

**TECHNOLOGICAL ASPECTS FOR PRODUCTION
OF BREAD FROM WHEAT-SORGHUM
COMPOSITE FLOUR**

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CERTIFICATE

This is to certify that the thesis entitled “**TECHNOLOGICAL ASPECTS FOR PRODUCTION OF BREAD FROM WHEAT-SORGHUM COMPOSITE FLOUR**” submitted by **Mr. Harsh Harishbhai Doctor** in partial fulfillment of the requirement for the award of the degree of **Master of Technology in Food Processing Technology** to the Anand Agricultural University is a record of bonafide research work carried out by him under my guidance and supervision.

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ABSTRACT

Production of wheat-sorghum composite flour bread is the most appropriate technique for utilization of sorghum millet crop and to supply multigrain healthy product. The present study was undertaken to investigate effect of technological aspects for production of bread from wheat-sorghum composite flour. To do so, the experiments were carried out in two stages. Initially, wheat-sorghum composite flour was analyzed for physical, chemical and rheological characteristics, as they give information about formulation and optimization of machining properties, which would help in scaling up the process and in automation.

It was found that the above properties were significantly affected by varying levels of sorghum in the composite flour blends. Pure refined wheat flour contains a higher amount of bio-chemical constituents like moisture, protein and fiber, while the fat content, ash content and carbohydrates are low in amount than pure sorghum millet flour. In the case of physical properties bulk density, tap bulk density, sedimentation value, water absorption capacity, wet gluten and dry gluten contents decreased and apparent porosity increased with increasing levels of sorghum flour incorporated with wheat flour.

Secondly, the effects of fermentation time (45, 55, 65 and 75 min) and baking temperature (165, 180, 195 and 210 °C) on the wheat-sorghum composite flour based breads were evaluated in detail with respect to the physical, textural and organoleptic quality of the final product. The above parameters were optimized for the production of acceptable quality of composite flour bread.

It was found that the suitable level of sorghum into composite flour was 30% when fermented for 75 minutes and baked at 195 °C, giving bread with optimum quality in terms of physical, textural and sensory characteristics. The composite flour blend of refined wheat flour and sorghum flour (70:30) had 11.6% moisture content, 14.17% protein content, 3.22% fat content, 67.03% carbohydrate, 1.34% ash content, 3.08% fiber content, 26.50% wet gluten content, 11.63% dry gluten content, 19.15 ml sedimentation value, 78.00% water absorption capacity, 0.40 g/ml bulk density, 1.37 g/ml tap bulk density, 0.71% apparent porosity, 22.37 g resistance to extension and 9.82 mm extensibility. This blend, when fermented for 75 minutes and baked at 195 °C produced bread weighing 184.84 g with a volume of 438.33 cm³, specific volume of 2.44 cm³/g, height of 5.77 cm and firmness of 1437.73 g. The overall acceptability of

this blend was found to be 5.44, and thus could be recommended for the bakery industry.

These results suggest that superior quality of bread can be formulated with high sorghum incorporation into composite flour by utilizing suitable additives and preservatives.

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LIST OF ABBREVIATIONS & SYMBOLS

Anon	Anonymous
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
ASTM	American Society for Testing and Materials
BD	Bulk density
cm	centimeter
cm ³	cubic centimeter
CO ₂	Carbon Dioxide
CRD	Completely Randomized Design
CV	Coefficient of variation
db	dry basis
df	degree of freedom
Dia.	Diameter
FAO	Food and Agricultural organization
Fig.	Figure
g	gram (s)
g/ml	Gram per milliliter
h	hour (s)
H ₂ SO ₄	Sulphuric acid
ha	Hacter
HP	Horsepower
i.e.	id est
kg	Kilogram
mg	milligram (s)
MT	Million ton (s)
mg/g	Milligram per gram
mg/ml	Milligram per milliliter
min	minute (s)
ml	milliliter (s)
mm	Millimeter
NaOH	Sodium hydroxide
ppm	Parts per million

s	second (s)
SD	Standard deviation
SV	Sedimentation value
T	Temperature
t	Time
V	Volume
var.	Variety
WAC	Water absorption capacity
wb	wet basis
w/w	Weight by weight
µg	Microgram
%	Percent
@	at the rate of
°C	degree Celsius

