indicates the intensity of colour i.e. lightness which varies from 100 for perfect white to 0 for perfect black and 'a' and 'b' values are chromaticity dimensions which give understandable designations of colour i.e. the value of 'a' measured redness when positive, grey when zero and blueness when negative. The change in colour was calculated from 'L', 'a' and 'b' readings as:

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

Where,

ΔL , Δa , and Δb are deviations from L, a, and b values of the fresh sample.

3.8 Preparation of flatbread

The dough prepared with different combination of *atta* was further processed for making flatbreads in the roti maker machine as shown in Fig. 3.8. About 25 g of dough was rolled into the roti maker for preparation of circular '*chapatti*'. The time taken to cook one flatbread under optimised circumstances was observed. The flatbreads were then observed for different physico-chemical properties as described below. The dough sheet (roti) was prepared and baked in roti maker. The flatbreads were allowed to cool at room temperature.



Fig. 3.8 Roti maker machine

3.9 Quality evaluation of flatbread

Different physico-chemical quality parameters of flatbread like the moisture content, colour, browning index, free fatty acid, peroxide value and the texture profile was determined using standard methods.

3.9.1 Browning intensity

Browning intensity was measured by shaking 5 g maize flatbread sample with 100 ml 70% ethanol for 2 hr, filtering and measuring optical density at 420 nm with the help of spectrophotometer (Khan *et al* 2011) as shown in Fig. 3.9.



Fig. 3.9 Flatbread samples dipped in ethanol for measuring browning intensity

3.9.2 Peroxide value (PV)

About 5 g of maize flour flatbread sample was dissolved in a mixture of acetic acid-chloroform (3:2 v/v) and saturated solution of KI (1 ml) was added. The liberated iodine was

titrated with a sodium thiosulphate solution (0.01 N) in the presence of an indicator. (AOCS 1990) The peroxide value is determined by the following formula:

$$\text{Peroxide value} = (S - B) \times N \text{ Thiosulphate} \times 200$$

Where, S = Titration of sample

B = Titration of blank

3.9.3 Free fatty acid (FFA)

Ten grams of flatbread sample was weighed into a flask, 30 ml of neutralised ethanol and a few drops of phenolphthalein indicator were added and the mixture was warmed to promote dissolving. The solution was titrated with NaOH (0.01 N) solution until a pink colour was stable for at least 20 seconds. (AOCS 1993) The free fatty acid value is determined by the following formula:

$$\text{FFA (\%)} = \frac{\text{Acid value}}{2}$$

3.9.4 Texture analysis of flatbread

Cutting force of flatbread was evaluated by using the texture analyzer. Flatbreads, which were packed in polypropylene pouches, were removed and three strips measuring 4 cm × 2 cm were cut. One strip at a time was placed on the centre of the sample holder and the blade was allowed to cut the flatbread strip. The force required to cut the flatbread strip into two pieces was recorded. The speed was maintained at 1.70 mm/s (Szczesniak 1975).

3.10 Microbial profile of flatbread

The total mold count was carried out on the flatbread samples after every 2 days of storage. Flatbread samples were taken aseptically and homogenized in 99 ml sterile peptone water 0.1% in a blender for about 2 minutes and serial dilutions were made. One millilitre of each dilution were pour plated in sterile Petri dishes, the stomacher dilution represent the 10⁻¹ dilution, 10⁻², 10⁻³, 10⁻⁴ and 10⁻⁵ dilution prepared by using 9 ml peptone water tubes and the melted plate count agar (PCA) was used and incubated for 48 hours at 35°C for total bacterial count. Counts of visible colonies by using colony counter was made and expressed as log CFU/g of the original sample (Olaoye *et al* 2006).

3.11 Sensory evaluation

Organoleptic characteristics were determined through evaluation of overall acceptability by a semi trained panel consisting of staff members and students on a 9 point - +hedonic scale having a score of 9 for extreme liking and 1 for extreme disliking. The flatbread samples were cut in small pieces and presented to the sensory panel which sniffed

the sample pieces and described the perceived odour qualities. The panel finally agrees on characteristic attributes in a group discussion. The samples were presented again to the panel in a second session and the intensities of predefined odour and other attributes were evaluated (Premlatha *et al* 2012).

3.12 Storage of flatbreads

The flatbreads prepared under optimized conditions were packed in high density polyethylene (HDPE) of the thickness 200 gauge, under refrigerated and ambient conditions as presented in Fig. 3.10. The ambient temperature and relative humidity during storage was noted. The flatbreads were evaluated for change in moisture content, browning index, colour, peroxide value, free fatty acid, texture, overall acceptability and microbial load count at an interval of ten days for a total of thirty days of storage period under refrigerated and controlled conditions.



Fig. 3.10 Packed flatbreads

3.13 Statistical analysis

The data was analysed statistically by using RSM to determine the effects of different independent process variables on the various dependent parameters of the product (Montgomery 1995). Analysis was done using ANOVA using Design Expert software. Statistically significant differences among the means for the different methods were identified at 5% level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

The results obtained from the present investigation entitled ‘Optimization of process parameters for mechanized preparation of maize flour based flatbreads’ has been presented and discussed in this chapter. Maize grains of PMH1 variety were milled in a mini flour mill. The composite flour blends were prepared by supplementing maize flour with wheat flour and gram flour at different levels of 20%, 30% and 40% respectively. The dough was prepared by varying temperature of water using dough maker machine, when desired consistency of dough was obtained. The flatbreads were stored in HDPE package under refrigerated and controlled conditions. Different physico-chemical quality parameters viz. moisture content, browning index, colour change, free fatty acid value, peroxide value and texture were analysed. Microbial and sensory analysis was also done as discussed under:

4.1 Physico-chemical properties of whole maize and blended maize flour

4.2 Scanning Electron Microscope (SEM) analysis of flour

4.3 Optimization of process parameters for preparation of flatbreads

4.4 Effect of process parameters on quality of dough

4.5 Effect of process parameters and storage on quality of flatbreads

4.6 Microbial and sensory evaluation of flatbreads

4.1 Physico-chemical properties of whole maize and blended maize flour

The maize kernels of PMH1 variety were grounded in the mini burr mill. The maize flour with particle size of 180 μ was selected for the study. The physico-chemical properties for the whole and blended maize flour viz. moisture content, protein content, crude fat, ash content, crude fibre, carbohydrates, titrable acidity, colour change measurement, swelling power, water holding capacity and oil holding capacity were determined. The results of physico-chemical properties have been compiled in Table 4.1.

4.1.1 Moisture content

The moisture content of flour is important for two reasons, first, the higher the moisture content, the lower the amount of dry solids and secondly, the organisms present naturally in the flour start to grow at higher moisture contents, producing off odours and flavours. The moisture content of whole maize flour and blended maize flour varied from 8.56 \pm 0.01 to 8.66 \pm 0.01% as presented in Fig. 4.1.

Table 4.1: Physico-chemical properties of different flour samples

Sample	Moisture content (%)	Protein content (%)	Crude fat (%)	Ash content (%)	Crude fibre (%)	Carbohydrates (%)	Titration acidity (%)	Colour value (L)	Swelling power (%)	WHC (%)	OHC (%)
A	8.56 ± 0.01	10.45 ± 0.01	4.40 ± 0.01	2.38 ± 0.01	2.44 ± 0.01	70.13 ± 0.01	0.076 ± 0.001	70.03 ± 0.01	22.31 ± 0.01	70.32 ± 0.01	122.12 ± 0.01
B	8.59 ± 0.01	12.31 ± 0.01	5.37 ± 0.01	2.20 ± 0.01	2.71 ± 0.01	69.12 ± 0.01	0.080 ± 0.001	75.33 ± 0.01	30.32 ± 0.01	74.01 ± 0.01	125.07 ± 0.01
C	8.61 ± 0.02	12.43 ± 0.01	5.42 ± 0.01	2.21 ± 0.01	2.73 ± 0.01	68.79 ± 0.01	0.083 ± 0.001	75.41 ± 0.01	30.74 ± 0.02	74.09 ± 0.02	125.18 ± 0.01
D	8.58 ± 0.01	12.49 ± 0.01	5.45 ± 0.01	2.23 ± 0.01	2.74 ± 0.01	68.65 ± 0.01	0.085 ± 0.001	75.38 ± 0.01	30.95 ± 0.02	74.12 ± 0.02	125.21 ± 0.01
E	8.61 ± 0.02	12.78 ± 0.01	6.07 ± 0.01	2.25 ± 0.01	2.76 ± 0.01	66.45 ± 0.01	0.081 ± 0.001	65.39 ± 0.01	25.01 ± 0.02	72.34 ± 0.02	124.02 ± 0.01
F	8.65 ± 0.01	12.81 ± 0.01	6.11 ± 0.01	2.22 ± 0.01	2.80 ± 0.01	66.36 ± 0.01	0.079 ± 0.001	65.41 ± 0.02	25.16 ± 0.01	72.36 ± 0.01	124.05 ± 0.01
G	8.66 ± 0.01	12.84 ± 0.01	6.15 ± 0.01	2.25 ± 0.01	2.84 ± 0.01	66.16 ± 0.01	0.078 ± 0.001	65.51 ± 0.02	25.38 ± 0.01	72.38 ± 0.01	124.08 ± 0.01
H	8.56 ± 0.01	10.45 ± 0.01	4.40 ± 0.01	2.38 ± 0.01	2.44 ± 0.01	70.13 ± 0.01	0.076 ± 0.001	70.03 ± 0.02	24.31 ± 0.01	70.32 ± 0.01	122.12 ± 0.01
I	8.55 ± 0.01	12.39 ± 0.02	5.50 ± 0.01	2.21 ± 0.01	2.72 ± 0.02	68.74 ± 0.02	0.082 ± 0.001	75.29 ± 0.02	30.52 ± 0.02	74.11 ± 0.02	125.13 ± 0.01
J	8.57 ± 0.02	12.46 ± 0.02	5.54 ± 0.01	2.24 ± 0.01	2.75 ± 0.02	68.63 ± 0.02	0.084 ± 0.001	75.45 ± 0.02	30.82 ± 0.02	74.14 ± 0.02	125.16 ± 0.01
K	8.60 ± 0.02	12.50 ± 0.02	5.58 ± 0.01	2.27 ± 0.01	2.77 ± 0.02	68.42 ± 0.02	0.085 ± 0.001	75.52 ± 0.02	31.06 ± 0.02	74.16 ± 0.02	125.19 ± 0.01
L	8.55 ± 0.01	12.82 ± 0.01	6.10 ± 0.02	2.25 ± 0.01	2.83 ± 0.01	66.33 ± 0.01	0.077 ± 0.001	65.44 ± 0.01	25.30 ± 0.01	72.41 ± 0.01	124.07 ± 0.01
M	8.54 ± 0.01	12.87 ± 0.01	6.16 ± 0.01	2.29 ± 0.01	2.86 ± 0.01	66.04 ± 0.01	0.078 ± 0.001	65.47 ± 0.01	25.42 ± 0.01	72.43 ± 0.01	124.09 ± 0.01
N	8.53 ± 0.01	12.90 ± 0.01	6.20 ± 0.02	2.32 ± 0.01	2.88 ± 0.01	66.18 ± 0.01	0.079 ± 0.001	65.55 ± 0.01	25.51 ± 0.01	72.45 ± 0.01	124.11 ± 0.01
P-values	0.0031	0.0016	0.0043	0.0028	0.0022	0.0016	0.0018	0.0013	0.0018	0.0012	0.0044

The average moisture content for whole maize flour was found out to be $8.56\pm 0.01\%$. The average moisture content of maize flour blended with wheat was $8.58\pm 0.02\%$ while for the one blended with gram flour, the average moisture content was $8.59\pm 0.01\%$. It was higher in case of maize flour blended with gram rather than wheat. The difference in the moisture content of both is due to the difference in the individual moisture content of wheat and gram flours. Similar trends were reported by Kaushal *et al* (2012) for the blends of taro, rice and pigeon pea flour. It was observed that blending had a significant effect on moisture content ($p < 0.01$).

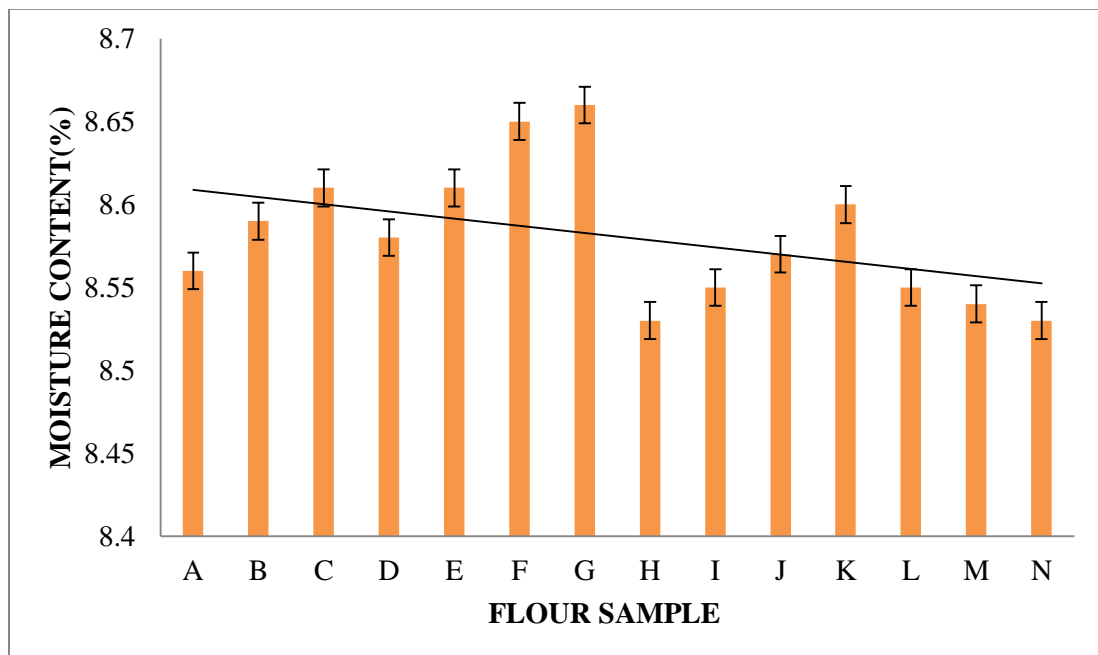


Fig. 4.1 Moisture content of different flour samples

4.1.2 Protein content

Protein is a macronutrient essential to build muscle mass. It is basically composed of amino acids. It is important to measure protein content as a higher percentage of protein means a harder flour best suited to make chewy, crusty flatbreads. The protein content of whole maize flour and blended maize flour varied from 10.41 ± 0.01 to $12.89\pm 0.02\%$ as presented in Fig. 4.2. The average protein content of whole maize flour was $10.41\pm 0.01\%$. The average protein content of maize flour blended with wheat was $12.43\pm 0.01\%$ while for the one blended with gram flour, the average protein content was $12.83\pm 0.02\%$. The protein presence was higher for gram blended flour than blended with wheat. The difference in protein content of both the blended flours is due to the fact that the protein content of gram flour is higher than the wheat flour. Similar trend was reported by Butt *et al* (2004) who studied the protein content for the blends of wheat and rice flour. It was observed that blending had a significant effect on protein content ($p < 0.01$).

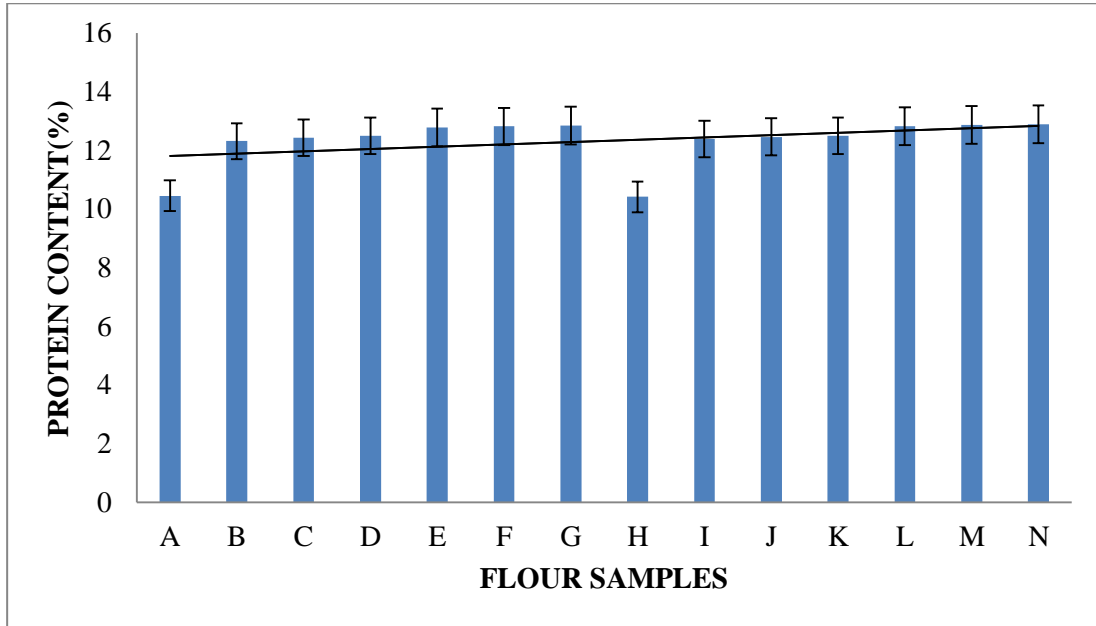


Fig. 4.2 Protein content for different flour samples

4.1.3 Crude fat content

The crude fat fraction is defined by the solvent and the extraction conditions (time, temperature, particle size, ratio of solvent to test portion etc.). Crude fat is more of a screening method because the test procedures do not identify a specific fat; instead, the methods measure the materials that can be dissolved in some solvent. The crude fat content of whole maize flour and blended maize flour varied from $4.36 \pm 0.01\%$ to $6.20 \pm 0.02\%$ as presented in Fig.4.3. The average crude fat content of whole maize flour was $4.36 \pm 0.01\%$. The average crude fat content of maize flour blended with wheat was $5.48 \pm 0.01\%$ while for the one blended with gram flour, the average crude fat content was $6.13 \pm 0.02\%$.

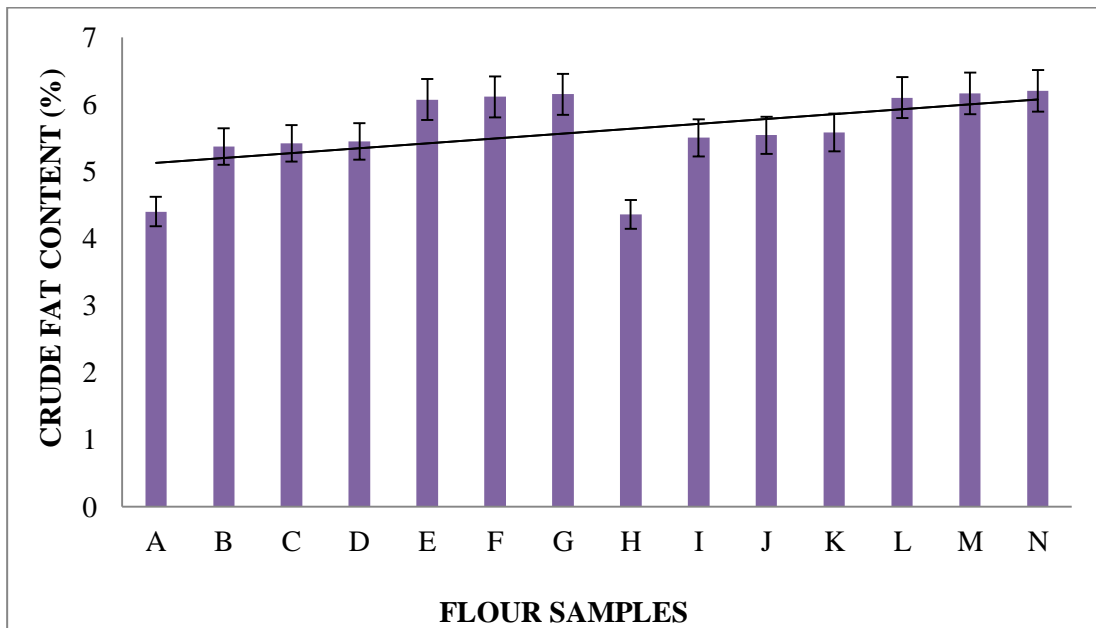


Fig. 4.3 Crude fat content for different flour samples

The crude fat content is higher for maize flour blended with gram than the flour blended with wheat. This may be due to the difference in the individual fat content of both the blended flours. Similar trend was reported by Yaseen *et al* (2007) for finding the crude fat content of corn flour blended with triticale flour. It was observed that blending had a significant effect on crude fat content ($p<0.01$).

4.1.4 Ash content

Ash content is the mineral or inorganic material in flour. It is important to measure ash content of flour as it is a good indicator of contamination in refined flour. The ash content of whole maize flour and blended maize flour varied from $2.20\pm 0.02\%$ to $2.32\pm 0.02\%$ as presented in Fig.4.4. The average ash content of whole maize flour was $2.20\pm 0.02\%$. The average ash content of maize flour blended with wheat flour was $2.22\pm 0.02\%$ while for the one blended with gram flour, the average ash content was $2.30\pm 0.02\%$. The ash content of gram blended maize flour is slightly higher than wheat blended flour. This may be due to the difference in the particle size of the two flours used as blend. Similar trend was reported by Tekle (2009) for blending taro flour with wheat. It was observed that blending had a significant effect on ash content ($p<0.01$).

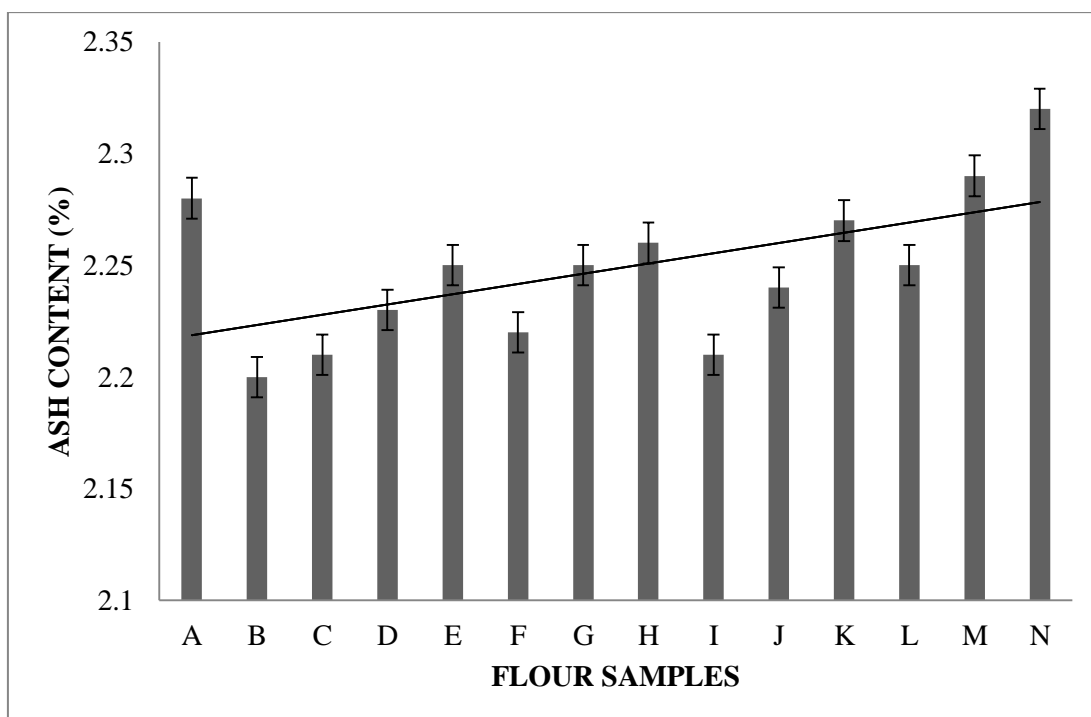


Fig. 4.4 Ash content of different flour samples

4.1.5 Crude fibre content

Crude fibre is a measure of the quantity of indigestible cellulose, pentosane, lignin, and other components of this type in flour. Crude fibre determination is adequate to estimate

the dietary fibre in flour. The crude fibre content of whole maize flour and blended maize flour varied from $2.40\pm 0.02\%$ to $2.88\pm 0.02\%$ as presented in Fig.4.5. The fibre content of whole maize flour was $2.40\pm 0.02\%$. The average fibre content of maize flour blended with wheat was $2.73\pm 0.02\%$ while for the one blended with gram flour, the average crude fibre content was $2.82\pm 0.02\%$. The fibre content of gram blended maize flour is higher than the wheat blended flour. The difference in the fibre content of the two flours used as blend is the reason for the higher fibre content of gram flour than the wheat flour. Similar trend was reported by Tekle (2009) for blending taro flour with wheat. It was observed that blending had a significant effect on crude fibre content ($p<0.01$).

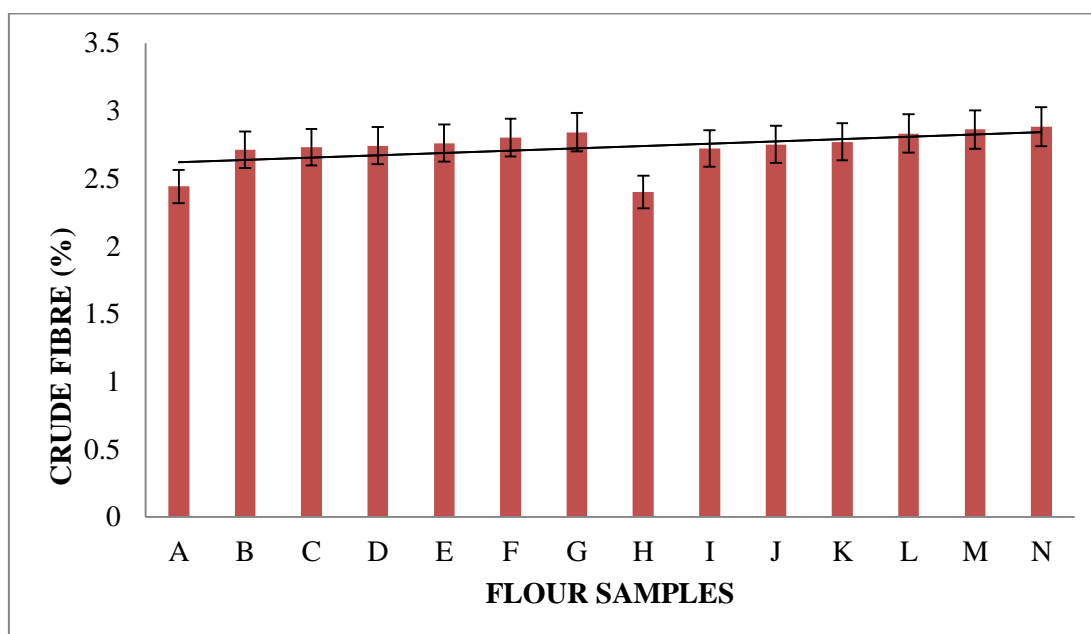


Fig. 4.5 Crude fibre for different flour samples

4.1.6 Carbohydrates content

Carbohydrates are chemically defined as neutral compounds of carbon, hydrogen and oxygen. The carbohydrate content of whole maize flour and blended maize flour varied from 66.04 ± 0.01 to $70.13\pm 0.01\%$ as shown in Fig. 4.6. The average carbohydrate content of whole maize flour was $70.13\pm 0.01\%$. The average carbohydrate content of maize flour blended with wheat was $68.72\pm 0.01\%$ while for the one blended with gram flour, the average crude fibre content was $66.25\pm 0.01\%$. The carbohydrate content of wheat blended maize flour was higher than the gram flour blended. While measuring the chemical composition of different blending ratios of corn and triticale flour, similar trend was reported by Hussein and Hegazy (2007) on researching the carbohydrate content of the flour. It was observed that blending had a significant effect on carbohydrate content ($p<0.01$).

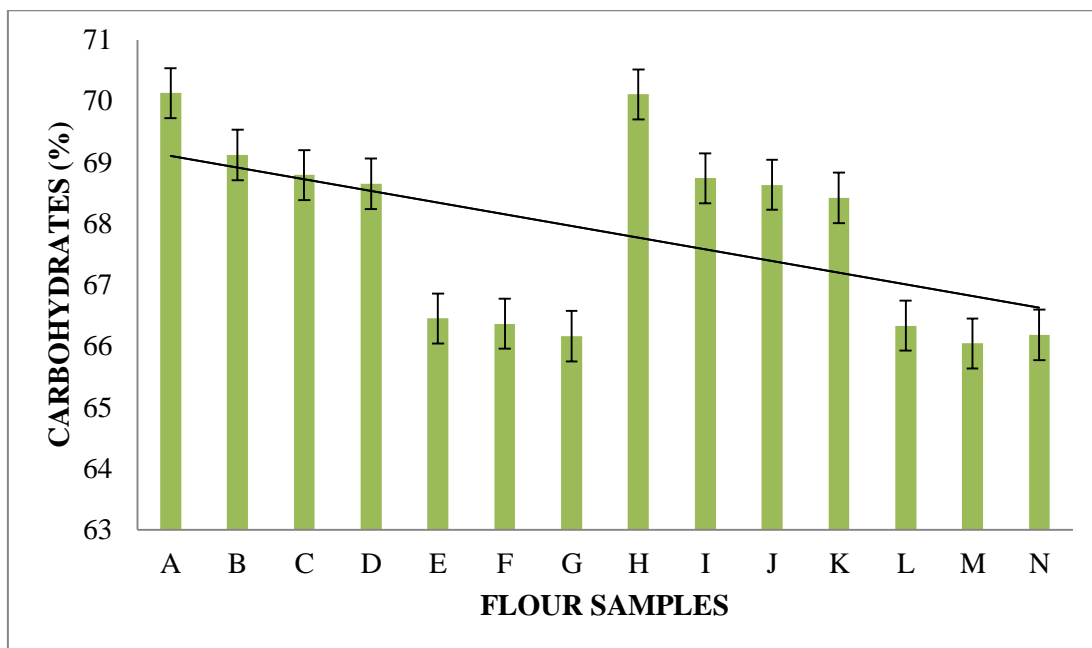


Fig. 4.6 Carbohydrate content for different flour blends

4.1.7 Titrable acidity

Total titrable acid is a measure of amount of acid present in the flour. Its determination is important to measure the perceivable acidity of the flour. The titrable acidity of whole maize flour and blended maize flour varied from $0.076 \pm 0.001\%$ to $0.085 \pm 0.001\%$ as presented in Fig.4.7. The average titrable acidity of whole maize flour was $0.076 \pm 0.001\%$. The average titrable acid content of maize flour blended with wheat was $0.083 \pm 0.001\%$ while for the one blended with gram flour, it was $0.078 \pm 0.001\%$. The titrable acidity of wheat blended flour was higher than the gram blended flour.

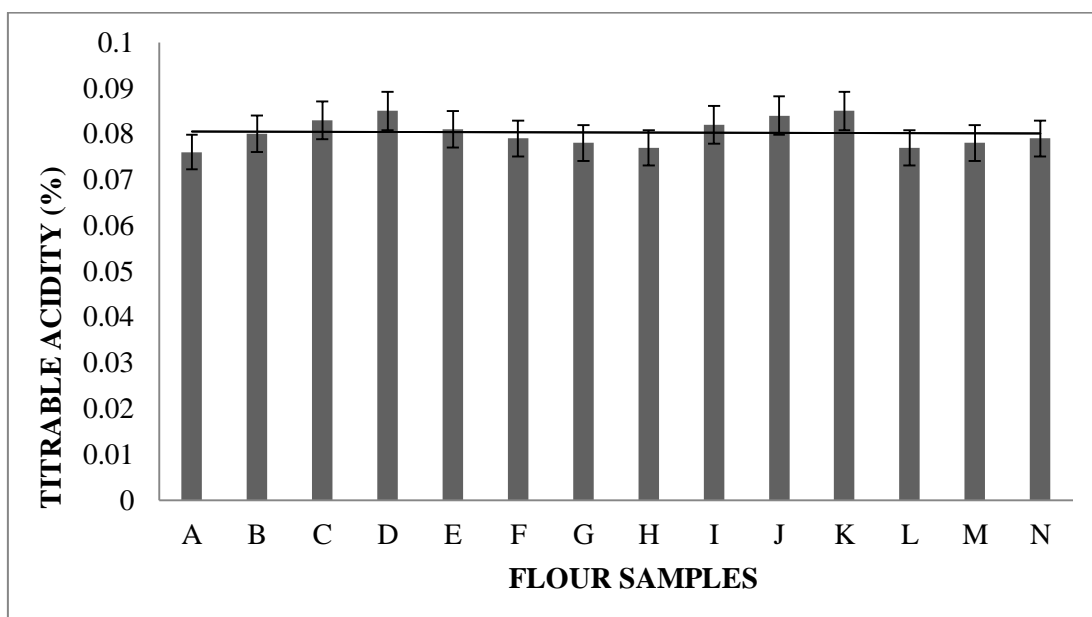


Fig. 4.7 Titrable acidity of different flour samples

Hruskova and Machova (2002) studied the acid content of the degermed and whole maize flour and the results showed a trend similar to this. It was observed that blending had a significant effect on acidity content ($p < 0.01$).

4.1.8 Colour value

Flour colour determination is important because it affects the crumb colour of the finished product i.e. flatbreads. The L of whole maize flour and blended maize flour varied from 65.41 ± 0.02 to 75.52 ± 0.02 as presented in Fig.4.8. The average colour value of whole maize flour was 70.05 ± 0.02 . The average colour change of the flour blended with wheat was found out to be 75.40 ± 0.02 while for the one blended with gram flour, it was 65.42 ± 0.02 . The colour value for flour blended with gram flour was less than the flour blended with wheat. This is due to the colour difference of both wheat and gram. Gram flour when mixed with maize flour provides a darker colour, thus decreasing the L value. Wheat flour when mixed with maize flour makes it light in colour, thus increasing the L value. Jamin and Flores (1998) studied the colour difference for different varieties of corn flour and the results showed a trend similar to this. It was observed that blending had a significant effect on colour ($p < 0.01$).

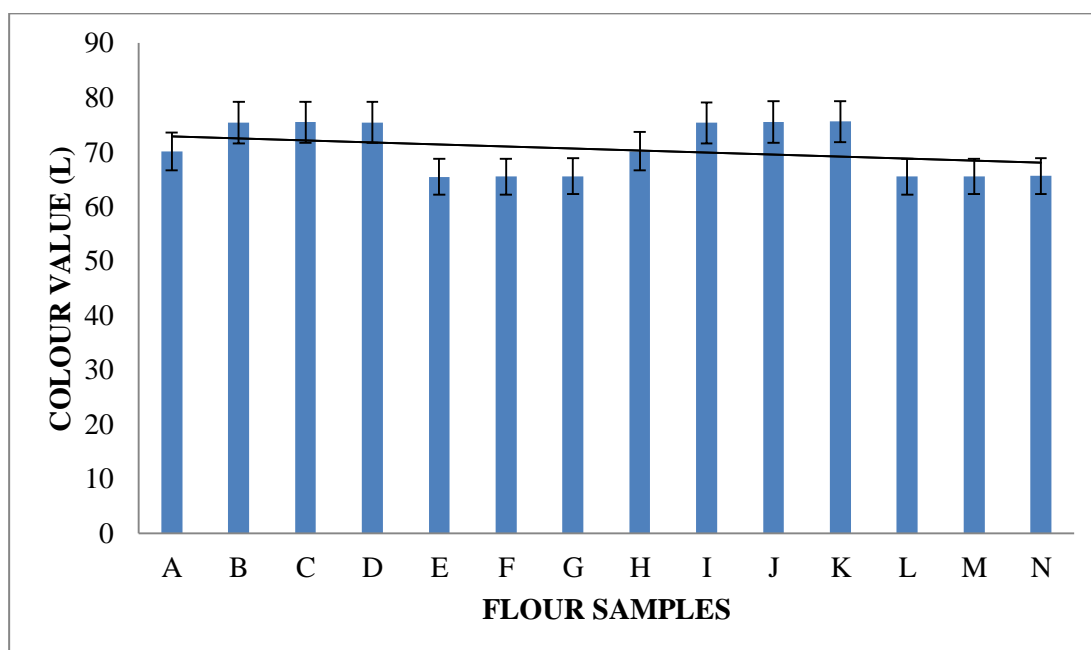


Fig. 4.8 Colour value of different flour samples

4.1.9 Swelling power

Swelling power is defined as the wet weight of flour over its dry weight. The determination of swelling power of flour is important for a crunchy and chewable processing of flatbread. The swelling power of whole maize flour and blended maize flour varied from $22.31 \pm 0.01\%$ to $31.06 \pm 0.01\%$ as presented in Fig.4.9. The average swelling capacity of whole maize flour was $22.31 \pm 0.01\%$. The average swelling power of the flour blended with wheat

was found out to be $30.74 \pm 0.01\%$ while for the one blended with gram flour, it was $25.30 \pm 0.01\%$. The swelling power of maize flour blended with wheat was higher than the one blended with gram flour. The main reason for the difference in swelling power is the difference in the amylose content of wheat and gram flours. A similar trend was reported by Moorthy (2002) for the swelling capacity calculation of cassava flour. It was observed that blending had a significant effect on the swelling capacity ($p < 0.01$).

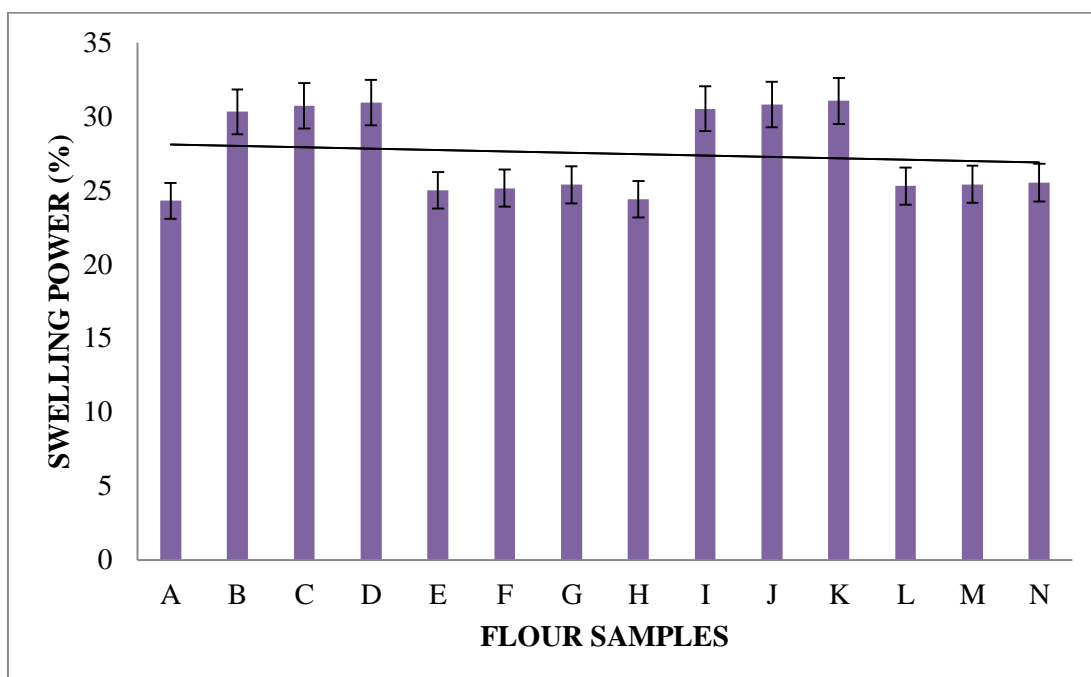


Fig. 4.9 Swelling power of different flour samples

4.1.10 Water holding capacity

Water holding capacity (WHC) is the ability of proteins to prevent water from being released or expelled from their three-dimensional structure. WHC plays an important role in developing food texture. The water holding capacity of whole maize flour and blended maize flour varied from $70.32 \pm 0.01\%$ to $74.16 \pm 0.01\%$ as presented in Fig.4.10. The average moisture holding capacity of whole maize flour was $70.34 \pm 0.01\%$. The average water retaining power of the flour blended with wheat was found out to be $74.09 \pm 0.01\%$ while for the one blended with gram flour, it was $72.42 \pm 0.01\%$. Water absorption capacity of wheat blended maize flour is higher than the gram blended maize flour. The main reason for the difference in the moisture retaining capacity of the blended flours is the molecular structure which inhibits water absorption. A similar observation was reported by Butt and Batool (2010) while measuring the water absorption capacity (WAC) of rice, green gram and potato flour blended to wheat flour. It was observed that blending had a significant effect on the water holding capacity ($p < 0.01$).

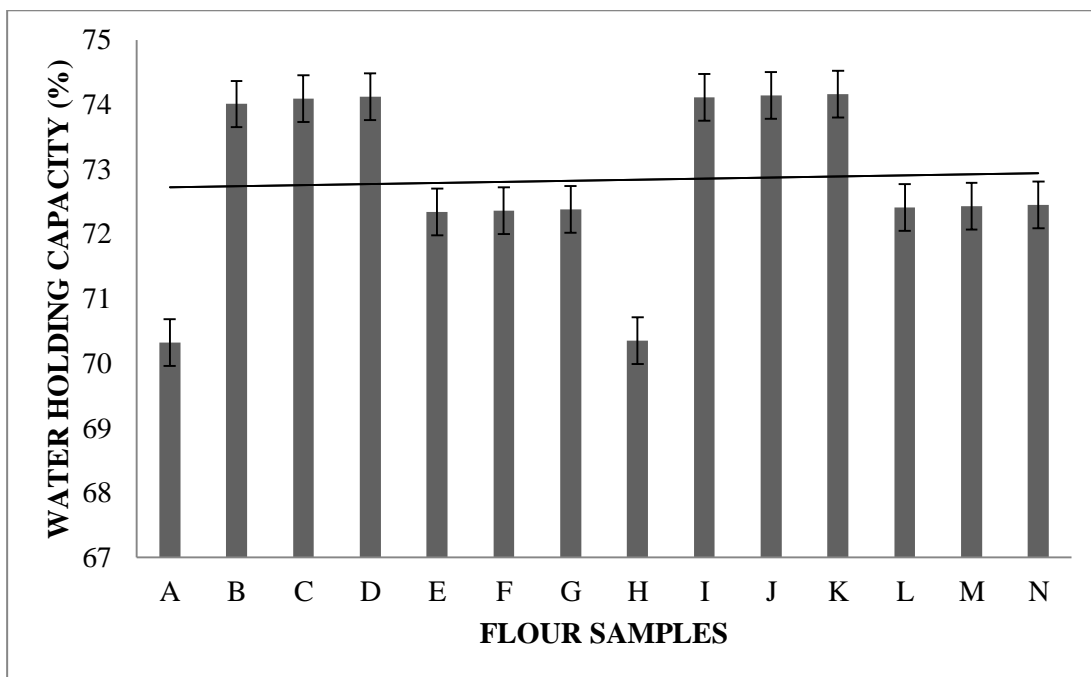


Fig. 4.10 Water holding capacity of different flour samples

4.1.11 Oil holding capacity

Oil holding capacity is the amount of oil that can be absorbed per gram of the sample. It is important to determine OHC for the flavour retention of flatbreads and to improve their palatability. The oil holding capacity of whole maize flour and blended maize flour varied from $122.12 \pm 0.02\%$ to $125.19 \pm 0.02\%$ as presented in Fig.4.11.

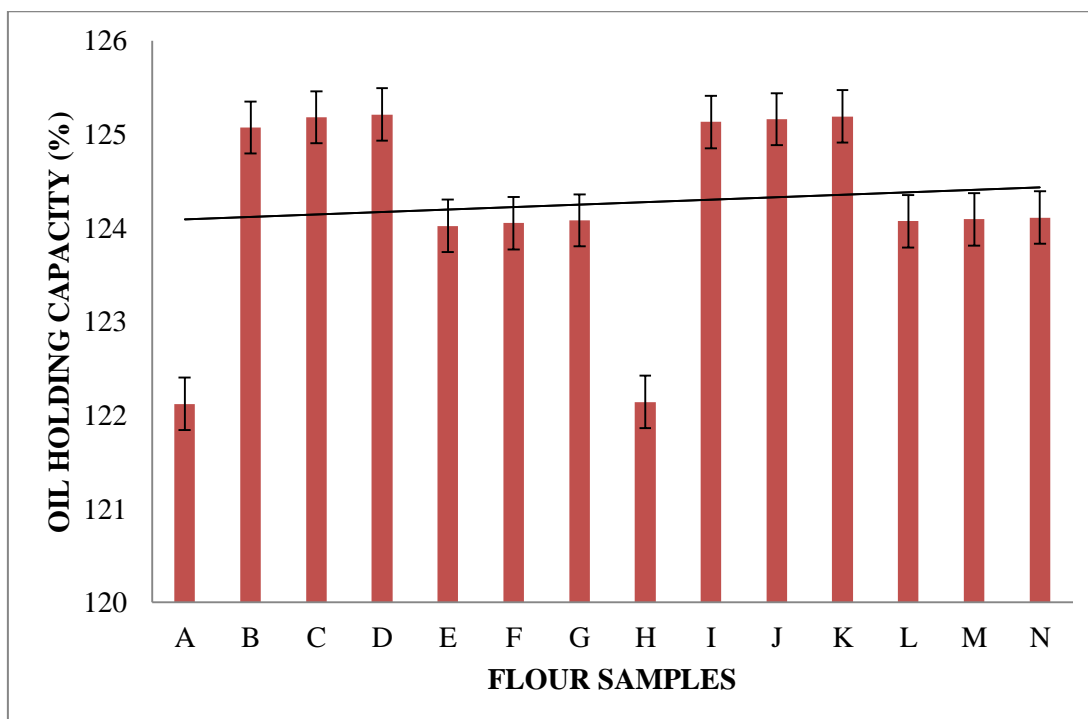


Fig. 4.11 Oil holding capacity of different flour samples

The average oil holding capacity of whole maize flour was $122.3 \pm 0.01\%$. The average oil holding power of the flour blended with wheat was found out to be $125.15 \pm 0.02\%$ while for the one blended with gram flour, it was $124.13 \pm 0.01\%$. Oil holding capacity of wheat blended maize flour is higher than the gram blended maize flour. The main reason for the difference in the oil retaining capacity is the presence of high fat content. Similar findings were observed by Kaushal *et al* (2012) and Aremu *et al* (2007) while measuring the oil absorption capacity (OAC) of rice, green gram and potato flour blended to wheat flour. It was observed that blending had a significant effect on the oil holding capacity ($p < 0.01$).