CHAPTER I

INTRODUCTION

Development of food products conforming to consumer needs is the biggest challenge for processed food industries. Food formulators perceive health and wellness as the consumer trend. With the changes in the socio-economic scenario taking place at a rapid pace, increased participation of women in work force and altered attitudes to leisure activities, the time for planning and cooking foods has significantly reduced. This has given boost to the manufacture and marketing of convenience foods. Furthermore, with the increase in life expectancy as well as standard of living, consumers not only require convenience but also anticipated health benefits from the food.

Bakery industry has seen a revolution over the past 150 years. The small artisan bakeries, which were present in every village, made way for high technological bakery industry. Industrial mono production took over from the high variety bakeries as bread could be produced in a more efficient way. Productivity became the key of success. Different baking technologies were developed to respond better to new market demands (Decock and Cappelle, 2005). New materials and ingredients were introduced in bread composition while research generated a constant and impressive progress in bread making. Continuous improvement in baking technology is worth investigating primarily for better quality product, development of nutritionally superior product and economic consideration (Mondal and Datta, 2008).

Bread is an important staple food in both developed and developing countries. Wheat (*Triticum Aestivum*) flour of both hard and soft wheat classes has been the major ingredient of leavened bread for many years because of its functional proteins. Several developing countries have encouraged the initiation of programs to evaluate the feasibility of alternative locally available underutilized flours as a substitute for wheat flour. Many efforts have been carried out to promote the use of composite flours, in which a portion of wheat flour is replaced by locally grown crops, to be used in bread (Olaoye *et al.*, 2006). Composite flours are a mixture of different flours rich in starch, protein, mineral or fiber, with or without wheat flour, for certain groups of food items particularly for production of bakery products. Composite flours have many advantages including: better supply of human nutrition, saving money when wheat importation is expensive, promotion of high-yielding, domestic plant species which are otherwise underused. Earlier, composite flours were made in order to avoid

high wheat flour consumption. According to the food item expected, industries were thinking about replacing a certain proportion of wheat by other cereal flours. A lot of trials with different kinds of composite flours were made. In most cases the composite flour is made by around 70% of wheat flour and the rest by other flours (like cassava, peanut, soy, millets) or starch (Seibel, 2007).

As the core of human nutrition, grains are ubiquitous and multifaceted staple foods addressed to the population worldwide as either a carrier of macro- and micro-nutrients or tailored foods for specific targeted groups as healthy, convenient and indulgent raw materials providing perfect vectors for diversity and innovation. It raises a great deal of recent interest that minor cereals (rye, oat, sorghum and millet) constitute highly nutritional (dietary fiber, resistant starch, minerals, vitamins, bioactive compounds) grains with potential bread making applications (Skrabanja *et al.*, 2001; Kim *et al.*, 2004 and Angioloni and Collar, 2011).

Sorghum or Jowar (*Sorghum bicolor*) is one of the main staple foods for the world's poorest and most food-insecure people across the semi-arid tropics. India ranks first in production of sorghum (7 MT) and second in production of wheat after China (wheat productions are 87 MT and 117 MT respectively) (FAO, 2011). Sorghum is the fifth most important cereal crop in the world, after wheat, maize, rice and barley (Anonymous, 2008); whereas, in India sorghum is the third important cereal crop after rice and wheat. Maharashtra, Karnataka, Andhra Pradesh, Gujarat, Tamilnadu and Madhya Pradesh are the major sorghum growing states. Sorghum often a recommended option for farmers operating in harsh environment where other crops do poorly, as it is grown with limited rainfall (400 to 500 mm) and often without application of any fertilizers or other inputs. However, it is grown for a variety of uses in India as well as in the world. (Kumaracharyulu *et al.*, 2011).

Sorghum is consumed in various forms around the world like un-baked bread, porridge, tortillas, couscous, gruel, steam-cooked products, alcoholic, non-alcoholic beverages and so on. The potential food and industrial applications of sorghum have been reported. (Brannan *et al.*, 2001 and Obizoba, 1988). It has the potential to be processed into starch, flour, grits, flakes and it is also used to produce a wide range of industrial products. It can also be malted and processed into malted foods, beverages and beer. Sorghum contains various phenolic and antioxidant compounds that could have health benefits, which make the grain suitable for developing functional foods and other applications. Processing of sorghum flour into products has faced several limitations. Sorghum, being a gluten-free cereal behaves quite differently from wheat and has poor rheological properties in terms of its pliability, extensibility and

rollability. The traditional method of preparing sorghum bread is usually very laborious and cumbersome (Kulamarva *et al.*, 2008).

Efforts to mechanize the production process of sorghum bread have been rare. Mechanization of the technology for sorghum bread preparation would require elucidation of the properties of sorghum dough, which play a role in its behavior. The rheological properties of doughs describe how they deform, flow or rupture under applied stress and could be used as a tool in the selection and specification of appropriate raw materials. Technological parameters would also affect the final product quality. Challenges and opportunities of utilization of minor cereals with poor viscoelastic value deserve a special attention in bread making applications due to their unique nutritional components. They are of importance in terms of product formulation and optimization, quality control, machining properties of the dough, scale-up of the process and automation (Bushuk, 1985 and Hamann and Macdonald, 1992).

Most of the research conducted on the use of composite flour for bread making purposes was devoted to studying the effects of different flour substitutions on bread making quality (Adeyemi and Idowu, 1990; Dhingra and Jood, 2004; Hsu *et al.*, 2004; Khalil *et al.*, 2000 and McWatter *et al.*, 2004). The literature available on the characteristics of composite flour, dough made up and bread production from wheat-sorghum composite flour is very limited. No systematic scientific research seems to have been carried out on the subject. The need was felt to study the composite flour with sorghum as one of the component in detail. It may give new opportunities to explore the possibilities of using sorghum as a novel source of substitute wheat to give a better supply of human nutrition in South East Asia especially in India. The present investigation was planned mainly to evaluate the impact of sorghum incorporation on the characteristics of the composite flour, dough and the effect of processing parameter on bread prepared from it. Keeping above facts in mind and with a view to develop a comprehensive technology for utilizing sorghum in composite flour, the research study entitled “Technological aspects for production of bread from wheat sorghum composite flour” was undertaken at Anand Agricultural University, Gujarat, India, with distinct and definite objectives as follows:

1. To study proximate chemical composition of composite flour
2. To study the physico-chemical and rheological properties of composite flour and dough
3. Optimization of baking parameters for development of bread from composite flour

4. To study organoleptic, physical and bio-chemical quality of the bread prepared from composite flour

The objective of this study is to highlight the nutritional benefits of sorghum, the significance of its physico-chemical and rheological properties in terms of processing and the effect of various technological aspects on composite flour bread properties.

CHAPTER II

REVIEW OF LITERATURE

This chapter illustrates the published literature related with this study. It consists of sorghum and its significance, chemical composition, physico-chemical and rheological properties of sorghum-wheat composite flour as well as dough, bread from composite flour and effect of different baking parameters on the bread quality.

2.1 Sorghum

Sorghum (*Sorghum Bicolor*) is a native crop of tropical and subtropical regions of Africa and Asia. Sorghum is a major cereal in the semi-arid regions of the world where it is an important food and feed crop (Kulamarva *et al.*, 2008). Sorghum is one of the major cereal crops consumed in India after rice (*Oryza Sativa*) and wheat (*Triticum Aestivum*). The crop is primarily produced in Maharashtra and southern regions of Karnataka and Andhra Pradesh. These three states together account for close to 80% of the all-India production. Madhya Pradesh, Gujarat and Rajasthan are the other states producing sorghum. India is the third largest producer of sorghum in the world with 7.00 MT during 2011 and almost entire production of sorghum (95%) in the country comes from the above regions/states (FAO, 2011). Sorghum is a drought resistant crop and has an easy adaptability for a wide range of growing conditions and it has the potential to be incorporated in the diets of human populations around the world, more specifically to those intolerant to wheat (Obizoba, 1988). The sorghum kernel is generally spherical with an average size of 4 mm long, 2 mm wide, 2.5 mm thick and 1000 kernel weight of 25-35 g (Rooney *et al.*, 1982). The sorghum kernel is naked, like wheat and has three distinct anatomical components: the pericarp (outer layer), germ (embryo) and endosperm (storage tissue), (Taylor and Belton, 2002) and the average composition of this constituents are 6, 10 and 84%, respectively (Rooney and Serna-Saldivar, 2003).