4.2 Scanning Electron Microscope (SEM) analysis of flour

The morphology of starches of PMH1 variety of maize flour sample was performed with a high vacuum scanning electron microscope as presented in Fig 4.12 to 4.15. Before the analysis, the sample was fixed on the specimen holder with carbon tape and mounted on bronze specimen holder. The analysis conditions used 15 kV electron acceleration voltage and 12-20 Pa of pressure in the specimen chamber obtaining the images with the secondary electron signal as follows:

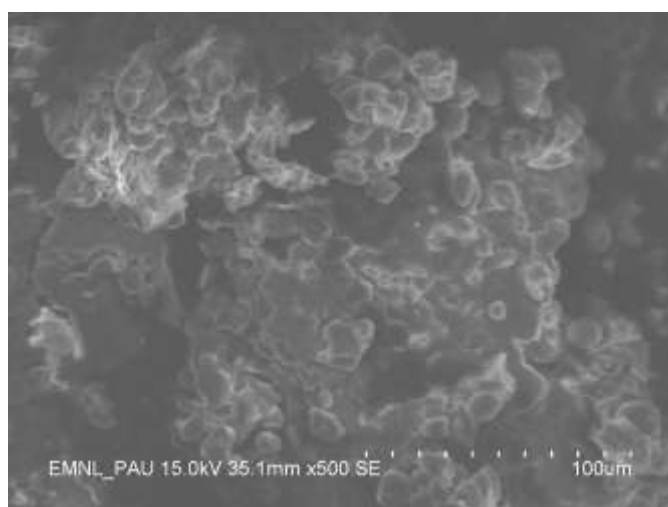


Fig. 4.12 Accelerating voltage=15 kV; Magnification= $\times 500$; Working distance=35.1 mm

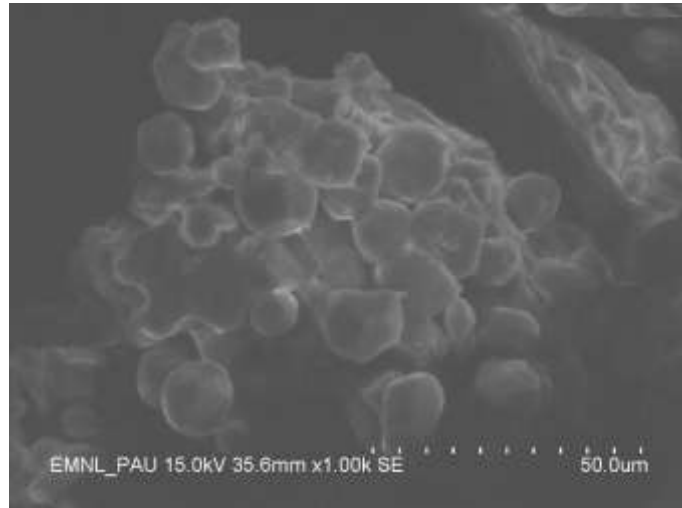


Fig. 4.13 Accelerating voltage=15 kV; Magnification= $\times 1k$; Working distance=35.6 mm

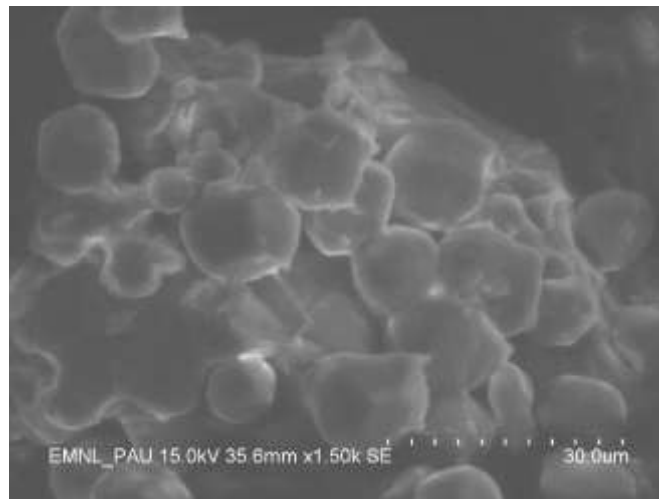


Fig. 4.14 Accelerating voltage=15 kV; Magnification= $\times 1.5k$; Working distance=35.6 mm

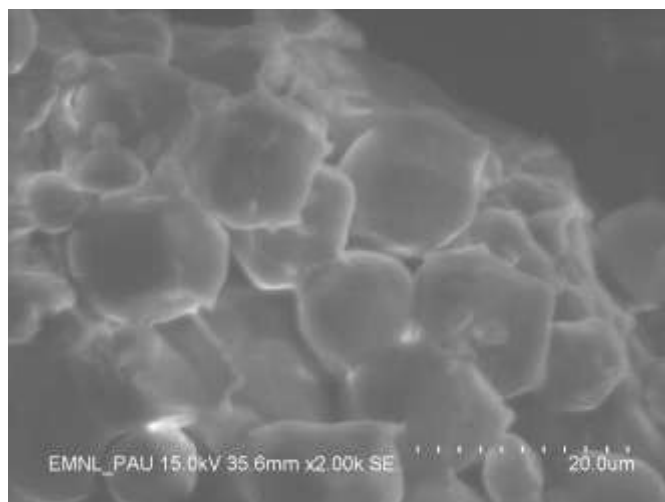


Fig. 4.15 Accelerating voltage = 15 kV; Magnification= $\times 2k$; Working distance=35.6 mm

4.3 Optimization of process parameters for preparation of flatbreads

4.3.1 Optimization of process parameters for preparation of gram flour blended flatbreads

Moisture Content

Moisture content is an indicator of the amount of water present in the flatbread. Moisture content can affect the physical and chemical properties of flatbread, which directly correlate to the freshness and stability of flatbread for consumers. The effect of process parameters on moisture content of flatbreads was presented in Fig. 4.16. It was observed that the maximum moisture content (49.68%) was observed at 40% flour blending, 18°C of water temperature and 10 minutes resting time of dough while the minimum moisture content (40.24%) was observed at 40% flour blending, 27°C of water temperature and 20 minutes of resting time of the dough.

Analysis of variance showed significant negative quadratic effect of resting time and blending and negative linear effect of resting time and water temperature but positive quadratic effect of blending and positive linear effect of blending significant at level 5% with R² value of 0.87. The significant model developed for moisture content in terms of independent variables (in coded levels) is given below:

$$\text{Moisture content} = 43.10 - 0.11A + 0.97B - 0.23C - 0.020AB - 0.048AC + 0.12BC - 0.74A^2 - 1.18B^2 + 5.15C^2$$

Browning Index

Browning index is defined as the brown colour purity, one of the most common indicators of browning in the processed flatbreads. It is important to measure the browning index of flatbreads during storage as its undesirable brown discolouration negatively affects its colour, taste and nutritional value. Fig. 4.17 shows the effect of process parameters on browning index of flatbreads. It was observed that the maximum browning index (0.089) was observed at 20% flour blending, 36°C of water temperature and 10 minutes resting time of dough while the minimum browning index (0.029) was observed at 30% flour blending, 18°C of water temperature and 0 minutes of resting time of the dough.

Analysis of variance showed significant negative quadratic effect of resting time and negative linear effect of blending but positive quadratic effect of blending, water temperature and positive linear effect of resting time and water temperature significant at level 5% with R² value of 0.99. The significant model developed for browning index in terms of independent variables (in coded levels) is given below:

$$\text{Browning index} = 0.044 + 0.023A - 0.017B + 0.033C - 0.017AB + 0.01AC - 0.082BC - 0.047A^2 + 0.032B^2 + 0.022C^2$$

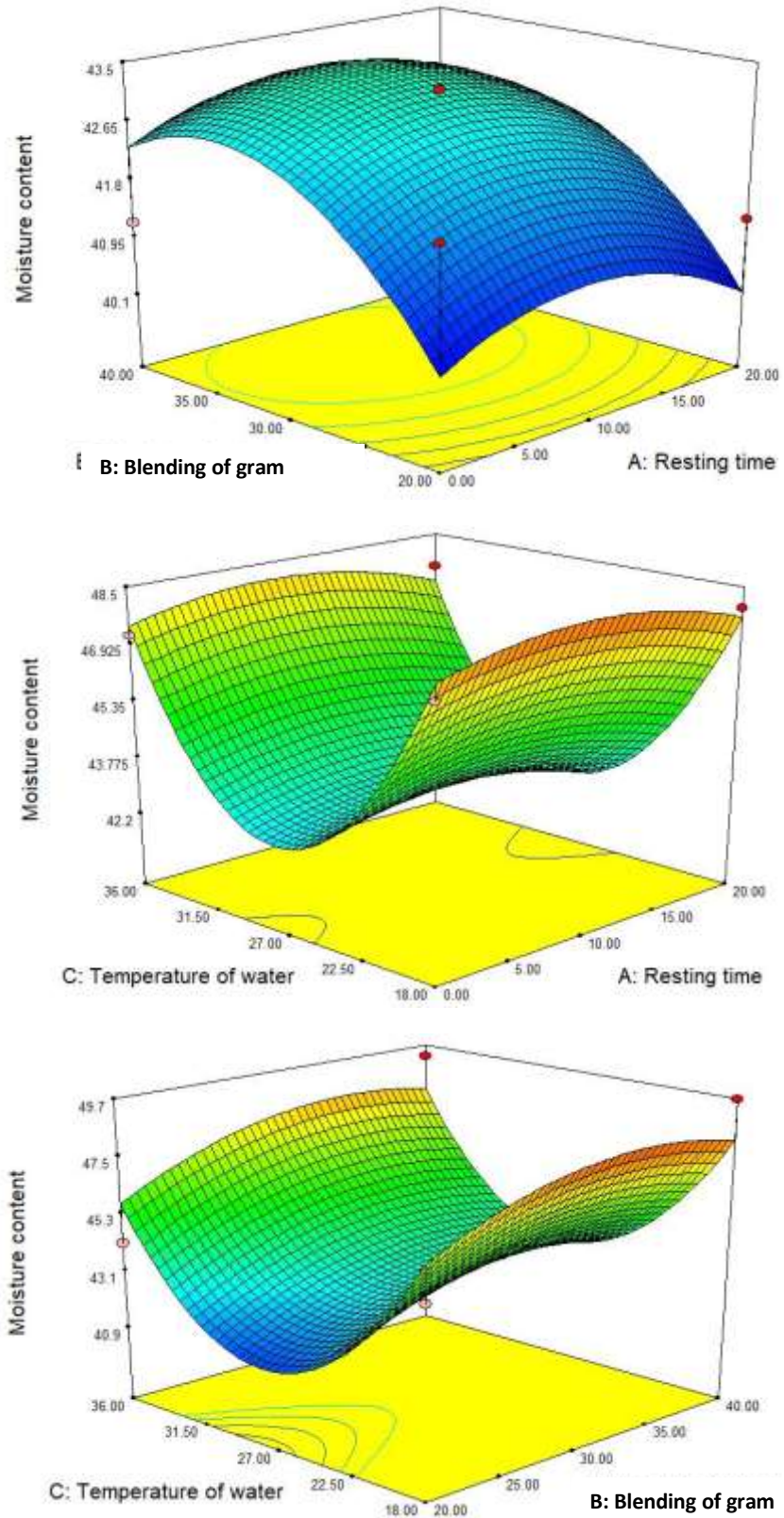


Fig. 4.16 3D model graphs showing the effect of temperature of water, blending of flour and resting time on moisture content

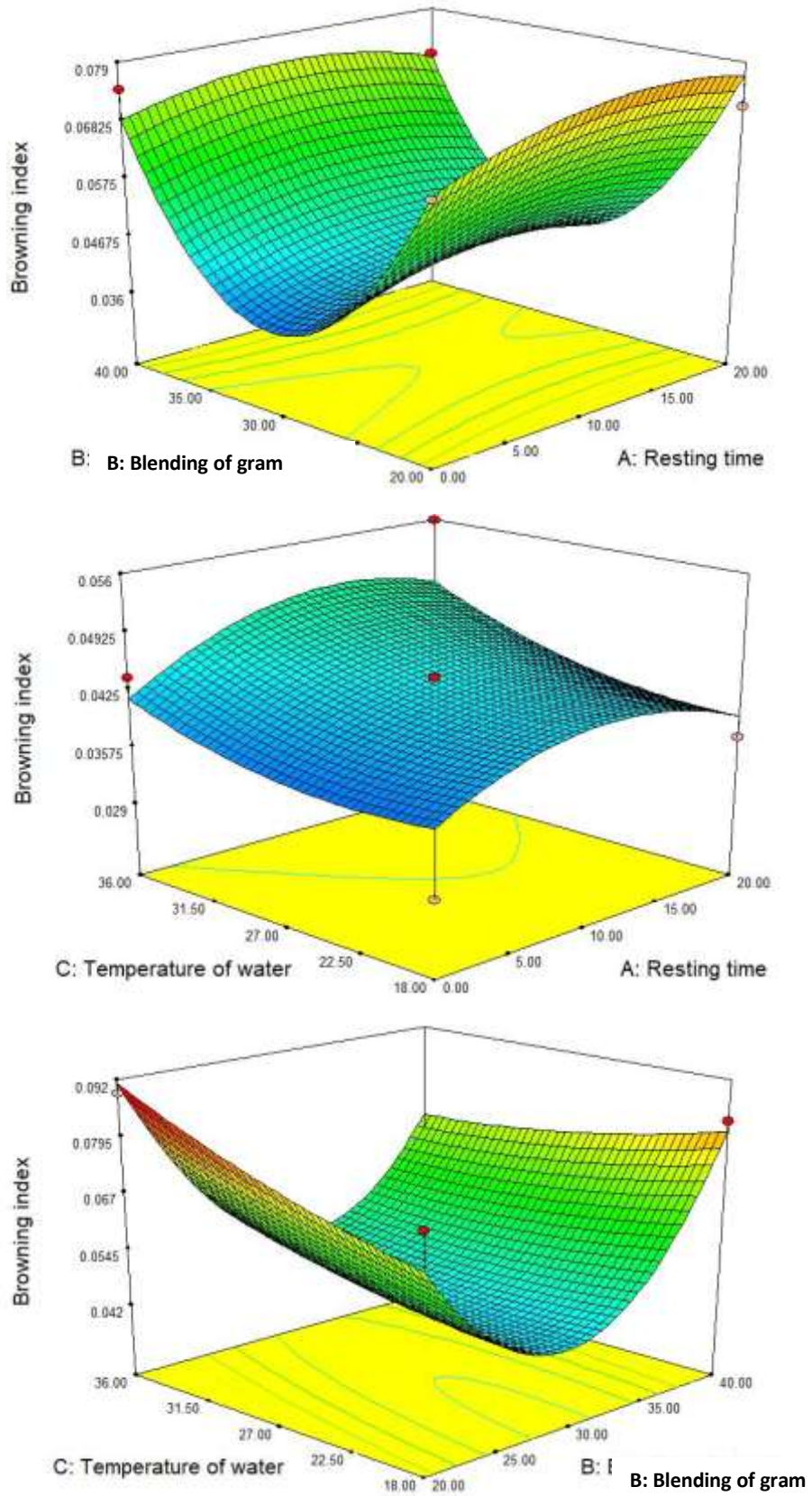


Fig. 4.17 3D model graphs showing the effect of temperature of water, blending of flour and resting time on browning index

Peroxide value

The peroxide value is the amount of oxygen consumed in the reaction that reduces all the unsaturated (C=C) bonds in a given amount of a lipid mixture during autoxidation. It is an important factor of consideration for flatbreads as it indicates the degree of primary oxidation and therefore, its likeliness of becoming rancid during storage. Fig. 4.18 shows the effect of process parameters on peroxide value of flatbreads. It was observed that the maximum peroxide value (7.09) was observed at 30% flour blending, 18°C of water temperature and 20 minutes resting time of dough while the minimum peroxide value (6.22) was observed at 40% flour blending, 27°C of water temperature and 20 minutes of resting time of the dough.

Analysis of variance showed significant negative quadratic effect of resting time, blending and negative linear effect of water temperature but positive quadratic effect of water temperature significant at level 5% with R² value of 0.97. The significant model developed for peroxide value in terms of independent variables (in coded levels) is given below:

$$\text{Peroxide value} = 6.47 + 0.14A + 0.056B - 0.11C - 0.018AB - 0.022AC + 0.020BC - 0.046A^2 - 0.036B^2 + 0.35C^2$$

Free Fatty Acid

Free fatty acids (FFA) are produced by the hydrolysis of oils and fats. The level of FFA depends on time, temperature and moisture content because the oils and fats are exposed to various environments such as storage, processing or heating. FFA are an important factor of consideration as they are mainly responsible for taste and texture of flatbreads. Fig. 4.19 shows the effect of process parameters on free fatty acid value of flatbreads. It was observed that the maximum free fatty acid value (1.48%) was observed at 30% flour blending, 18°C of water temperature and 20 minutes resting time of dough while the minimum free fatty acid value (1.053%) was observed at 20% flour blending, 36°C of water temperature and 10 minutes of resting time of the dough.

Analysis of variance showed significant negative quadratic effect of water temperature and negative linear effect of water temperature but positive quadratic effect of resting time, blending and positive linear effect of resting time and blending significant at level 5% with R² value of 0.98. The significant model developed for free fatty acid in terms of independent variables (in coded levels) is given below:

$$\text{Free fatty acid} = 1.21 + 0.015A + 0.020B - 0.18C - 0.0656AB - 0.021AC - 0.029BC + 0.042A^2 + 0.023B^2 - 0.053C^2$$

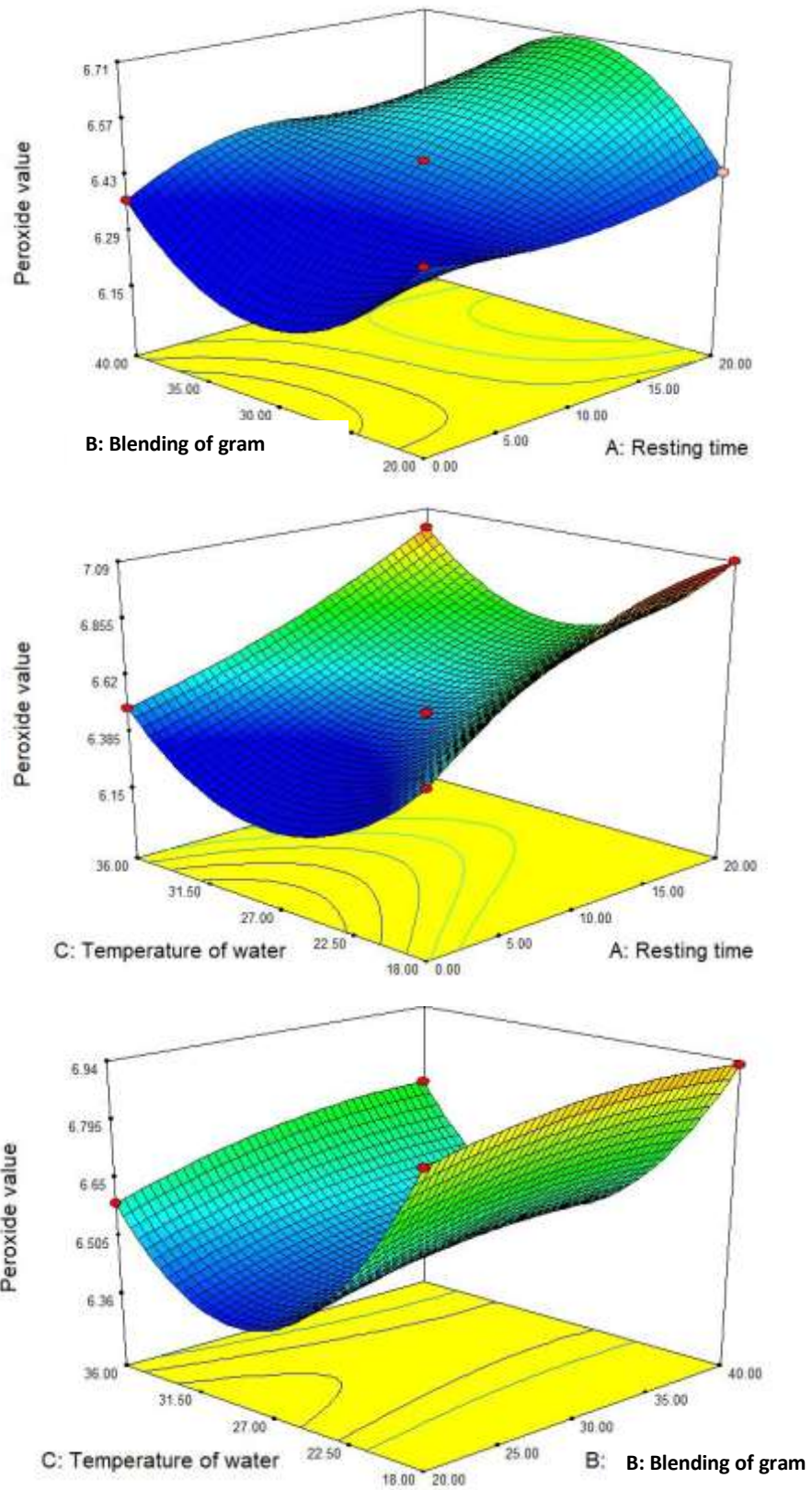


Fig. 4.18 3D model graphs showing the effect of temperature of water, blending of flour and resting time on peroxide value

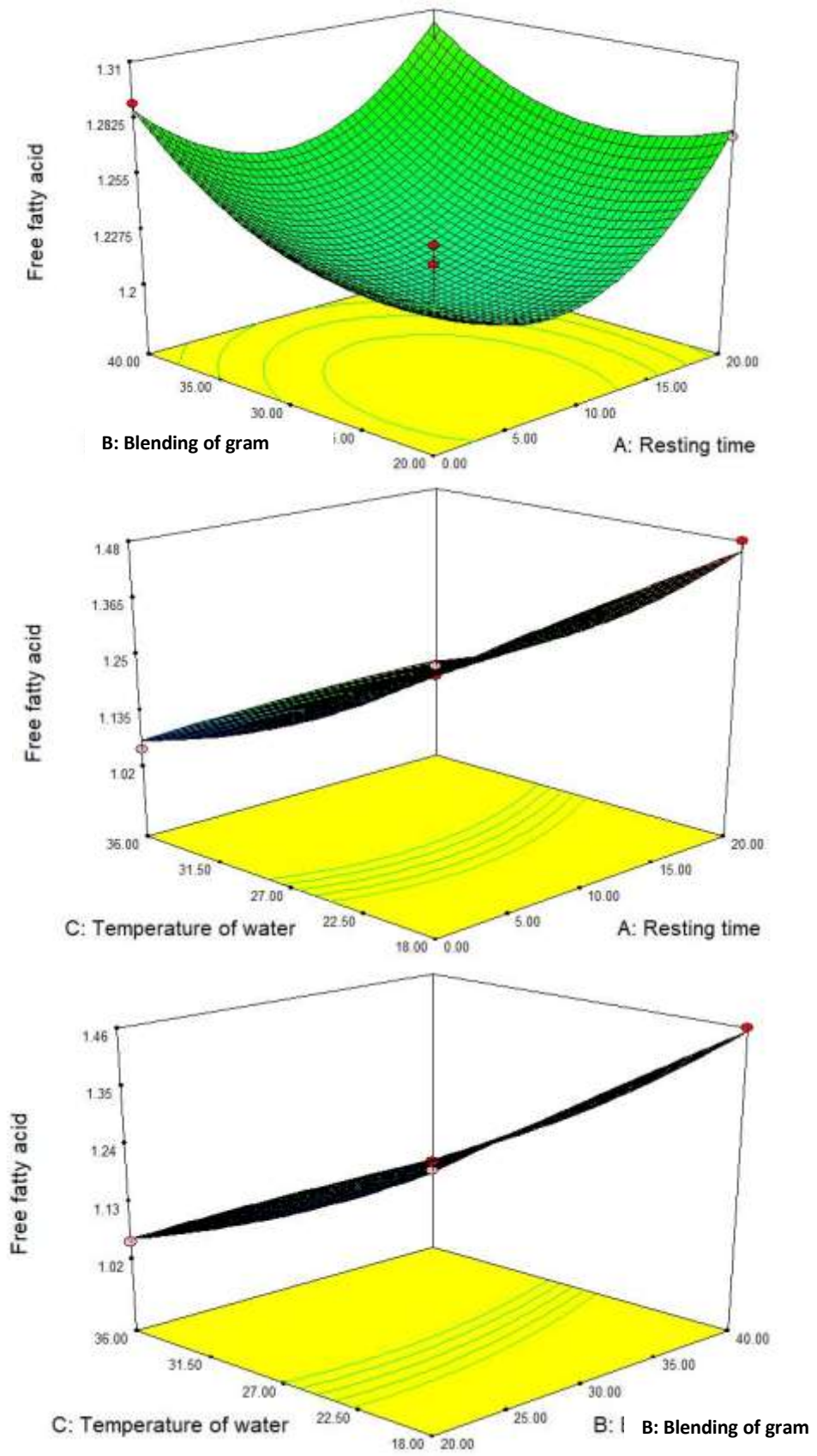


Fig. 4.19 3D model graphs showing the effect of temperature of water, blending of flour and resting time on free fatty acid

Cutting Force

Cutting force is an indicator of hardness or softness of the flatbreads. It is an important response study in flatbread storage as higher is the cutting force, higher is the hardness of the flatbread, thus making it unfit for consumption. Fig. 4.20 shows the effect of process parameters on the cutting force of flatbread. It was observed that the maximum cutting force (4.9078 N/Kg) was observed at 40% flour blending, 18°C of water temperature and 10 minutes resting time of dough while the minimum cutting force (3.3914 N/Kg) was observed at 20% flour blending, 36°C of water temperature and 10 minutes of resting time of the dough.