Nutritional value of sorghum

Sorghum, like other cereals, is an excellent source of starch and protein. It is a gluten-free cereal, which bears significance in the present day scenario where the occurrence of celiac disease (CD), an immunological response to gluten intolerance is on the rise. Grain sorghum contains phenolic compounds like flavonoids (Shahidi and Naczki, 1995), which have been found to inhibit tumor development (Huang and Ferraro, 1992 and Yang *et al.*, 2009). The starches and sugars in sorghum are released more slowly than in other cereals (Klopfenstein and Hosoney, 1995) and hence it could

be beneficial to diabetic (Toomey, 1988 and Farrar *et al.*, 2008). Level of antioxidants in sorghum is high relative to other grains and fruits (Awika *et al.*, 2004). Sorghum also helps in treating human melanoma (Gomez-Cordovés *et al.*, 2001) and may help in managing cholesterol (Carr *et al.*, 2005). Van Rensburg (1981) and Chen *et al.* (1993) reported that populations consuming sorghum millet had lower incidences of esophageal cancer compared to those consuming wheat or maize. Sorghum starch does not contain gluten. This makes sorghum a possible grain for those who are gluten sensitive (Popkin *et al.*, 2001). Luteolin, a flavone present in sorghum millets, has been reported to have antioxidant, anti-inflammatory, cancer-preventive, anti-arrhythmic properties (Duke, 1992 and Watanabe, 1999). Tricin has been reported to have anti-tumor and anti-leukemic properties (Lee *et al.*, 1981 and Watanabe, 1999).

Chemical composition of sorghum

The average chemical composition of sorghum and wheat as reported by various researchers is given in Table 2.1. Moisture content of sorghum is in the range of 9.11 to 12%, carbohydrate content is in the range of 55.6 to 75.5%, the range of protein and fat are 7.3 to 15.6% and 0.5 to 5.2%. Fiber and ash content of sorghum are 1.2 to 6.6 and 1.1 to 2.5 respectively.

Table 2.1 Chemical composition of sorghum and wheat as reported by various researchers

Parameters (%)	Source				
	Sorghum				Wheat
	Rooney and Clark (1968)	Gopalan <i>et al.</i> (1971)	Waniska and Rooney (2000)	Kulamarva <i>et al.</i> (2008)	Angioloni and Collar (2012)
Moisture	9.11	11.9	-	12	14.3
Carbohydrate	71.16	72.6	55.6 – 75.2	70.7	70.0
Protein	11.3	10.4	7.3 – 15.6	10.4	12.1
Fat	3.4	1.9	0.5 – 5.2	3.1	1.34
Fibre	2.7	1.6	1.2 – 6.6	2.0	-
Ash	1.7	1.6	1.1 – 2.5	1.6	0.54

2.2 Physico-chemical and rheological properties of composite flour and dough

Rice starch was added to wheat flour to form composite flours. The rheological characteristics of mixtures showed a decrease in the farinograph absorption and an increase in mechanical tolerance index when rice starch was added at 40% level. Dough stability, development time, arrival time and over-all farinograph profile scores were decreased. Extensograph data showed an increase in dough deadness and a drop in

dough extensibility. Although dough rheology data indicated that the addition of rice starch weakened the dough, bread of acceptable quality was obtained when rice starch was added at 25% level (Seyam and Kidman, 1976).

Bamidele *et al.* (1990) studied the possibility of producing bread from wheat-plantain composite flour. The chemical analysis of the composite flour showed that it contained less protein; higher carbohydrate and minerals than wheat flour. With increasing levels of supplementation with plantain the water absorption capacity, dough development time and mixing quality of the composite flour decreased. However, the mixing tolerance time increased.

Rao and Rao (1997) investigated the effect of incorporation of sorghum flour to wheat flour on chemical and rheological parameters. Sorghum flours were incorporated into wheat flour at 5, 10, 15 and 20% levels. The water absorption of flour blends and dough strength decreased with the increase in the level of sorghum flour.

Sharma *et al.* (1999) studied the effect of blending of cowpea flour in wheat flour on rheological, baking and sensory characteristics of bread, chapatti, cookies and muffins. Farinograph water absorption, dough development time, mixing tolerance index and dough stability increased significantly with increase in the amount of cowpea flour. Incorporation of cowpea flour was lowered gelatinization time and peak viscosity.

Hugo *et al.* (2003) has worked on fermented sorghum and its use in composite flour. In this study whole sorghum flour was fermented and dried under forced draught at 60 °C, and evaluated for its effect on sorghum and wheat composite bread quality. In comparison with unfermented sorghum flour, fermentation decreased the flour pH from 6.2 to 3.4, total starch and water-soluble proteins and increased enzyme-susceptible starch, total protein, and the *in vitro* protein digestibility. It appears that the low pH of fermented sorghum flour inactivated amylases and increased the viscosity of sorghum flour, thus improving the gas-holding capacity of sorghum and wheat composite dough. Fermentation of sorghum flour, particularly in a sourdough bread making process appears to have considerable potential for increasing sorghum utilization in bread.

Dhingra and Jood (2004) incorporated soybean (full-fat and defatted) and barley flours into wheat flour at 5, 10, 15 and 20% substitution levels. The gluten content, sedimentation value and water absorption capacity of the flour blends and the mixing time of the dough decreased with increase in the level of soybean and barley flour

separately and in combinations. Protein and glutenin contents increased significantly on blending of soyflour (full-fat and defatted) to wheat flour.

Hooda and Jood (2005) studied the effect of supplementation of wheat flour with fenugreek flour from 5 to 20% levels on composite dough. The results showed that the protein, lysine, mineral and fiber content of dough were increased with the increase the level of fenugreek flour.

Shahzadi *et al.* (2005) prepared composite flour samples by blending commercial wheat flour with various legumes i.e. lentil, chickpea and guar gum in different proportion to study their rheological and baking performance. Rheological behavior of the composite flours showed decreased in water absorption capacity and increased in dough development time in a storage period of 60 days.

See *et al.* (2007) determined the physico-chemical characteristics of dough supplemented with four different levels (control, 5%, 10%, and 15%) of pumpkin flour. The physical and chemical attributes were determined in the raw pumpkin and pumpkin flour. On increasing the level of substitution from 5% to 15% pumpkin flour, the level of ash and crude fiber significantly increased. However, there was a significant reduction in protein and fat content.

Ammar *et al.* (2009) investigated the effects of using taro (*Colocasia Esculenta*) flour as partial substitution of wheat flour in balady bread (Egyptian bread) with substitution levels of 5, 10, 15 and 20% on the farinograph, extensograph properties of the produced dough. The farinograph results showed that the increase of substitution level increase the water absorption, dough weakening and dough extensibility but decrease the mixing time, dough stability and resistance to extension. Also, the increase of the taro flour level resulted in decreasing in the crude protein, ash, total carbohydrates while fiber content increased.

Pawse (2009) incorporated pigeon pea husk into refined wheat flour and studied physical, bio-chemical and rheological properties of composite flour and dough. Result showed that as the level of pigeon pea husk increased rheological properties also increased and all physical and bio-chemical properties were significantly affected.

Poongodi and Jemima (2009) evaluated composite flours made with kodo (*Paspalum Scrobiculatum*), barnyard millet (*Echinochloa Colona*), whole wheat, and defatted soy flour. They found that wet and dry gluten content, bulk density and water absorption capacity decreased significantly, while oil absorption capacity,

gelatinization temperature, protein content and crude fiber content increased significantly on increasing the proportion of pearl millet flour in the composite flour.