Analysis of variance showed significant negative linear effect of water temperature but positive quadratic effect of resting time, blending and water temperature significant at model 5% with R² value of 0.90. The significant model developed for cutting force in terms of independent variables (in coded levels) is given below:

$$\text{Cutting force} = 3.42 + 0.14A + 0.41B - 0.047C - 0.075AB + 0.04AC + 0.062BC + 0.014A^2 + 0.073B^2 + 0.085C^2$$

Colour change

Colour change is an indicator of the freshness of the flatbread during storage. It is an important factor of consideration as it affects the taste, appearance and overall acceptability of the finished product. Fig. 4.21 shows the effect of process parameters on colour change of flatbread. It was observed that the maximum colour change (75.53) was observed at 30% flour blending, 18°C of water temperature and 0 minutes resting time of dough while the minimum colour change (59.87) was observed at 40% flour blending, 36°C of water temperature and 10 minutes of resting time of the dough.

Analysis of variance showed significant negative quadratic effect of blending and water temperature and negative linear effect of resting time, blending and water temperature but positive quadratic effect of water temperature significant at model 5% with R² value of 0.88. The significant model developed for colour change in terms of independent variables (in coded levels) is given below:

$$\text{Colour change} = 70.87 - 2.35A - 1.12B - 2.16C - 0.10AB - 0.068AC + 1.31BC + 2.20A^2 - 2.49B^2 - 4.81C^2$$

Overall acceptability

Overall acceptability is a scientific discipline used to invoke, measure, analyze and interpret reactions to the characteristics of flatbreads as perceived by senses of sight, smell, taste, touch and hearing. Fig. 4.22 shows the effect of process parameters on overall acceptability of flatbread. It was observed that the maximum acceptability (9) was observed at 30% flour blending, 27°C of water temperature and 10 minutes resting time of dough while the minimum acceptability (8) was observed at 30% flour blending, 36°C of water temperature and 0 minutes of resting time of the dough.

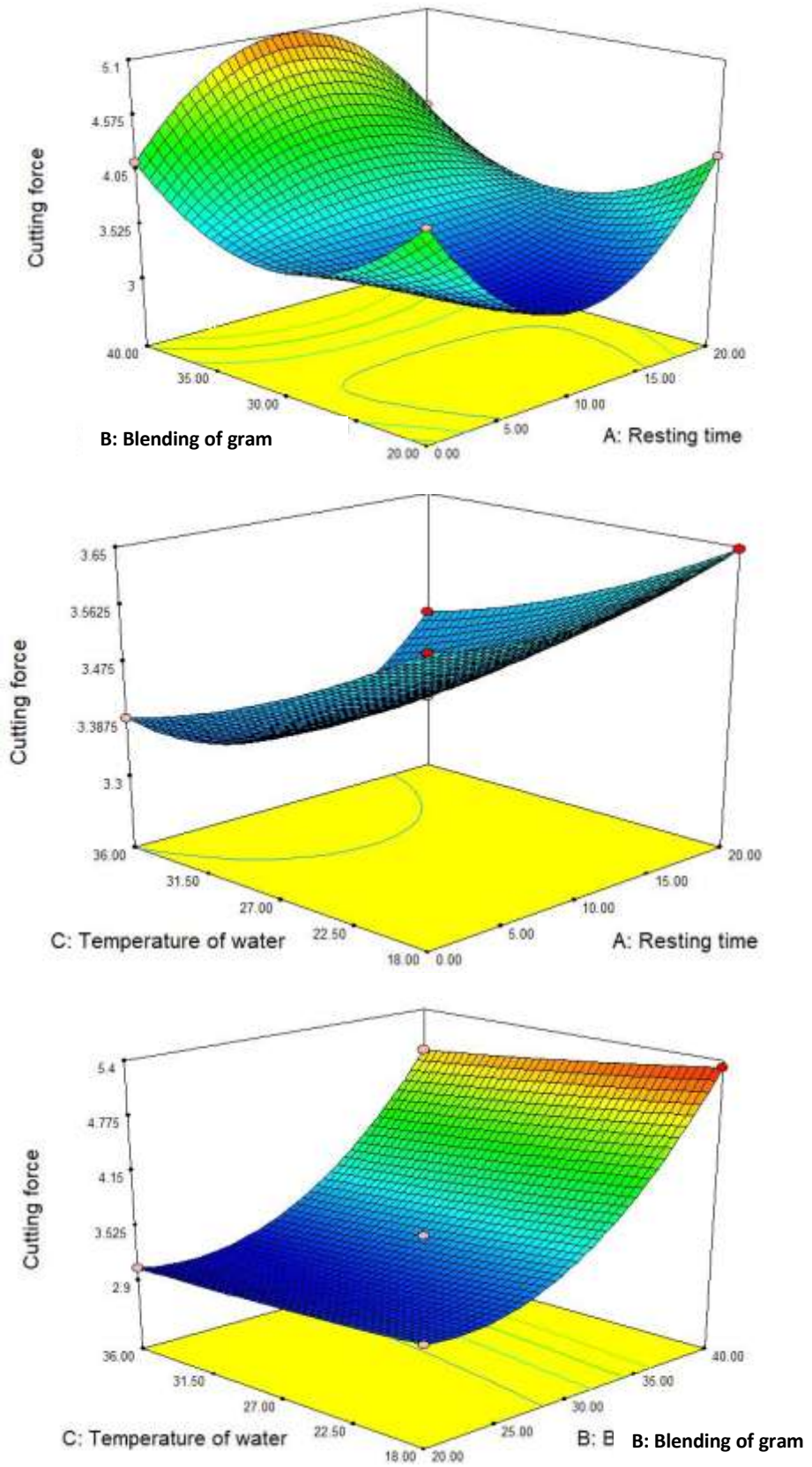


Fig. 4.20 3D model graphs showing the effect of temperature of water, blending of flour and resting time on cutting force

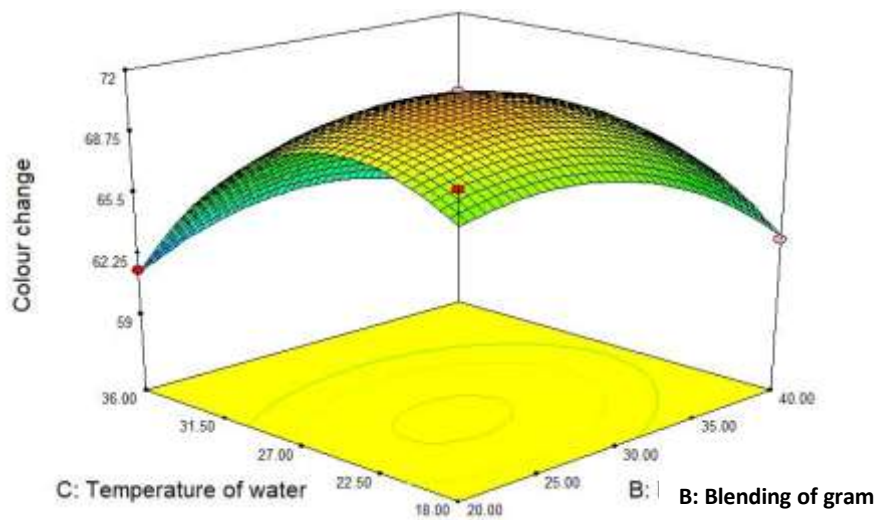
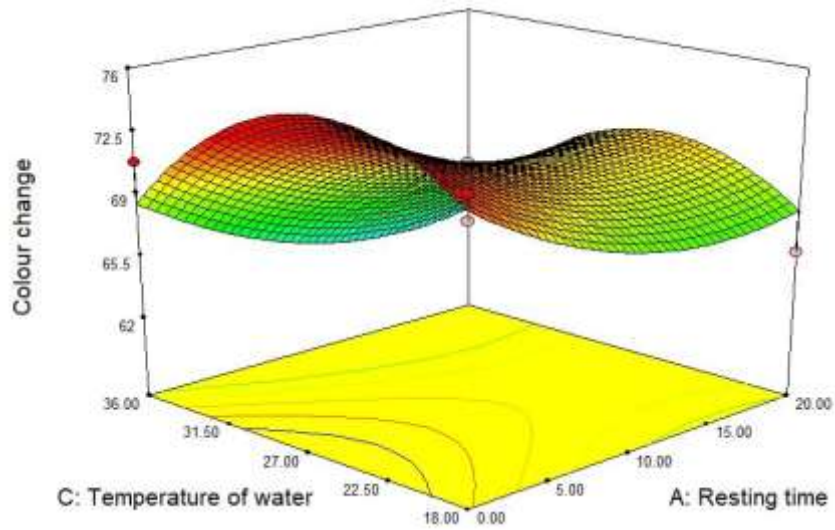
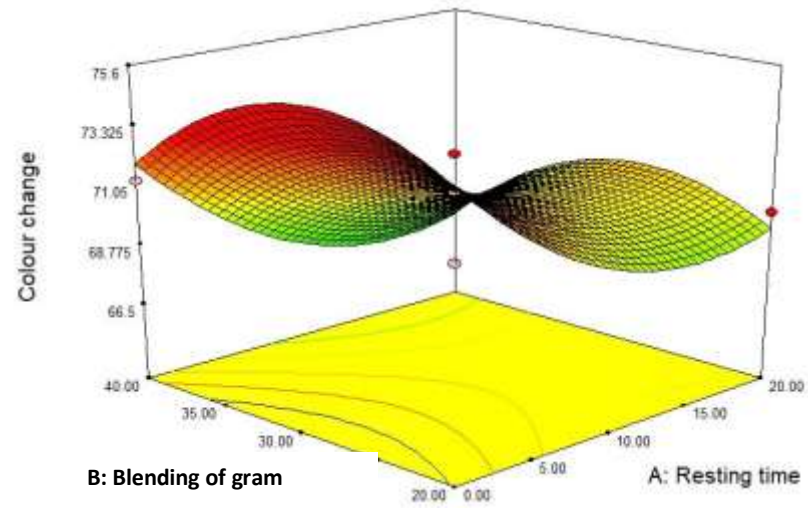


Fig. 4.21 3D model graphs showing the effect of temperature of water, blending of flour and resting time on colour change

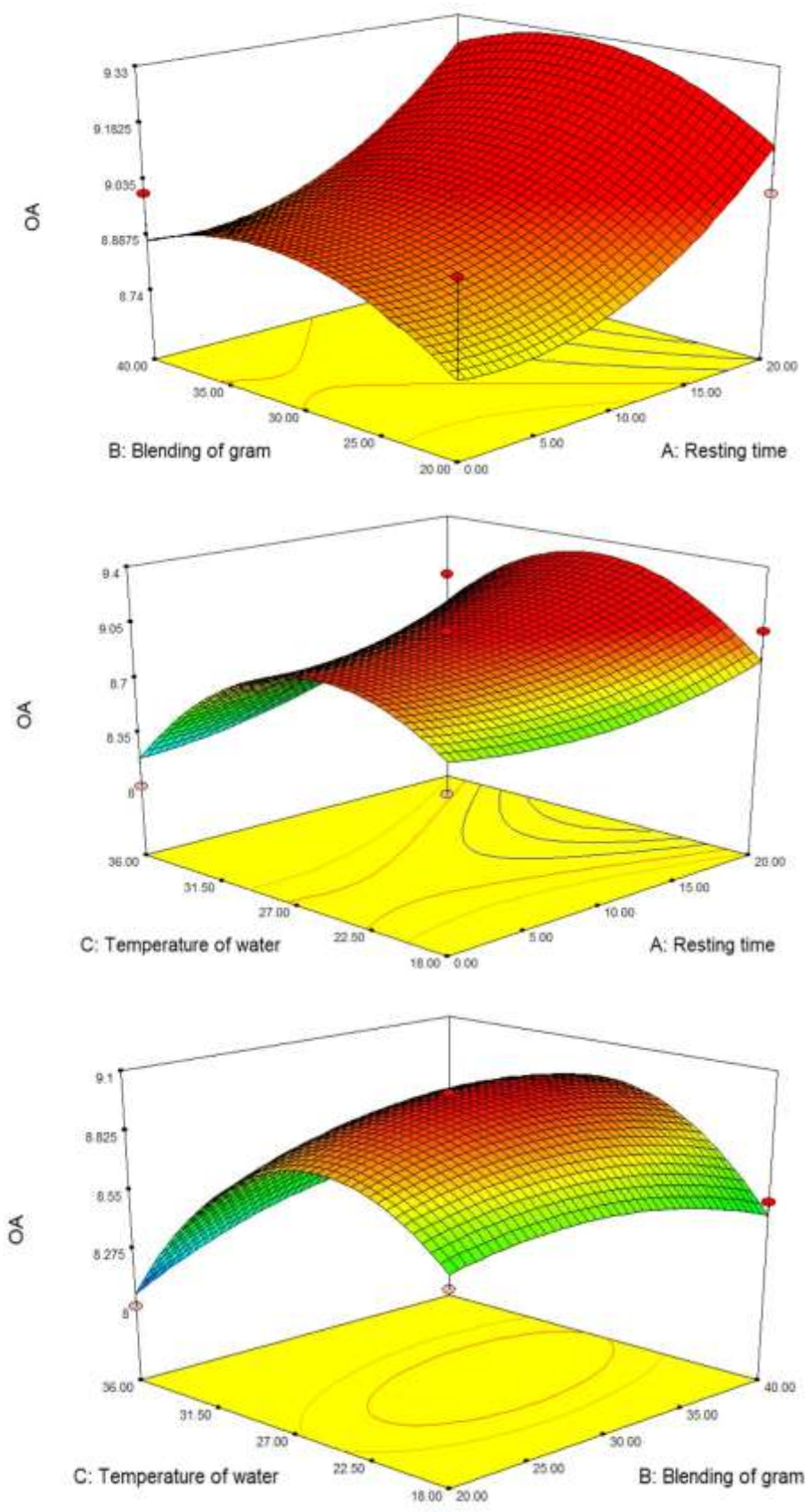


Fig. 4.22 3D model graphs showing the effect of temperature of water, blending of flour and resting time on overall acceptability

Analysis of variance showed significant negative quadratic effect of blending and water temperature and negative linear effect of water temperature but positive quadratic effect of resting time and positive linear effect of resting time and blending significant at model 5% with R² value of 0.84 The significant model developed for overall acceptability in terms of independent variables (in coded levels) is given below:

$$\text{Overall acceptability} = 9 + 0.19A + 0.062B - 0.13C + 0.12AC + 0.12BC + 0.12A^2 - 0.12B^2 - 0.50C^2$$

4.3.2 Optimization results for gram flour blended flatbreads

The optimization results of process parameters and responses are presented in Table 4.2. The process parameters were optimized using numerical optimization technique. The main criteria for constraints optimized were moisture content, browning index, peroxide content, free fatty acid, colour change and cutting force. In order to optimize the process conditions using numerical optimization technique, moisture content, browning index, peroxide value, free fatty acid, cutting force was minimum and colour change, overall acceptability was maximum. The optimum conditions for flatbread preparation of gram flour for resting time, blending and temperature were 12.45 minutes, 38.90% and 31.47°C respectively. The overall desirability was 0.858.

Table 4.2 Optimum values of process parameters and responses

Independent variables	Goal	Lower Limit	Upper Limit	Optimization values	Actual values
Resting time (min)	Is in range	0	20	12.45	-
Blending (%)	Is in range	20	40	38.90	-
Temperature of water (°C)	Is in range	18	36	31.47	-
Responses					
Moisture content	Minimize	40.24	49.68	44.14	42.11
Browning Index	Minimize	0.029	0.089	0.066	0.068
Peroxide value	Minimize	6.35	7.09	6.53	6.51
Free fatty acid	Minimize	1.053	1.48	1.146	1.149
Cutting force	Minimize	3.0413	5.3211	4.6991	4.6344
Colour change	Maximize	59.87	73.53	65.74	65.14
Overall acceptability	Maximize	8	9	8.8858	8.5

4.3.2 Optimization of process parameters for preparation of wheat flour blended flatbreads

Moisture Content

Moisture content is an indicator of the amount of water present in the flatbread. Moisture content can affect the physical and chemical properties of flatbread, which directly correlate to the freshness and stability of flatbread for consumers. Fig. 4.23 shows the effect of process parameters on the moisture content of flatbreads. It was observed that the maximum moisture content (54.08%) was observed at 40% flour blending, 27°C of water temperature and 20 minutes resting time of dough while the minimum moisture content (51.09%) was observed at 20% flour blending, 36°C of water temperature and 10 minutes of resting time of the dough.

Analysis of variance showed significant negative quadratic effect of blending and negative linear effect of water temperature but positive quadratic effect of resting time and water temperature and positive linear effect of resting time and blending significant at model 5% with R² value of 0.84. The significant model developed for moisture content in terms of independent variables (in coded levels) is given below:

$$\text{Moisture content} = 57.07 + 0.79A + 3.81B - 0.38C + 2.33AB + 0.048AC + 0.20BC + 1.71A^2 - 1.47B^2 + 1.23C^2$$

Browning Index

Browning index is defined as the brown colour purity, one of the most common indicators of browning in the processed flatbreads. It is important to measure the browning index of flatbreads during storage as its undesirable brown discolouration negatively affects its colour, taste and nutritional value. Fig. 4.24 shows the effect of process parameters on browning index of flatbread. It was observed that the maximum browning index (0.096 Nm) was observed at 20% flour blending, 36°C of water temperature and 10 minutes resting time of dough while the minimum browning index (0.053 Nm) was observed at 40% flour blending, 18°C of water temperature and 10 minutes of resting time of the dough.

Analysis of variance showed significant negative quadratic effect of blending and negative linear effect of resting time and blending but a positive quadratic effect of resting time and water temperature and positive linear effect of water temperature significant at level 5% with R² value of 0.97. The significant model developed for browning index in terms of independent variables (in coded levels) is given below:

$$\text{Browning index} = 0.067 - 0.052A - 0.016B + 0.016C + 0.010AB + 0.070AC + 0.027BC + 0.012A^2 - 0.062B^2 + 0.011C^2$$

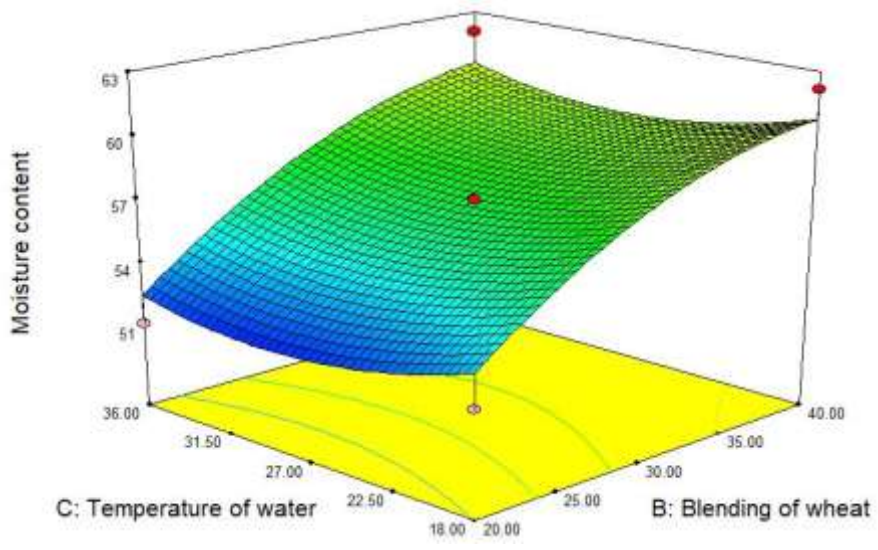
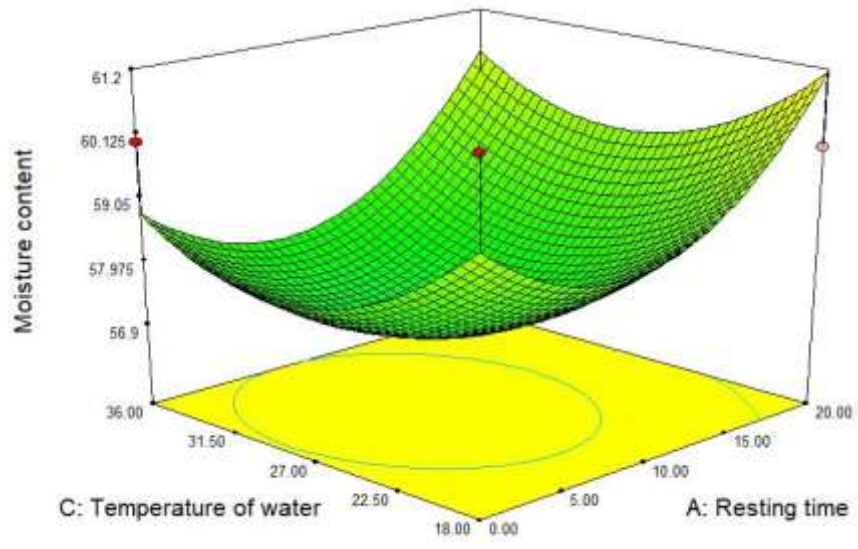
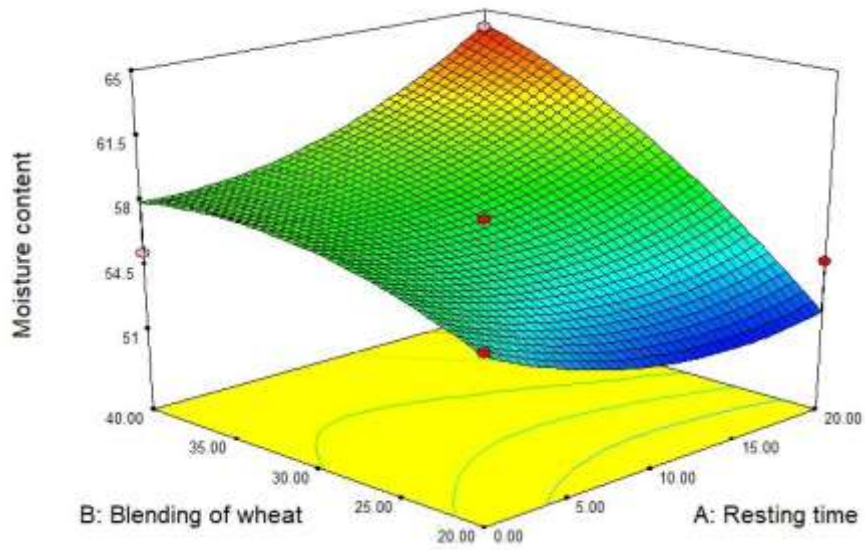


Fig. 4.23 3D model graphs showing the effect of temperature of water, blending of flour and resting time on moisture content

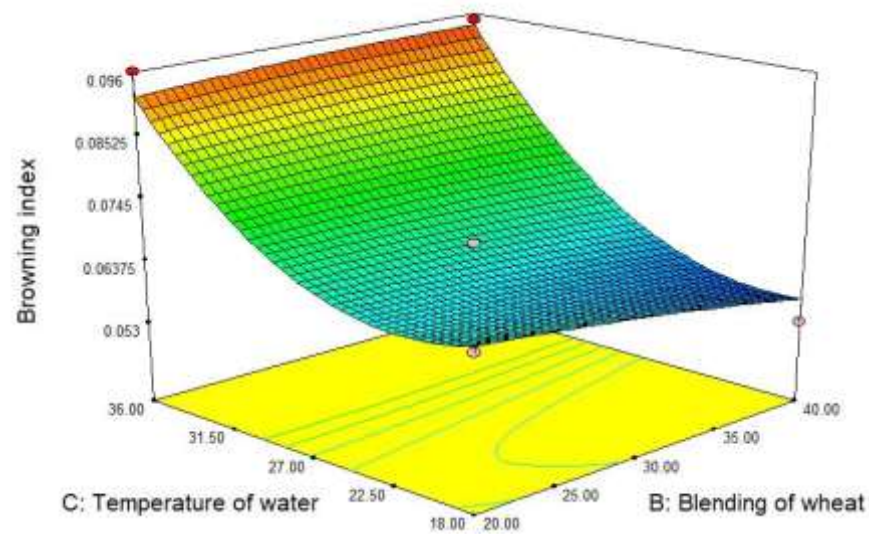
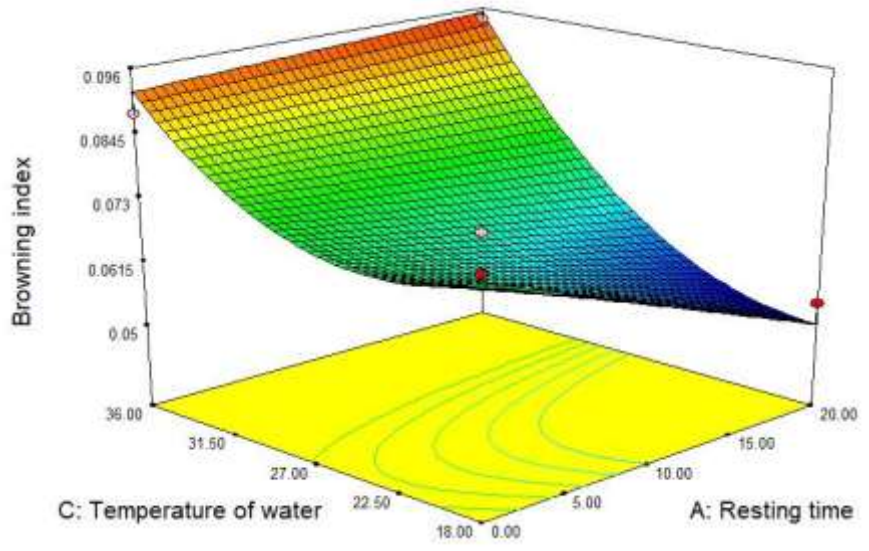
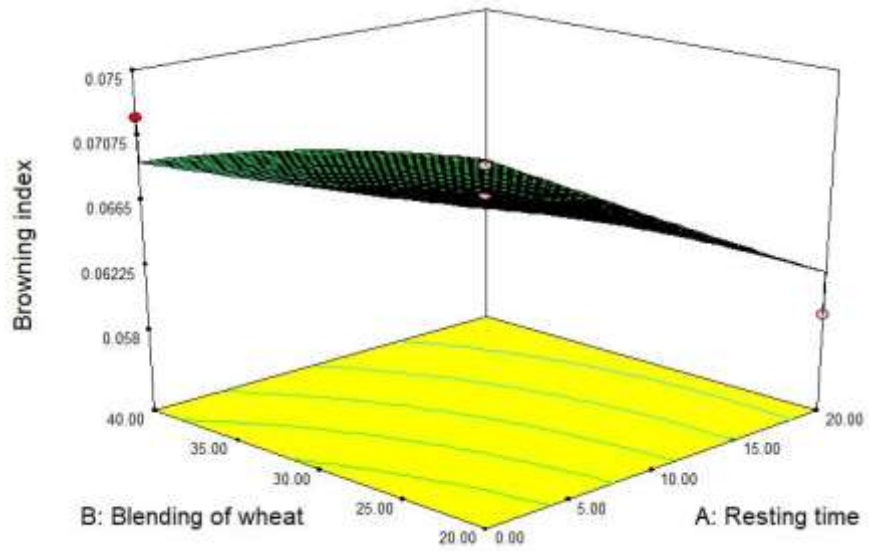


Fig. 4.24 3D model graphs showing the effect of temperature of water, blending of flour and resting time on browning index

Peroxide value

The peroxide value is the amount of oxygen consumed in the reaction that reduces all the unsaturated (C=C) bonds in a given amount of a lipid mixture during autoxidation. It is an important factor of consideration for flatbreads as it indicates the degree of primary oxidation and therefore, its likeliness of becoming rancid during storage. Fig. 4.25 shows the effect of process parameters on the peroxide value of flatbread. It was observed that the maximum peroxide value (7.09%) was observed at 40% flour blending, 18°C of water temperature and 10 minutes resting time of dough while the minimum peroxide value (6.12%) was observed at 20% flour blending, 27°C of water temperature and 0 minutes of resting time of the dough.

Analysis of variance showed significant negative quadratic effect of resting time and blending and negative linear effect of water temperature but a positive quadratic effect of water temperature and positive linear effect of resting time significant at model 5% with R² value of 0.94. The significant model developed for peroxide value in terms of independent variables (in coded levels) is given below:

$$\text{Peroxide value} = 6.54 + 0.15A + 0.20B - 0.062C - 0.010AB - 0.037AC - 0.032BC - 0.057A^2 - 0.098B^2 + 0.26C^2$$

Free Fatty Acid

Free fatty acids (FFA) are produced by the hydrolysis of oils and fats. The level of FFA depends on time, temperature and moisture content because the oils and fats are exposed to various environments such as storage, processing or heating. FFA are an important factor of consideration as they are mainly responsible for taste and texture of flatbreads. Fig. 4.26 shows the effect of process parameters on free fatty acid content of flatbread. It was observed that the maximum free fatty acid value (1.522%) was observed at 30% flour blending, 18°C of water temperature and 20 minutes resting time of dough while the minimum fatty acid (1.048%) was observed at 30% flour blending, 36°C of water temperature and 0 minutes of resting time of the dough.

Analysis of variance showed significant negative quadratic effect of resting time, blending and water temperature and negative linear effect of water temperature but a positive linear effect of resting time and blending significant at model 5% with R² value of 0.97. The significant model developed for free fatty acid value in terms of independent variables (in coded levels) is given below:

$$\text{Free fatty acid} = 1.43 + 0.039A + 0.043B - 0.18C - 0.065AB - 0.043AC - 0.011BC - 0.046A^2 - 0.051B^2 - 0.14C^2$$

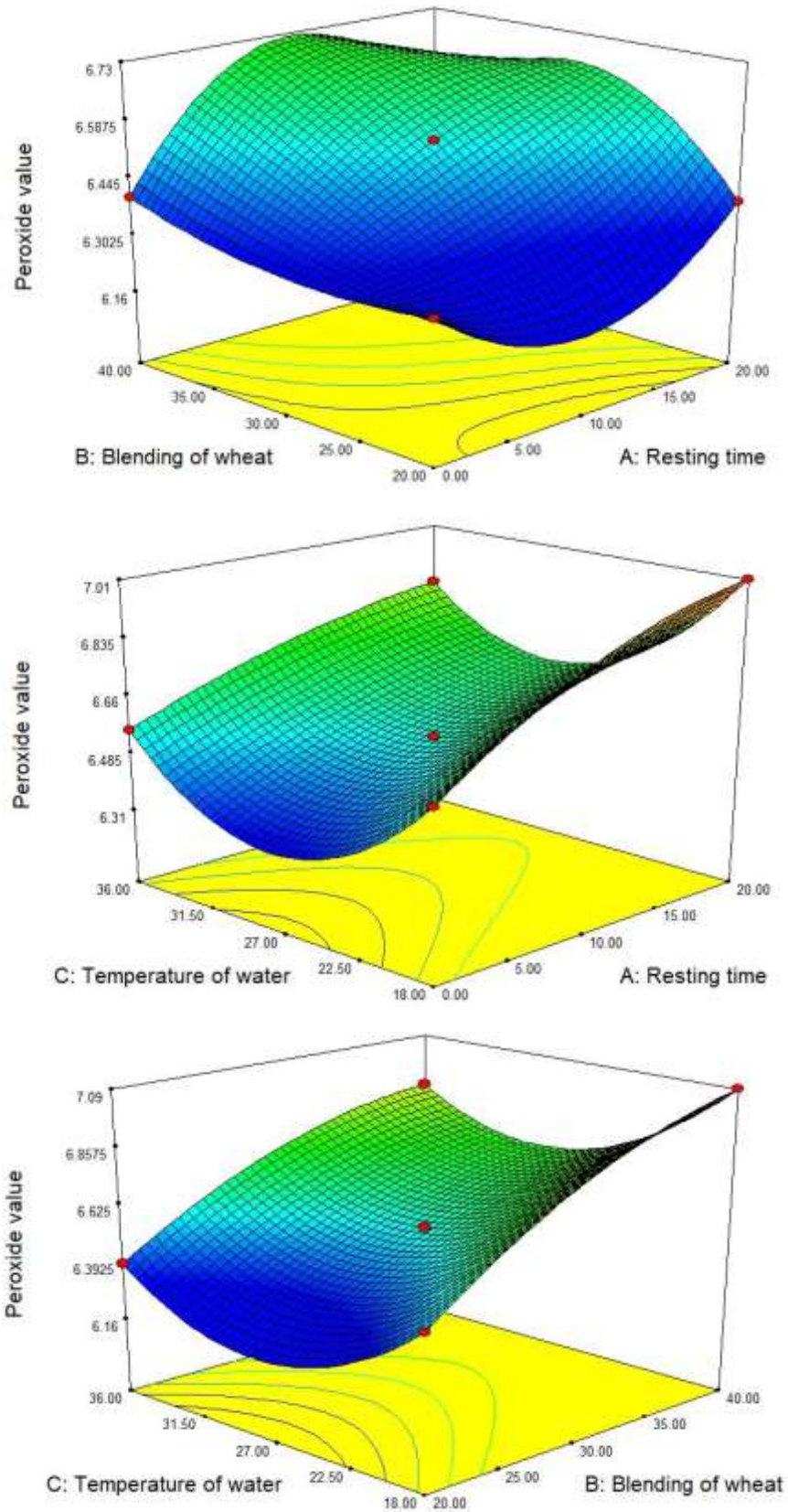


Fig. 4.25 3D model graphs showing the effect of temperature of water, blending of flour and resting time on peroxide

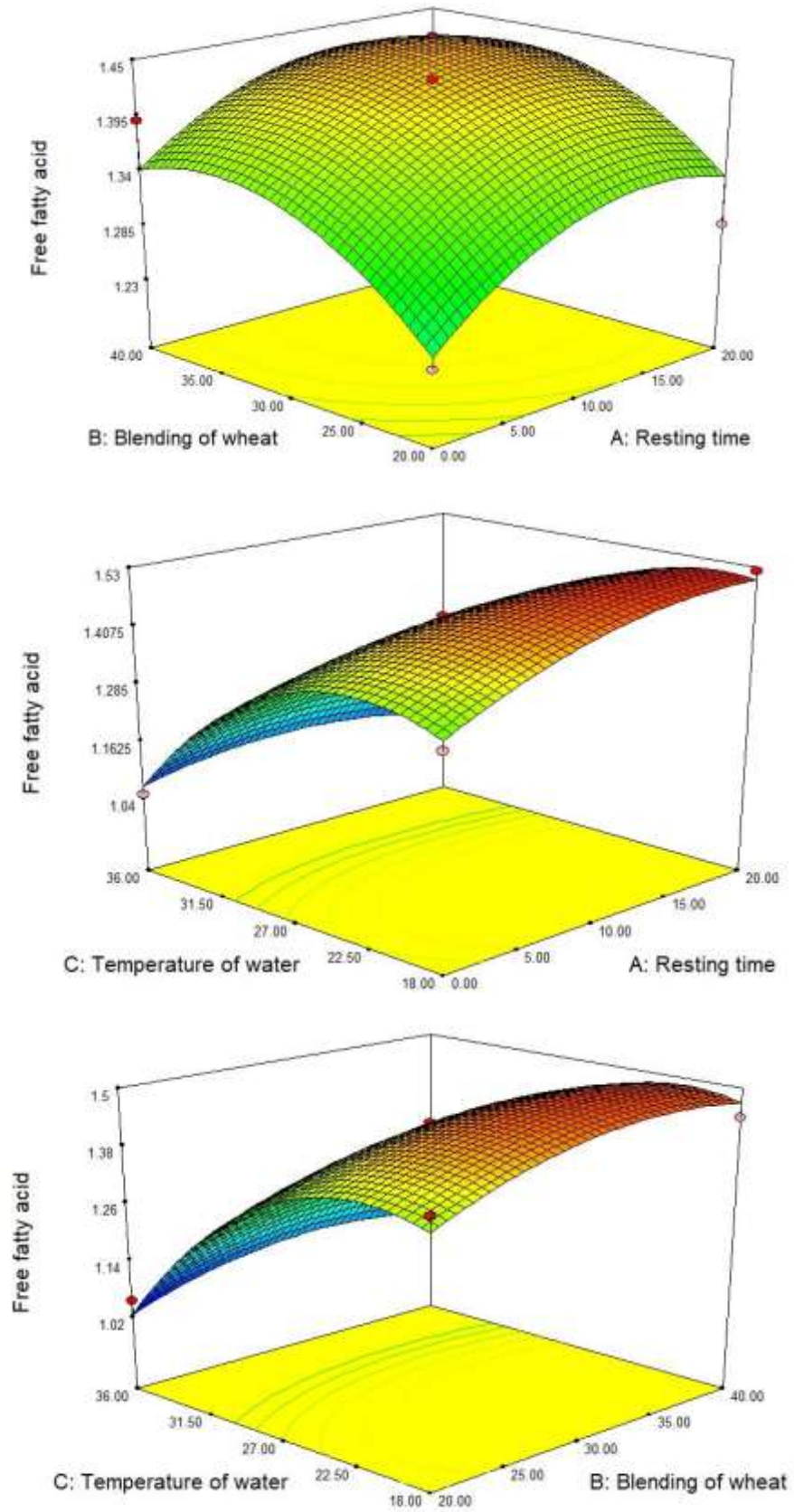


Fig. 4.26 3D model graphs showing the effect of temperature of water, blending of flour and resting time on FFA

Cutting Force

Cutting force is an indicator of hardness or softness of the flatbreads. It is an important response study in flatbread storage as higher is the cutting force, higher is the hardness of the flatbread, thus making it unfit for consumption.

Fig. 4.27 shows the effect of process parameters on cutting force of flatbreads. It was observed that the maximum cutting force (2.92 N/Kg) was observed at 30% flour blending, 18°C of water temperature and 0 minutes resting time of dough while the minimum cutting force (2.3001 N/Kg) was observed at 40% flour blending, 27°C of water temperature and 0 minutes of resting time of the dough.

Analysis of variance showed significant negative quadratic effect of water temperature and negative linear effect of water temperature but a positive quadratic effect of resting time and blending and positive linear effect of resting time and blending significant at model 5% with R² value of 0.93. The final equation predicting cutting force as affected by resting time, blending percentage and water temperature is given below:

$$\text{Cutting force} = 2.51 + 0.058A + 0.051B - 0.046C + 0.25AB + 0.0494AC + 0.016BC + 0.023A^2 + 0.041B^2 - 0.12C^2$$

Colour change

Colour change is an indicator of the freshness of the flatbread during storage. It is an important factor of consideration as it affects the taste, appearance and overall acceptability of the finished product.

Fig. 4.28 shows the effect of process parameters on colour change value of flatbread. It was observed that the maximum colour change (76.67) was observed at 30% flour blending, 18°C of water temperature and 20 minutes resting time of dough while the minimum colour change (62.33) was observed at 30% flour blending, 36°C of water temperature and 0 minutes of resting time of the dough.

Analysis of variance showed significant negative quadratic effect of resting time and blending and negative linear effect of water temperature but a positive quadratic effect of water temperature and positive linear effect of resting time and blending significant at model 5% with R² value of 0.82. The significant model developed for colour change in terms of independent variables (in coded levels) is given below:

$$\text{Colour change} = +71.88 + 3.22A + 0.22B - 2.39C - 1.05AB + 1.21AC - 1.18BC - 1.60A^2 - 1.09B^2 + 0.43C^2$$

Overall acceptability

Overall acceptability is a scientific discipline used to invoke, measure, analyze and interpret reactions to the characteristics of flatbreads as perceived by senses of sight, smell, taste, touch and hearing.

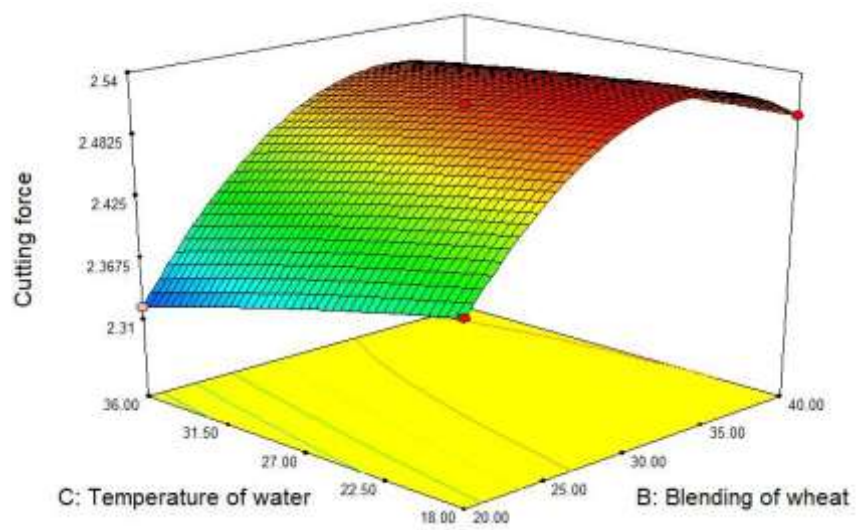
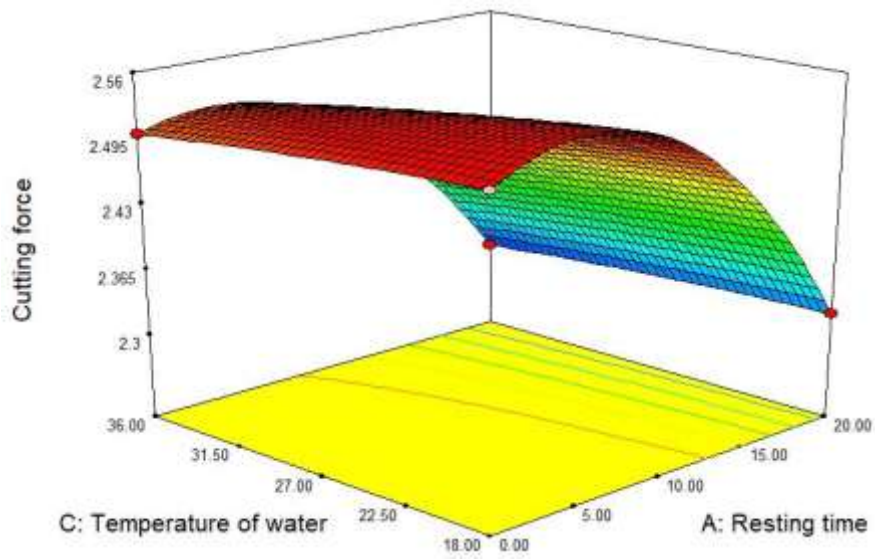
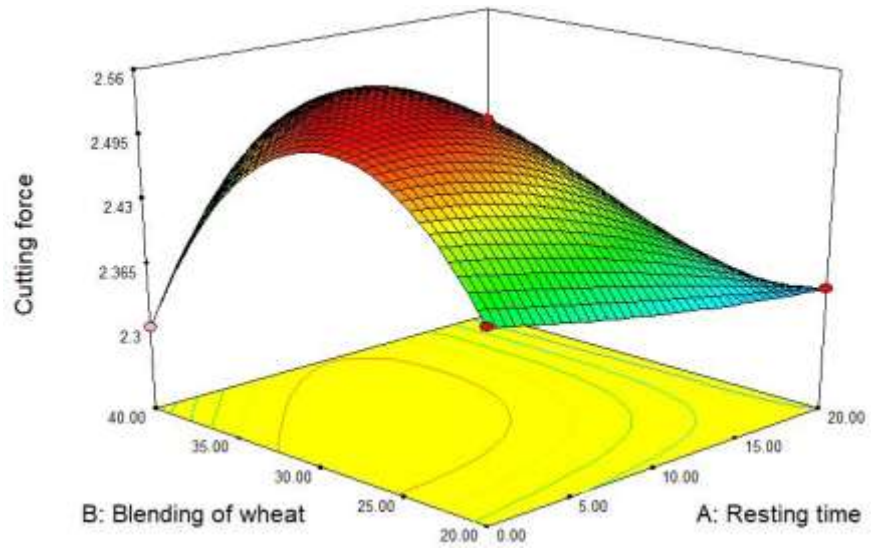


Fig. 4.27 3D model graphs showing the effect of temperature of water, blending of flour and resting time on texture

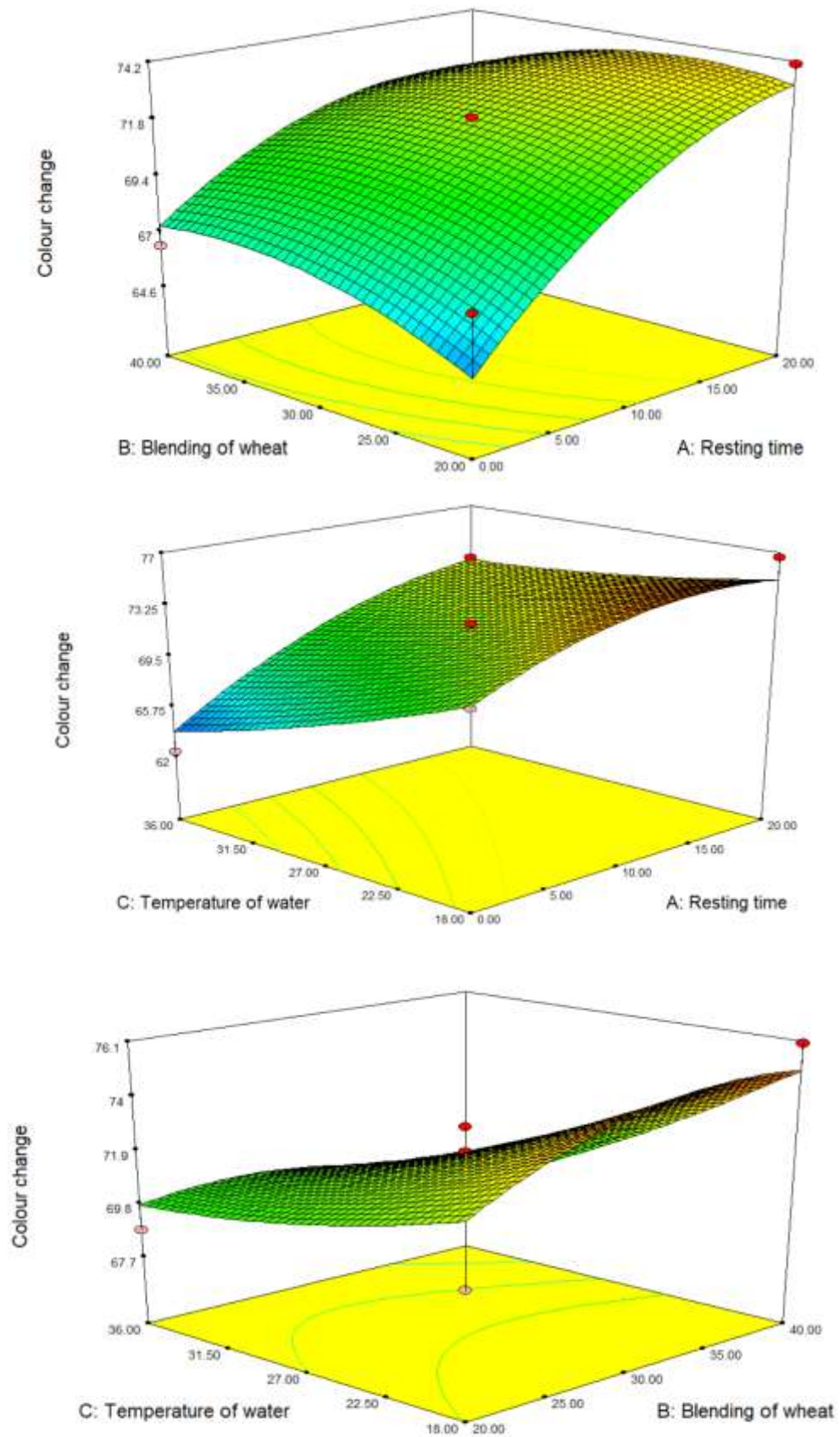


Fig. 4.28 3D model graphs showing the effect of temperature of water, blending of flour and resting time on colour change

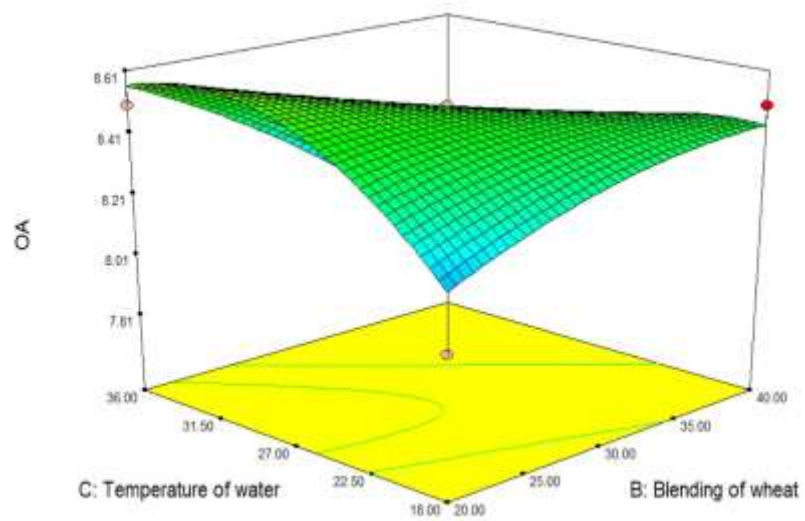
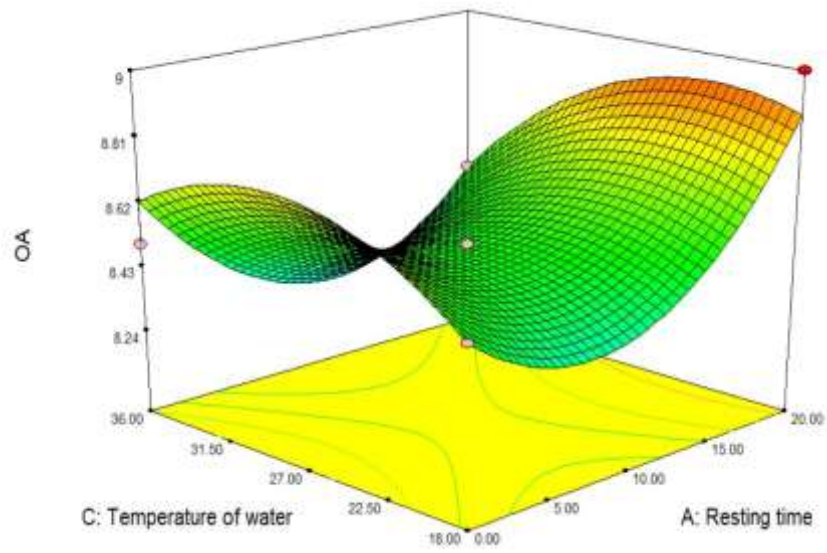
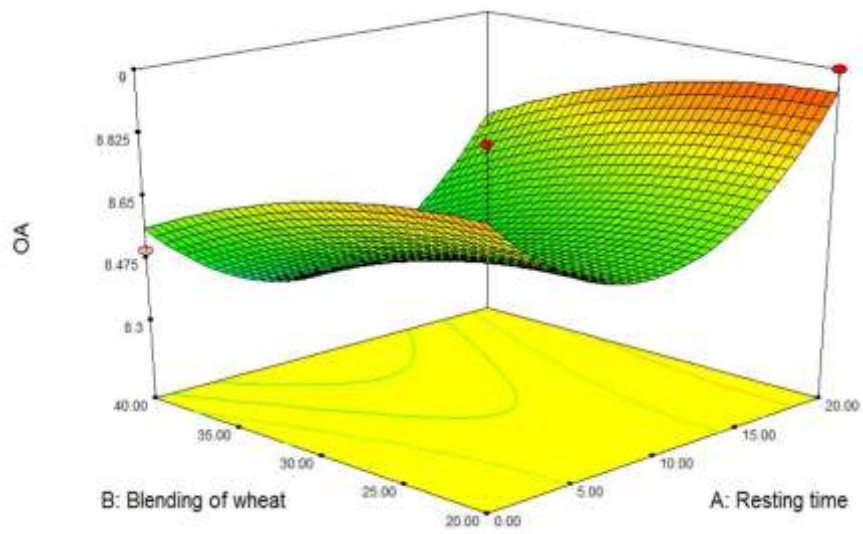


Fig. 4.29 3D model graphs showing the effect of temperature of water, blending of flour and resting time on overall acceptability

Fig. 4.29 shows the effect of process parameters on overall acceptability of flatbread. It was observed that the maximum acceptability (9) was observed at 30% flour blending, 18°C of water temperature and 20 minutes resting time of dough while the minimum acceptability (8) was observed at 20% flour blending, 18°C of water temperature and 10 minutes of resting time of the dough.

Analysis of variance showed significant negative quadratic effect of blending and water temperature and negative linear effect of blending and water temperature but positive quadratic effect of resting time and positive linear effect of resting time significant at model 5% with R² value of 0.84 The significant model developed for overall acceptability in terms of independent variables (in coded levels) is given below:

$$\text{Overall acceptability} = 8.50 + 0.063A - 0.13B - 0.062C + 0.13AC - 0.25BC + 0.31A^2 - 0.063B^2 - 0.19C^2$$

4.3.4 Optimization results for wheat flour blended flatbreads of 180µ sieve size

The optimization results of process parameters and responses are presented in Table 4.3. The process parameters were optimized using numerical optimization technique. The main criteria for constraints optimized were moisture content, browning index, peroxide content, free fatty acid, colour change and cutting force.

Table 4.3 Optimum values of process parameters and responses

Independent variables	Goal	Lower Limit	Upper Limit	Optimization value	Actual value
Resting time (min)	Is in range	0	20	20	-
Blending (%)	Is in range	20	40	20	-
Temperature of water (°C)	Is in range	18	36	29.68	-
Responses					
Moisture content	Minimize	51.09	64.08	54.66	51.38
Browning Index	Minimize	0.053	0.096	0.078	0.076
Peroxide value	Minimize	6.32	6.71	6.342	6.32
Free fatty acid	Minimize	1.048	1.522	1.216	1.221
Cutting force	Minimize	2.3001	3.3018	2.5442	2.5434
Colour change	Maximum	62.33	76.67	66.42	66.45
Overall acceptability	Maximize	8	9	8.9395	8

In order to optimize the process conditions using numerical optimization technique, moisture content, browning index, peroxide value, free fatty acid, cutting force was minimum and colour change and overall acceptability was. The optimum conditions for flatbread preparation of wheat flour of 180 μ sieve size for resting time, blending and temperature were 20 minutes, 20% and 29.68°C respectively. The overall desirability was 0.783.

4.4 Effect of process parameters on the quality of dough

The dough was prepared according to the results of the optimum parameters obtained from the Response Surface Methodology (RSM) and was tested for the texture and color properties as under:

4.4.1. Texture analysis

The cutting force of whole maize dough was 0.2955 N/Kg while for gram flour blended and wheat flour blended dough, it was 0.3101 N/Kg and 0.3205 N/Kg respectively as shown in Fig. 4.29. Wheat flour blended dough has a higher cutting force than the gram flour blended maize dough. This is be due to the higher binding strength of wheat due to the presence of gluten. Similar findings were done by Gracia *et al* (2017) for dough profile analysis of maize dough fortified with nontoxic *Jatropha curcas* L. flour.

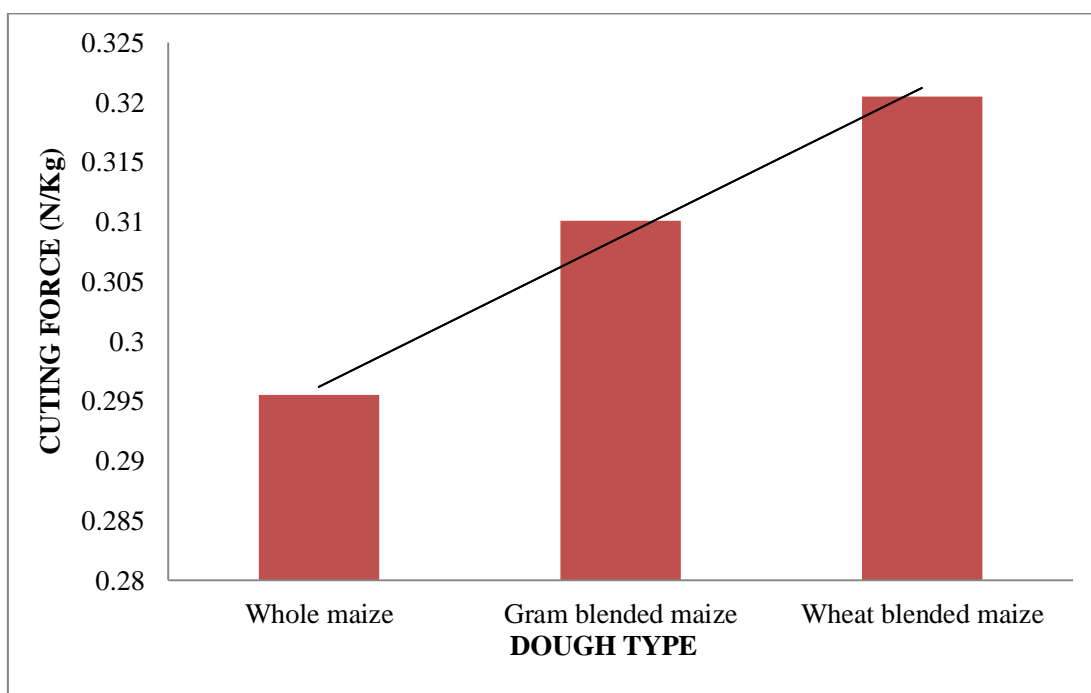


Fig. 4.29 Cutting force of dough

4.2.2 Color value

The color value or L value of whole maize dough was 80.12 while for the gram blended and wheat blended dough, it was 82.56 and 84.02 respectively as shown in Fig. 4.30.

Wheat blended dough has a higher L value than the gram blended dough. This is due to the difference in the pigment content of the respective blended flour samples used. The lesser is the yellow color, the higher is the whiteness. Similar results were obtained by Lamsal and Faubion (2009) while measuring the color difference of chestnut flours air dried at different conditions.

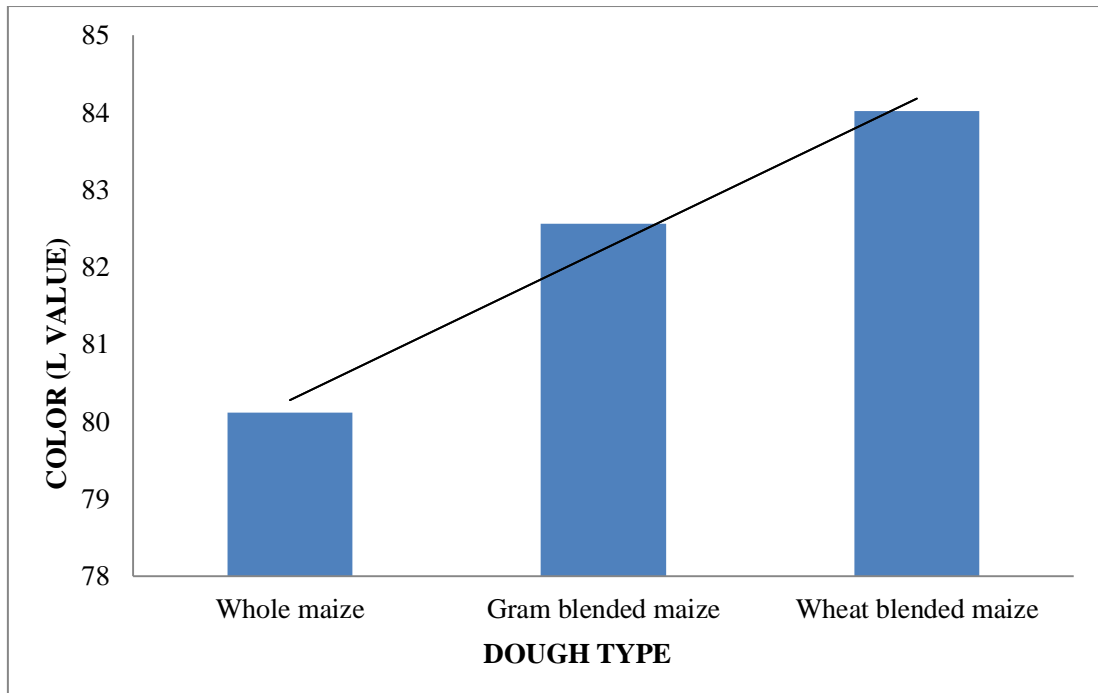


Fig. 4.30 L value of dough

4.5 Effect of process parameters and storage on the quality of maize flour based flatbreads

Maize flour based flatbreads prepared at optimum combination of blending with wheat and gram flour were stored in a zip lock packaging of HDPE packaging material. The flatbreads were stored in refrigerated conditions as well as controlled conditions. The results regarding flatbread storage have been compiled as under:

4.5.1 Moisture content

The initial moisture content of gram flour blended and wheat flour blended flatbread was 42.11% and 51.38% respectively as shown in Fig. 4.31. The moisture content of flatbreads decreased linearly with storage period in both the storage conditions; whereas the decrease was more prominent in ambient storage conditions. In case of gram flour blended flatbreads, the decrease in moisture content was 10.92% and for wheat flour blending, it was 8.14% after 6 days of storage. In refrigerated storage, the decrease was 6.83% and 7.04% for gram flour based and wheat flour based flatbreads respectively after 30 days of storage. This is due to the evaporation of moisture during cooking of flatbreads and furthermore with their storage. Similar findings were reported by Peluola-Adeyemi *et al* (2016) while measuring the moisture content of wheat flatbreads blended with cocoyam flour.

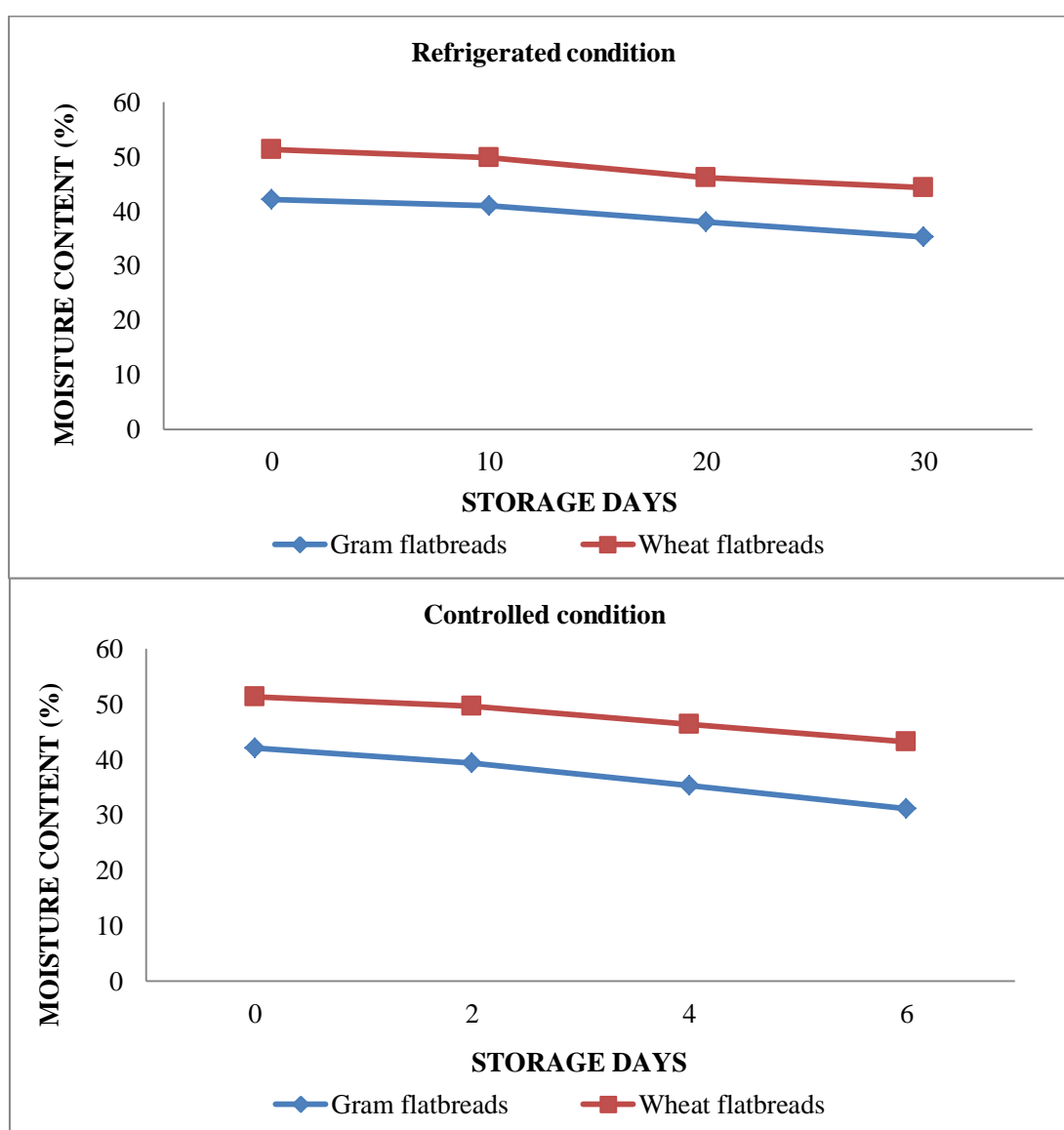


Fig. 4.31 Effect of storage condition on moisture content of flatbread

4.5.2 Browning Index

The initial browning index of gram flour blended and wheat flour blended flatbread was 0.068 Nm and 0.076 Nm respectively as shown in Fig. 4.32. The browning index of flatbreads increased linearly with storage period in both the storage conditions; whereas the increase was more prominent in ambient storage conditions. In case of gram flour blended flatbreads, the increase in browning index was of 0.011 Nm and for wheat flour blending, it was 0.006 Nm after 6 days of storage. In refrigerated storage, the increase was 0.008 Nm and 0.004 Nm for gram flour based and wheat flour based flatbreads respectively after 30 days of storage. The main reason for the increased browning index is the increased rate of autoxidation of lipids. Similar findings were reported by Khan *et al* (2011) while doing the evaluation of shelf life of chapaties without the use of preservatives.

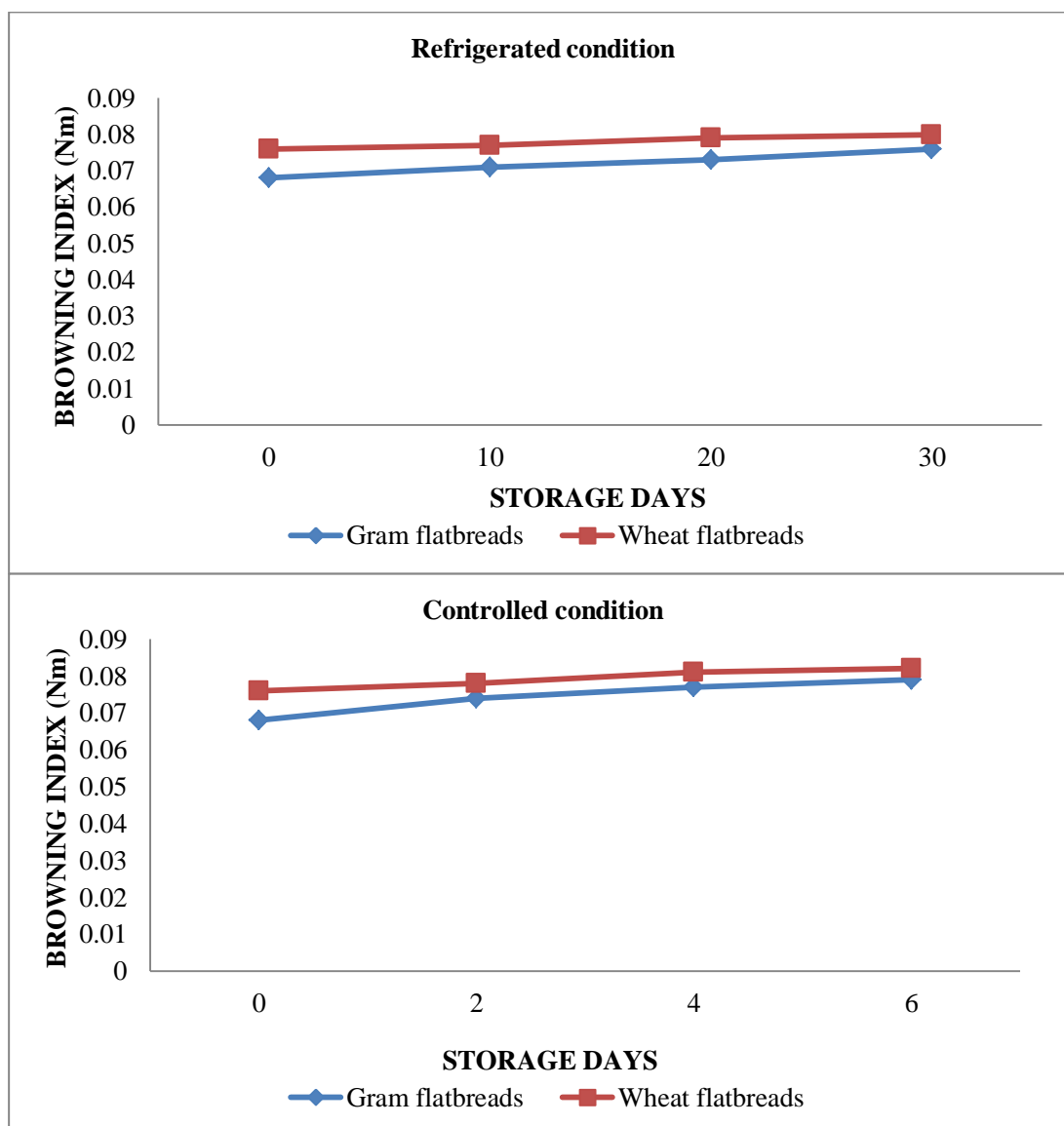


Fig. 4.32 Effect of storage condition on browning index of flatbread

4.5.3 Color change assessment

The initial color change value of gram flour blended flatbread was 65.14, and for wheat blended flatbread, it was 66.45 as shown in Fig. 4.33. The decrease in color change value of flatbreads with respect to storage period was observed in both the storage conditions, whereas the decrease was more prominent in ambient storage conditions. This is due to the darkening of the flatbreads with the passage of time. Similar trend of recordings were observed by Khan *et al* (2014) while measuring the color change values while conducting the experiment on shelf life of potato stuffed paratha using thermal processing.

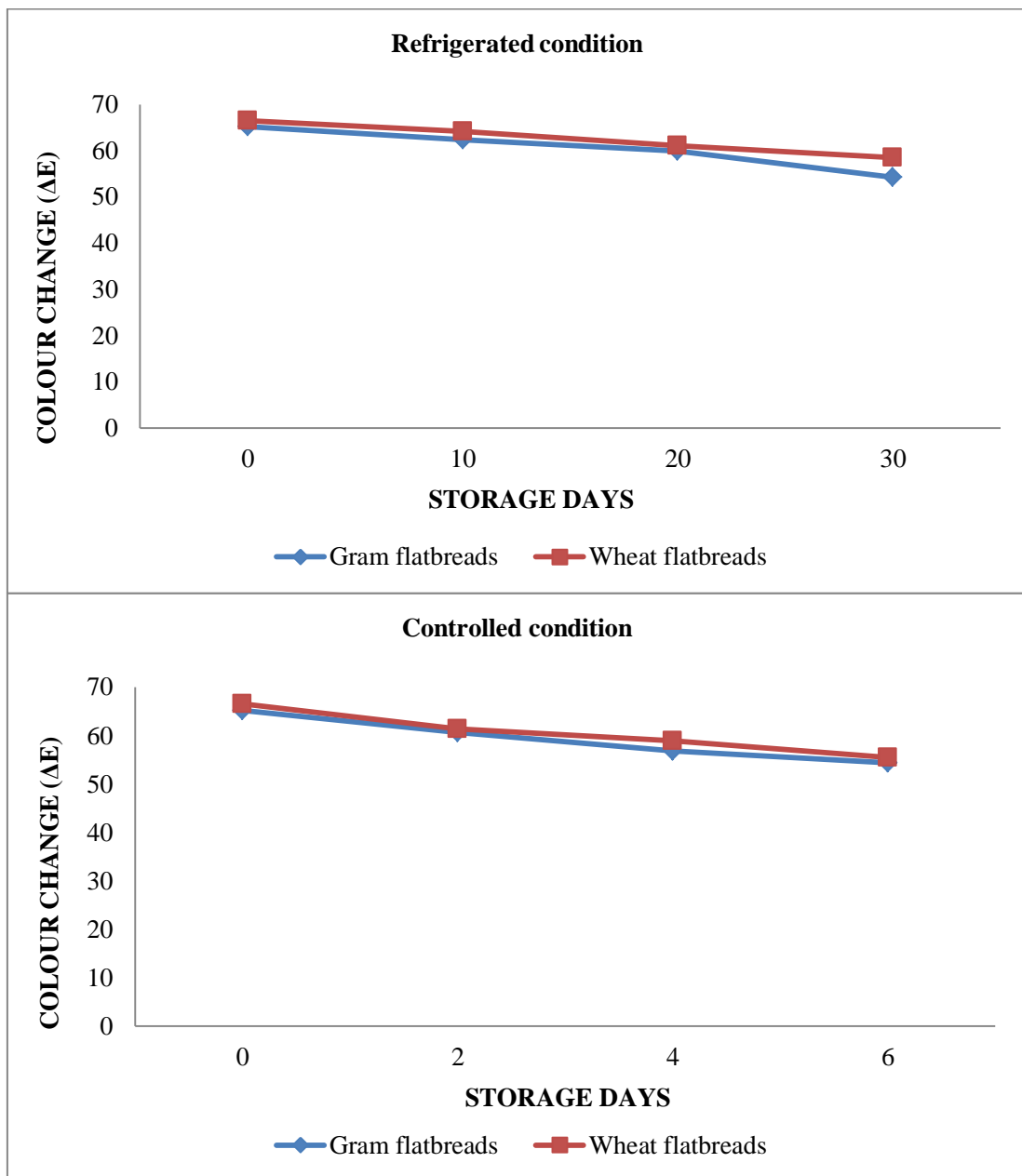


Fig. 4.33 Effect of storage condition on color change of flatbread

4.5.4 Cutting force

The initial cutting force of gram flour blended and wheat flour blended flatbread was 4.6344 N/Kg and 2.5434 N/Kg respectively as shown in Fig. 4.34. The cutting force of flatbreads increased linearly with storage period in both the storage conditions; whereas the increase was more prominent in ambient storage conditions. In case of gram flour blended flatbreads, the increase in cutting force was 0.1098 N/Kg and for wheat flour blending, it was 0.1575 N/Kg after 6 days of storage. In refrigerated storage, the increase was 0.1017 N/Kg and 0.0.1751 N/Kg for gram flour based and wheat flour based flatbreads respectively after 30 days of storage. The main reason for increase in force required to cut the flatbreads is the loss of moisture in them with the increasing number of storage days. Similar trends were reported by Gujral and Pathak (2002) while measuring the cutting force of major Indian traditional foods.

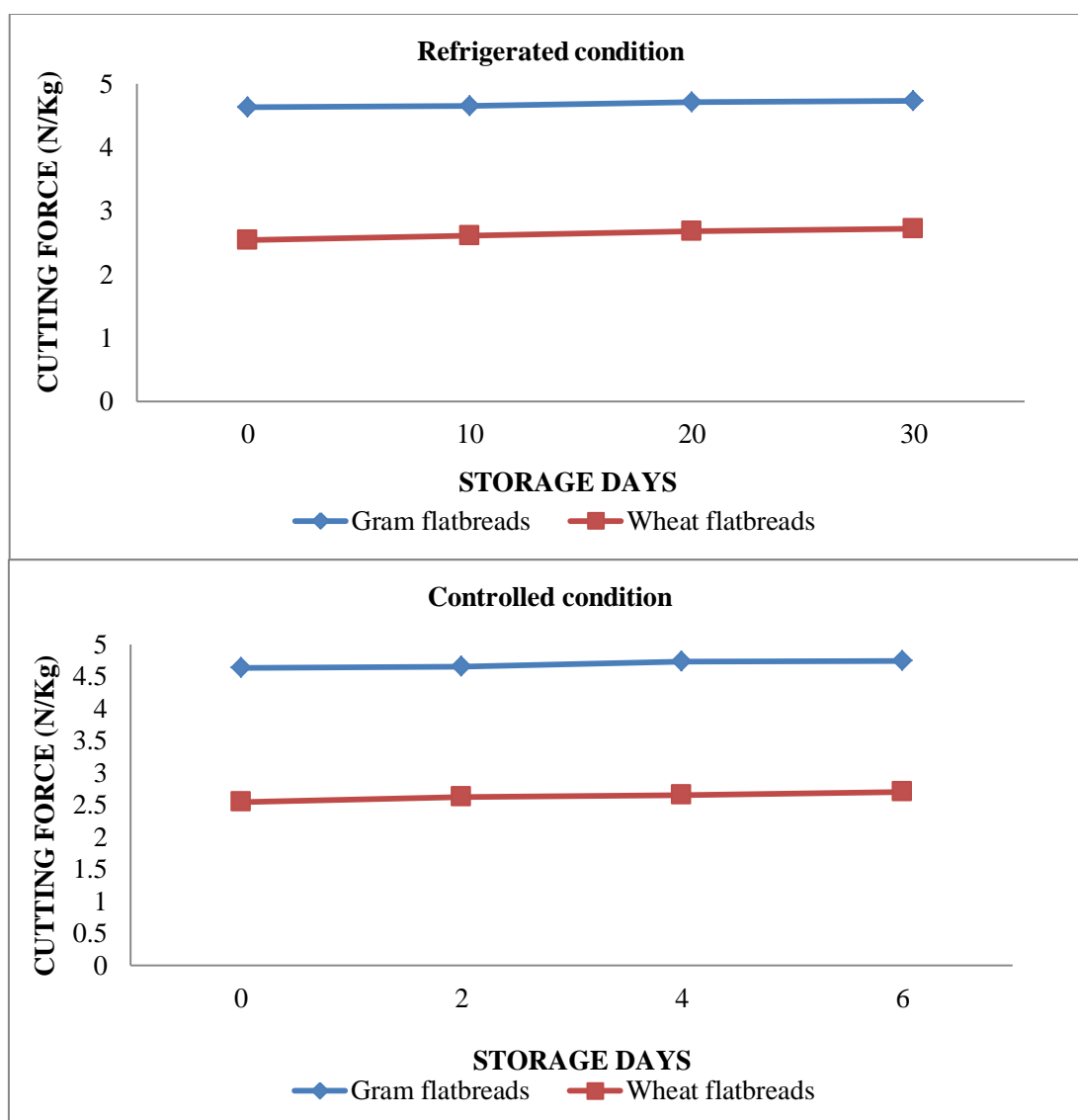


Fig. 4.34 Effect of storage condition on cutting force of flatbread

4.5.5 Free fatty acid

The initial free fatty acid content of gram flour blended and wheat flour blended flatbread was 1.149% and 1.221% respectively as shown in Fig. 4.35. The FFA value of flatbreads increased linearly with storage period in both the storage conditions; whereas the increase was more prominent in ambient storage conditions. In case of gram flour blended flatbreads, the increase in FFA value was 0.014% and for wheat flour blending, it was 0.027% after 6 days of storage. In refrigerated storage, the increase was 0.012% and 0.017% for gram flour based and wheat flour based flatbreads respectively after 30 days of storage. This increase is mainly due to the rancidity in the flatbreads with the increase in storage period. Similar trends were reported by Bindu *et al* (2007) while evaluating the shelf life of ready to eat black clam product in indigenous retort pouches.

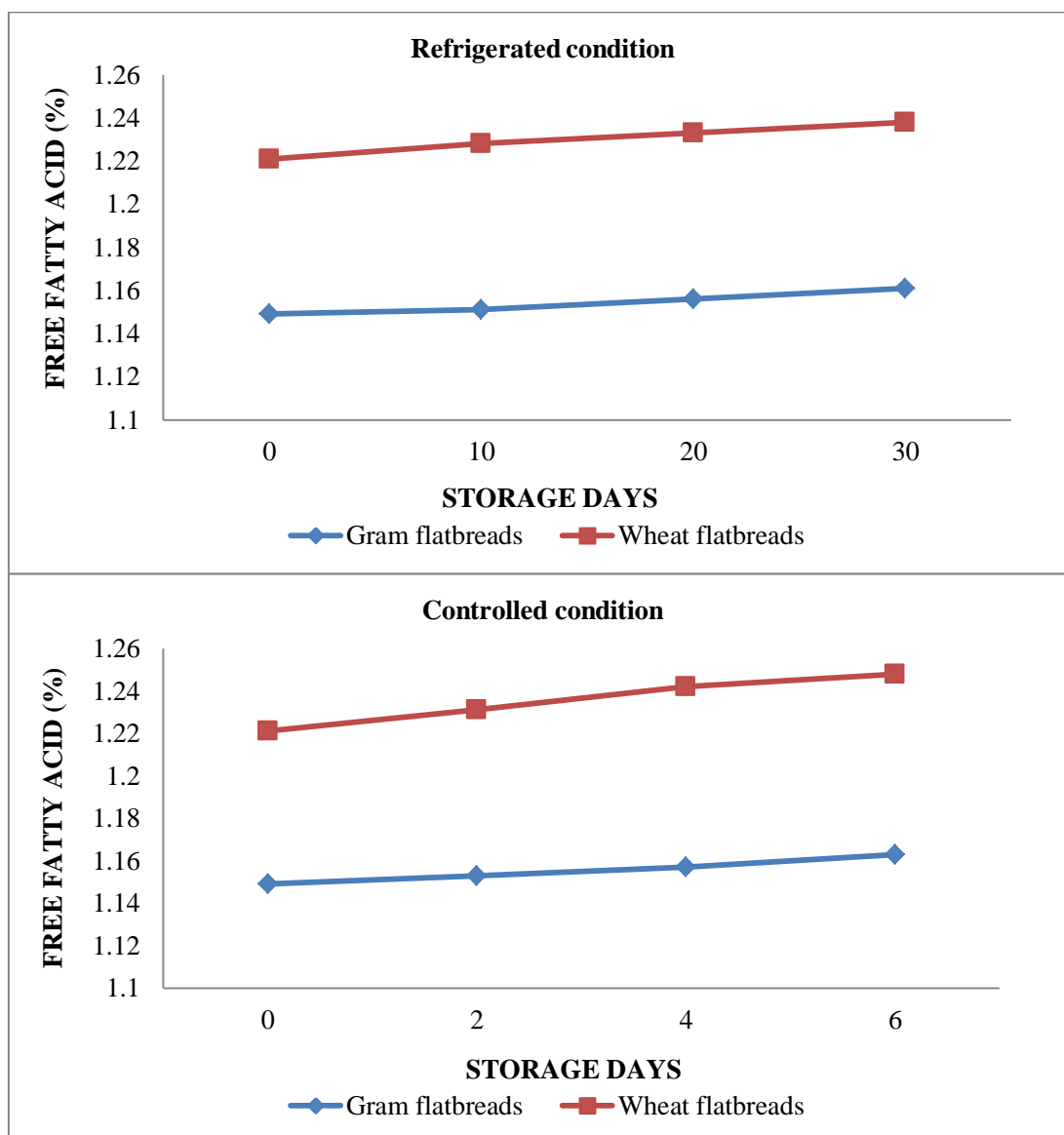


Fig. 4.35 Effect of storage condition on free fatty acid value of flatbread

4.5.6 Peroxide value

The initial peroxide value of gram flour blended and wheat flour blended flatbread was 6.51% and 6.32% respectively as shown in Fig. 4.36. The peroxide value of flatbreads increased linearly with storage period in both the storage conditions; whereas the increase was more prominent in ambient storage conditions. In case of gram flour blended flatbreads, the increase in peroxide value was 0.13% and for wheat flour blending, it was 0.19% after 6 days of storage. In refrigerated storage, the increase was 0.12% and 0.15% for gram flour based and wheat flour based flatbreads respectively after 30 days of storage. The reason for increase in peroxide content during storage is the primary oxidation of fats present in the flatbread. Similar trend in the peroxide content was observed by Khan *et al* (2011) while evaluating the shelf life of chapaties without the use of chemical preservatives.

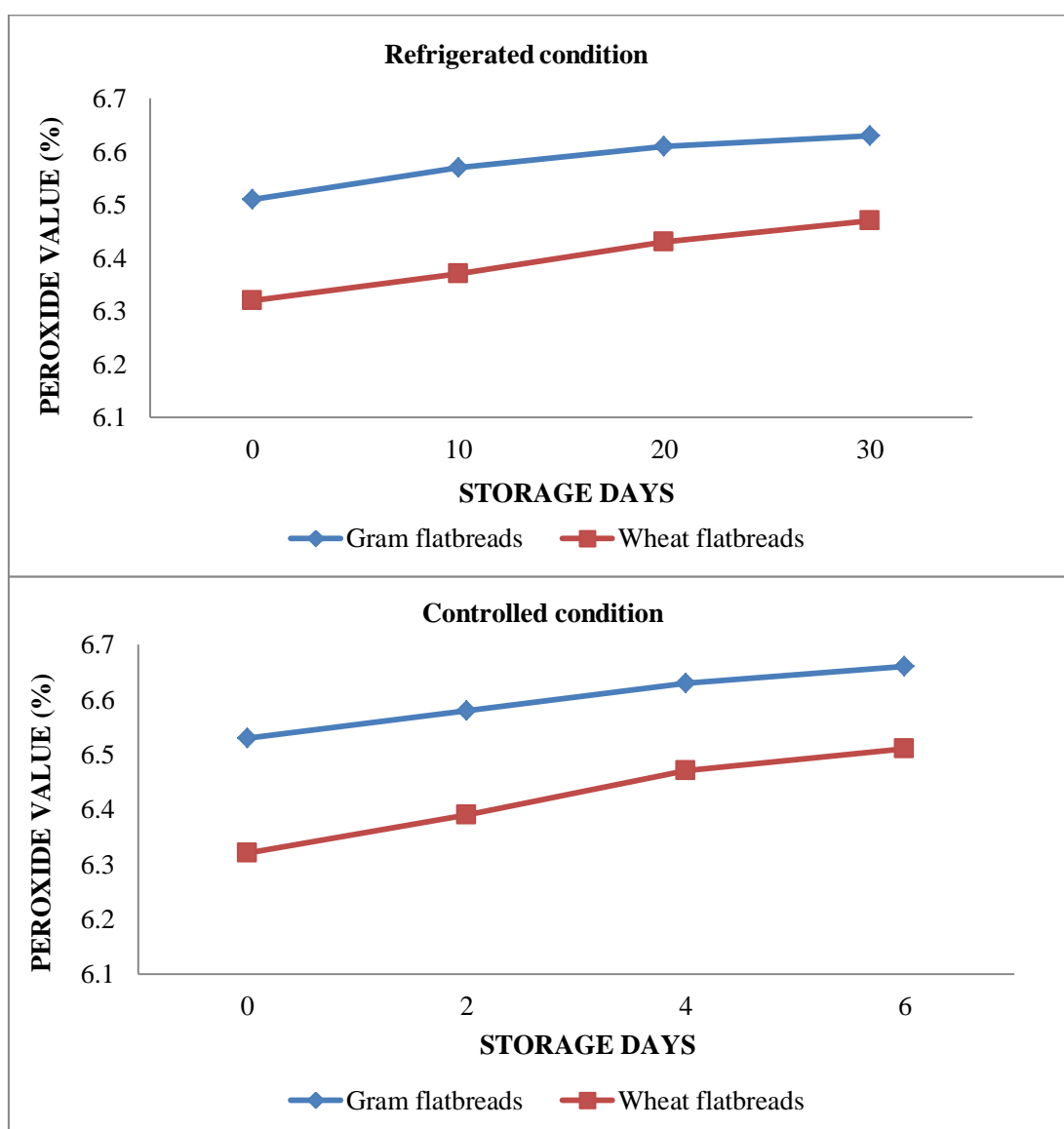


Fig. 4.36 Effect of storage condition on peroxide value of flatbread

4.6 Microbial and sensory analysis

4.6.1 Microbial analysis

The initial colony count of gram flour blended and wheat flour blended flatbread was zero as shown in Fig. 4.37. The colony count of flatbreads increased linearly with storage period in both the storage conditions; whereas the increase was more prominent in ambient storage conditions. In case of gram flour blended flatbreads, the increase in count of colonies was 50 and for wheat flour blending, it was 51 after 6 days of storage. In refrigerated storage, the increase was up to 40 and 45 for gram flour based and wheat flour based flatbreads respectively after 30 days of storage. This is due to the contamination of flatbreads with time. Similar readings were observed by Wahab *et al* (2003) while finding the effect of microbial count on overall quality of bread.

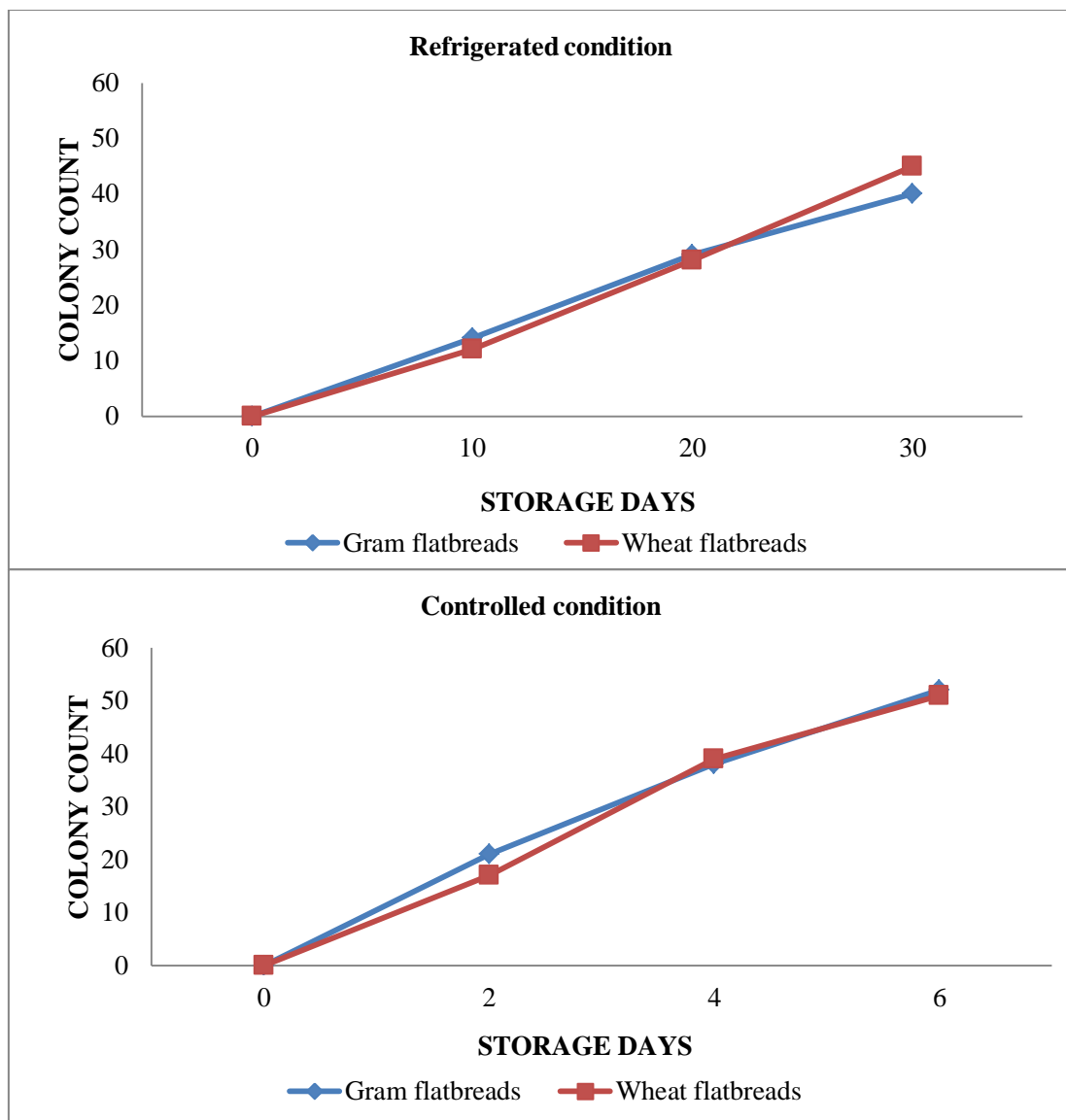


Fig. 4.37 Effect of storage condition on colony count of flatbread

4.6.2 Sensory analysis

The sensory evaluation of wheat and gram blended flatbreads based on the standard 9 point hedonic scale was evaluated. The initial overall acceptability of gram flour blended and wheat flour blended flatbread was 8.5 and 8 respectively as shown in Fig. 4.38. The overall acceptability of flatbreads decreased linearly with storage period in both the storage conditions; whereas the decrease was more prominent in ambient storage conditions. In case of gram flour blended flatbreads, the decrease in overall acceptability was 4.5 and for wheat flour blending, it was 5.5 after 6 days of storage. In refrigerated storage, the decrease was up to 4.5 and 4 for gram flour based and wheat flour based flatbreads respectively after 30 days of storage.

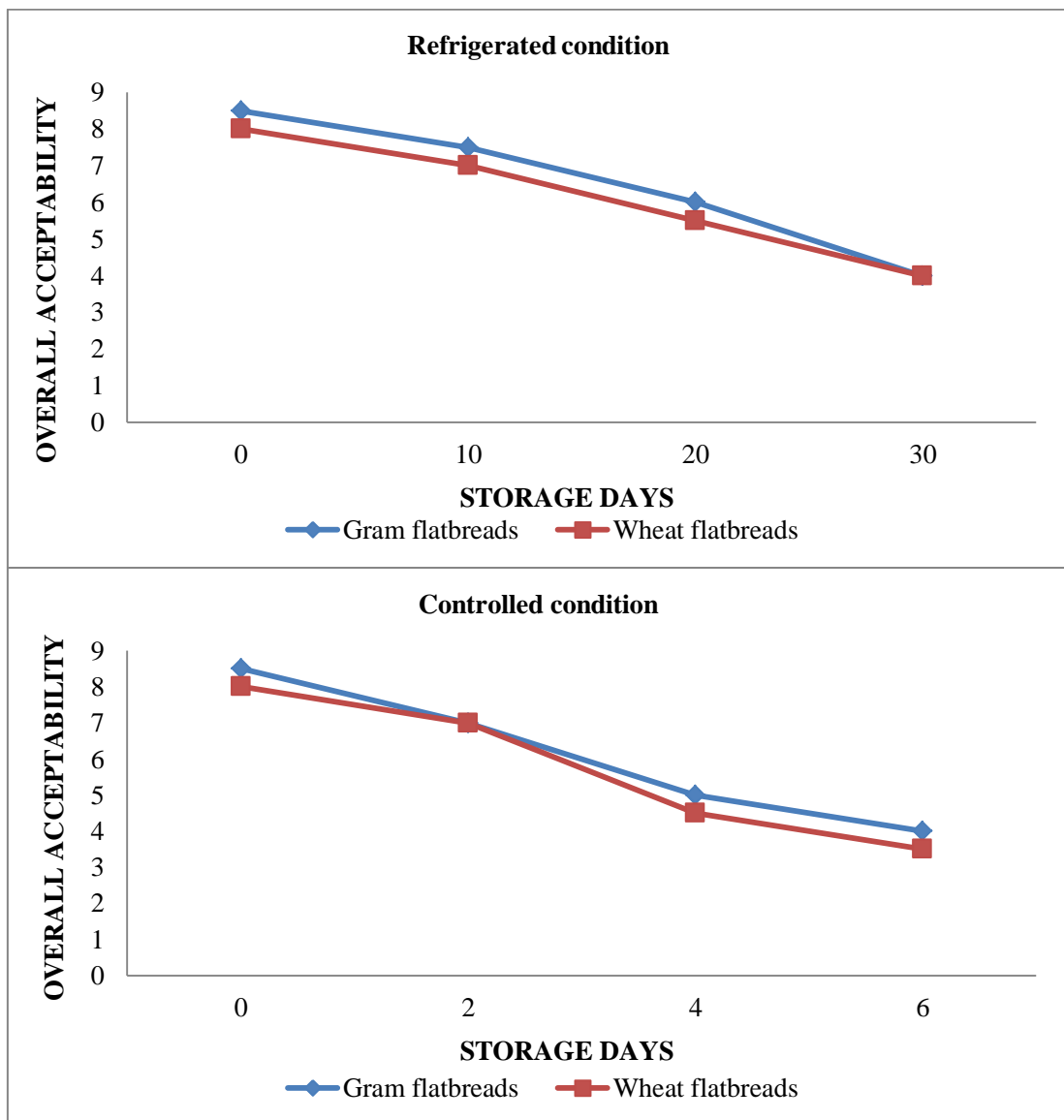


Fig. 4.38 Sensory analysis of flatbreads

CHAPTER V

SUMMARY

The present study was conducted on the optimization of process parameters of maize flour based flatbreads using Roti maker machine. The PMH1 variety of maize kernels was procured and was milled into flour. Flour was separated into two grain sizes of 180 μ and 355 μ through sieve analysis. Maize flour was blended with wheat and gram flour in the blending percentage of 20, 30 and 40. Flour samples were tested for physico-chemical properties like moisture content, protein content, crude fat, ash content, crude fiber, carbohydrates, titrable acidity, color, swelling power, water holding capacity and oil holding capacity. The optimization of process parameters was done using Box-Behnken design using Response Surface Methodology (RSM). The analysis of variance (ANOVA) was carried out using Design Expert 10 DX7.0 software. The three independent variables set were resting time of dough (0, 10 and 20 min), blending percentage of flour (20, 30 and 40%) and temperature of water to knead the dough (18°, 27° and 36°C). The response surface plots were generated for different variables using the same software. The optimization of mechanized preparation of maize flour based flatbreads aimed at finding the levels of resting time of dough, blending ratio and temperature of water which could give maximum overall acceptability, minimum color change, minimum moisture content, minimum free fatty acid, minimum peroxide value, minimum cutting force and minimum browning index. The maize flour blended with gram and wheat flour was kneaded into dough and tested for texture and color values. The flatbreads prepared at the optimized conditions were stored in HDPE packaging under refrigerated and controlled conditions. Different parameters like moisture content, browning index, color change, cutting force, free fatty acid, peroxide value, colony count and overall acceptability were measured at regular intervals of time. The following conclusions were drawn from the present study:

- Physico chemical properties of whole maize flour were moisture content (8.56 \pm 0.01%), protein content (10.45 \pm 0.01%), crude fat (4.40 \pm 0.01%), ash content (2.38 \pm 0.01%), crude fiber (2.44 \pm 0.01%), carbohydrates (70.13 \pm 0.02%), titrable acidity (0.076 \pm 0.001%), color value (70.03 \pm 0.01), swelling power (22.31 \pm 0.01%), water holding capacity (70.32 \pm 0.01%) and oil holding capacity (122.12 \pm 0.01%) respectively.
- The blending percentage of gram flour and wheat flour had a significant effect on protein content, crude fat, crude fiber, carbohydrates, titrable acidity, color value, swelling power, water holding capacity and oil holding capacity.
- Optimum conditions obtained were 12.45 min resting time, 38.90% blending percentage and 31.47°C water temperature for blending with gram flour and for wheat flour

blending, optimum conditions obtained were 20 min resting time, 20% blending percentage and 29.68°C water temperature respectively.

- Moisture content of flatbread decreases linearly with storage period in both the storage conditions respectively.
- Browning index increases linearly with storage period but the increase was more prominent in gram flour flatbread.
- The increase in cutting force was more prominent in wheat flour blended flatbread.
- The free fatty acid and peroxide value also increase with the increase in storage period in both the storage conditions respectively.
- The colony count was more pronounced in wheat flour blended flatbread in ambient condition.
- The gram flour blended flatbread was more acceptable than the wheat flour blended flatbread.

Based on the results of present study, it can be concluded that the maize flour based flatbread can be prepared by 40% blending with gram flour, resting time of dough 12.45 min and temperature of water 31.47°C using 'Roti maker machine'. Similarly, it can be prepared by 20% blending with wheat flour; resting time of 20 min and temperature of water 29.68°C. The gram flour blended flatbread had a more overall acceptance than wheat flour blended flatbread. The flatbread can be stored in refrigerated storage conditions up to 30 days and under ambient storage conditions up to 6 days without deterioration in quality parameters.

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ANNEXURE I

Statistical representation of blending on moisture content of flour

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	16.41981786	13	1.263063	4844.625	3.15E-23	2.507263
Within Groups	0.00365	14	0.000261			
Total	16.42346786	27				

Statistical representation of blending on protein content

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	36.28297143	13	2.790998	10282.62	1.63E-25	2.507263
Within Groups	0.0038	14	0.000271			
Total	36.28677143	27				

Statistical representation of blending on crude fat content of flour

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	22.72418571	13	1.748014	6440.053	4.3E-24	2.507263
Within Groups	0.0038	14	0.000271			
Total	22.72798571	27				

Statistical representation of blending on ash content of flour

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	3.083842857	13	0.237219	948.8747	2.82E-18	2.507263
Within Groups	0.0035	14	0.00025			
Total	3.087342857	27				

Statistical representation of blending on crude fibre content of flour

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	0.5574	13	0.042877	187.5865	2.26E-13	2.507263
Within Groups	0.0032	14	0.000229			
Total	0.5606	27				

Statistical representation of blending on carbohydrate content of flour

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	103.785075	13	7.983467	27597.17	1.62E-28	2.507263
Within Groups	0.00405	14	0.000289			
Total	103.789125	27				

Statistical representation of blending on titrable acid content of flour

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	0.001608464	13	0.000124	70.70173	1.88E-10	2.507263
Within Groups	0.0000245	14	1.75E-06			
Total	0.001632964	27				

Statistical representation of blending on colour change of flour samples

<i>Source of Variation</i>	<i>SS</i>	<i>Df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	113.6978857	13	8.745991	28475.32	1.3E-28	2.507263
Within Groups	0.0043	14	0.000307			
Total	113.7021857	27				

Statistical representation of blending on swelling power of flour samples

<i>Source of Variation</i>	<i>SS</i>	<i>Df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	48991.22976	13	3768.556	100677	1.89E-32	2.507263
Within Groups	0.52405	14	0.037432			
Total	48991.75381	27				

Statistical representation of blending on water holding capacity of flour samples

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	1832.285918	13	140.9451	555839.7	1.21E-37	2.507263
Within Groups	0.00355	14	0.000254			
Total	1832.289468	27				

Statistical representation of blending on oil holding capacity of flour samples

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	1258.768671	13	96.82836	315255.1	4.4E-36	2.507263
Within Groups	0.0043	14	0.000307			
Total	1258.772971	27				

ANNEXURE II

Effect of moisture content on flatbreads blended with gram flour

Storage days	Moisture content of gram flatbreads (Refrigerated conditions)
Day 0	42.11
Day 10	41.01
Day 20	38.09
Day 30	35.28
Storage days	Moisture content of gram flatbreads (Controlled conditions)
Day 0	42.11
Day 2	39.37
Day 4	35.33
Day 6	31.19

Effect of moisture content on flatbreads blended with wheat flour

Storage days	Moisture content of wheat flatbreads (Refrigerated conditions)
Day 0	51.38
Day 10	49.87
Day 20	46.21
Day 30	44.34
Storage days	Moisture content of wheat flatbreads (Controlled conditions)
Day 0	51.38
Day 2	49.66
Day 4	46.44
Day 6	43.24

Effect of browning index on flatbreads blended with gram flour

Storage days	Browning index of gram flatbreads (Refrigerated conditions)
Day 0	0.068
Day 10	0.071
Day 20	0.073
Day 30	0.076
Storage days	Browning index of gram flatbreads (Controlled conditions)
Day 0	0.068
Day 2	0.074
Day 4	0.077
Day 6	0.079

Effect of browning index on flatbreads blended with gram flour

Storage days	Browning index of wheat flatbreads (Refrigerated conditions)
Day 0	0.076
Day 10	0.077
Day 20	0.079
Day 30	0.080
Storage days	Browning index of wheat flatbreads (Controlled conditions)
Day 0	0.076
Day 2	0.078
Day 4	0.081
Day 6	0.082

Effect of color change on flatbreads blended with gram flour

Storage days	Colour change of gram flatbreads (Refrigerated conditions)
Day 0	65.14
Day 10	62.31
Day 20	59.87
Day 30	54.22
Storage days	Colour change of gram flatbreads (Controlled conditions)
Day 0	65.14
Day 2	60.55
Day 4	56.76
Day 6	54.31

Effect of color change on flatbreads blended with gram flour

Storage days	Colour change of wheat flatbreads (Refrigerated conditions)
Day 0	66.45
Day 10	64.11
Day 20	61.08
Day 30	58.55
Storage days	Colour change of wheat flatbreads (Controlled conditions)
Day 0	66.45
Day 2	61.33
Day 4	58.86
Day 6	55.41

Effect of cutting force on flatbreads blended with gram flour

Storage days	Cutting force of gram flatbreads (Refrigerated conditions)
Day 0	4.6344
Day 10	4.6552
Day 20	4.7121
Day 30	4.7361
Storage days	Cutting force of gram flatbreads (Controlled conditions)
Day 0	4.6344
Day 2	4.6611
Day 4	4.7314
Day 6	4.7442

Effect of cutting force on flatbreads blended with wheat flour

Storage days	Cutting force of wheat flatbreads (Refrigerated conditions)
Day 0	2.5434
Day 10	2.6112
Day 20	2.6835
Day 30	2.7185
Storage days	Cutting force of wheat flatbreads (Controlled conditions)
Day 0	2.5434
Day 2	2.6201
Day 4	2.6511
Day 6	2.7009

Effect of free fatty acid on flatbreads blended with gram flour

Storage days	Free fatty acid of gram flatbreads (Refrigerated conditions)
Day 0	1.149
Day 10	1.151
Day 20	1.156
Day 30	1.161
Storage days	Free fatty acid of gram flatbreads (Controlled conditions)
Day 0	1.149
Day 2	1.153
Day 4	1.157
Day 6	1.163

Effect of free fatty acid on flatbreads blended with wheat flour

Storage days	Free fatty acid of wheat flatbreads (Refrigerated conditions)
Day 0	1.221
Day 10	1.228
Day 20	1.233
Day 30	1.238
Storage days	Free fatty acid of wheat flatbreads (Controlled conditions)
Day 0	1.221
Day 2	1.231
Day 4	1.242
Day 6	1.248

Effect of peroxide content on flatbreads blended with gram flour

Storage days	Peroxide value of gram flatbreads (Refrigerated conditions)
Day 0	6.51
Day 10	6.57
Day 20	6.61
Day 30	6.63
Storage days	Peroxide value of gram flatbreads (Controlled conditions)
Day 0	6.53
Day 2	6.58
Day 4	6.63
Day 6	6.66

Effect of peroxide content on flatbreads blended with wheat flour

Storage days	Peroxide value of wheat flatbreads (Refrigerated conditions)
Day 0	6.32
Day 10	6.37
Day 20	6.43
Day 30	6.47
Storage days	Peroxide value of wheat flatbreads (Controlled conditions)
Day 0	6.32
Day 2	6.39
Day 4	6.47
Day 6	6.51

ANNEXURE III
Wheat Blended Flatbreads

S. No.	Day 0					Day 10					Day 20					Day 30				
	Appearance	Taste	Texture	Aroma	OA	Appearance	Taste	Texture	Aroma	OA	Appearance	Taste	Texture	Aroma	OA	Appearance	Taste	Texture	Aroma	OA
1	9	9	8	9	8.5	8.5	8	7	7.5	7.5	7.5	7	5	4.5	5.5	5	4	4	3	3
2	8	9	8	9	8	7.3	7	7	7.5	7	6.5	6	5.5	4	5	4.5	4	4	3	4
3	9	9	8	9	8.5	8	8.5	7	7	7	7	7	5	5	5.5	5	4	4	3.5	4
4	8.5	8	8.5	9	8	8	8	7.5	7	8	6.5	7	5	4	5	4.5	3	3	3	3
5	8	8.5	8	9	8	7.5	7	6.5	7	7	6.5	6.5	5	4.5	5	4	4.5	4	3	3
6	9	8	9	9	9	8.5	7.5	7	7	7	7	6	5	5	5.5	5	4	4	3	3
7	8	8	8	9	8	7.5	7.5	7	7	7	6.5	6	5	5	5.5	4	3	4	3	4
8	8	8	8	9	8	7	7.5	7	7.5	7.5	6	6	5	5	5	4	3	4	3	3
9	9	8	8	9	8.5	8	7	7	7	7	7	6	6	5	5	4.5	4	4	3	4
10	8	8.5	8.5	9	8.5	7.5	7	7.5	7	7	7	6	5	5	5	5.5	3	4	3	4
11	9	9	8	9	8.5	8	8.5	7	7	7	7	7	5	5	5.5	5	4	4	3.5	4
12	8	8	8	9	8	7	7.5	7	7	7	6.5	6	6.5	5	6	4	4.5	4	3	3
13	8.5	8	8.5	9	8	8	7	7.5	7.5	7.5	7	6	6	5	6	4	4	4	3	4
14	9	8.5	8.5	9	8.5	8.5	7	7	7.5	7.5	7.5	6.5	5	5	5	4	3	4	3	4
15	9	9	8	9	8.5	8	8.5	7	7	7	7	7	5	5	5.5	5	4	4	3.5	4
16	9	9	8	9	8.5	8	8.5	7	7	7	7	7	5	5	5.5	5	4	4	3.5	4
17	9	9	8	9	8.5	8	8.5	7	7	7	7	7	5	5	5.5	5	4	4	3.5	4

Gram Blended Flatbreads

S.No.	Day 0					Day 10					Day 20					Day 30				
	Appearance	Taste	Texture	Aroma	OA	Appearance	Taste	Texture	Aroma	OA	Appearance	Taste	Texture	Aroma	OA	Appearance	Taste	Texture	Aroma	OA
1	8.5	8.5	8.5	8.5	8.5	7.5	7	7	7	7	6	6	6	5.5	6	5	4.5	5	4.5	4.5
2	8.5	8.5	8	8	8.5	7	7.5	7	7	7	6	6	6.5	6	6	5	5	5	4	5
3	8	8.5	8.5	8	8.5	7	7	7.5	7	7	6	6	6	5.5	6	5	4	5	4	4
4	8	8	8	8.5	8	7	7	7	7	7	6.5	6	6.5	6	6.5	5	4.5	4.5	4	4.5
5	9	8.5	8	8	8.5	8	7.5	7.5	7	7.5	7	6	6.5	6	6	5.5	5	5	4	5
6	8.5	8	8	8	8	7.5	7	7	7	7	6	6	6.5	6	6	5	5	5	4	5
7	8	8	8	8	8	7	7	7	7	7	6	6	6	6	6	5.5	5	5	4	5
8	9	8.5	8	8	8.5	8	7	7	7	7	6.5	6	5.5	6	6	5	5	4.5	4	5.5
9	8.5	8	8	8	8	7	7	7	7	7	6	6	5.5	6	6	5	5	4	4	4.5
10	8.5	8	8	8	8	7	7	7.5	7	7	6	6	6	5.5	6	5	5	5.5	4	5
11	8	8.5	8.5	8	8.5	7	7	7.5	7	7	6	6	6	5.5	6	5	4.5	5	4	4
12	8.5	8	8.5	8.5	8.5	7.5	7	7.5	7	7.5	6.5	6	6.5	6.5	6.5	5.5	4	4.5	4	4.5
13	8	8.5	8.5	8	8.5	7	7	7.5	7	7	6	6	6.5	6.5	6.5	5	4	4	4.5	4
14	9	8.5	8	8	8.5	7.5	7	7	7	7	6	6	6	5.5	6	5	4.5	4.5	4.5	4.5
15	8	8.5	8.5	8	8.5	7	7	7.5	7	7	6	6	6	5.5	6	5	4	5	4	4
16	8	8.5	8.5	8	8.5	7	7	7.5	7	7	6	6	6	5.5	6	5	4	5	4	4
17	8	8.5	8.5	8	8.5	7	7	7.5	7	7	6	6	6	5.5	6	5	4	5	4	4

VITA

Name of the student : Prerna Kathuria
Father's name : Sh. Dinesh Kumar Kathuria
Mother's Name : Smt. Saroj Kathuria
Nationality : Indian
Date of birth : 17-12-1993
Permanent home address : H.No.-70, Block-B, Kitchlu Nagar, Ludhiana, Punjab, 141001.
Email id : prerna_kathuria@rediffmail.com

EDUCATIONAL QUALIFICATION

Bachelor Degree : B. Tech (Agricultural Engineering)
University : Punjab Agricultural University, Ludhiana
Year of award : 2016
OGPA/OCPA : 6.89/10.00

Master's degree : M. Tech (Processing and Food Engineering)
University : Punjab Agricultural University, Ludhiana
Year of award : 2020
OCPA : 7.23/10.00
Title of Master's thesis : Optimization of process parameters for mechanized preparation of maize flour based flatbread.