Guzowski (2011) prepared composite flours constituting different proportions of wheat flour and pearl millet flour and analyzed through various physical, nutritional and rheological parameters. Results showed that all physical properties were significantly affected by varying the proportion of pearl millet flour in the composite flour. The changes in physical and nutritional properties were more predominant than the rheological characters.

Saha *et al.* (2011) prepared biscuits from flour composites containing 60:40 and 70:30 (w/w) wheat:finger millet flour were evaluated for its dough characteristics. Hardness of dough measured by textural profile analysis was more in 60:40 combination than in 70:30. Extensograph data showed that resistance of dough increased with the increasing levels of wheat flour. Wheat flour had higher water absorption capacity than composite flour.

Yousif *et al.* (2012) has prepared wheat bread with varying levels of wholegrain white sorghum flour or red sorghum flour. Farinograph dough rheology indicated reduced water absorption and stability time and increased breakdown with increased sorghum flour addition.

Kouakou *et al.* (2013) determined the physico-chemical, rheological and functional properties of different composite flours containing millet flour, trade sugar, beans flour, yellow corn flour, soybean meal. Rheological and functional properties affected significantly with the change in composition.

2.3 Baking

Baking is a food cooking method using prolonged dry heat acting by convection normally in an oven. The most common baked item is bread but many other types of foods are baked. The aim of the bread making process is to convert wheat flour and other ingredients into a light, aerated and palatable food (Cauvain and Young, 2001).

Bread is a different food compared to some other common food items as it is leavened product obtained from fermentation of wheat flour sugars liberated from starch by the action of natural flour enzymes. Fermentation is caused by baker's yeast which is the trade name of organism *Saccharomyces Cerevisiae*. Due to fermentation sugar is converted to moisture and CO₂. As water vapor and CO₂ expand due to high temperature, they act as an insulating agent preventing high rate of temperature rise of bread crumb and possibility of excessive moisture evaporation. Sugar is added for

initiation of fermentation. Salt is added to strengthen the gluten and to convert the action of yeast for controlled expansion of the dough. Shortening (ghee or margarine) is added to increase the machinability or specifically slicability. As soon as the dough is properly baked into bread, a product with superior quality and sensory features occurs. Fresh bread usually presents an appealing brownish and crunchy crust, a pleasant aroma, fine slicing characteristics, a soft and elastic crumb texture and a moist mouth feel (Giannou *et al.*, 2003).

Baking technology is the engineering of food structures through formation of correct dough and batter to trap leavening gases and the fixing of these structures by the application of heat (Balaji, 1991). Bakery products are produced by three different methods. First method is straight dough method where mixing of ingredients is performed in one step. According to manufacturer's choice and available equipment, ingredients of the dough may differ. Sponge and dough method is the second one where mixing of ingredients is performed in two steps. Leavening agent is prepared during the first step. Yeast, certain quantity of water and flour are mixed together. The mixture is left to develop for few hours and afterwards it is mixed with the rest of the ingredients. Chorleywood method is the third method where all ingredients are mixed in an ultra-mixer for few minutes (Kulp, 1988; Hosenev, 1994; Cauvain, 1998; Kent and Evers, 1994 and Giannou *et al.*, 2003).

The qualities of bakery products rely on both formula and processing conditions. Some qualities can be improved by optimizing a formula (Larsen and Greenwood, 1991; Stampfli and Nersten, 1995; Cauvain, 1998 and Shimizu *et al.*, 2003). However, without the optimum processing condition, the final product quality can be much degraded. Processing of bakery products mainly consists of mixing, proving, baking and cooling. Each of these processes dominates different quality attributes (Kilborn and Preston, 1981; Larsen and Greenwood, 1991; Wesley *et al.*, 1998; Anonymous, 1995, 1998 and Grenier *et al.*, 2002). All quality attributes due to the thermal reactions are dominated by the baking process. The baking process is a step in which the raw dough piece is transformed into crumb and crust texture, under the influence of heat. The most apparent changes during this period are volume expansion, crust formation, inactivation of yeast and enzymatic activities, protein coagulation, partial starch gelatinization (Pylar, 1988) and moisture loss (Eliasson and Larsson, 1993). With the requisite quality attributes, the production presumes a carefully controlled baking process. Key baking conditions which place vital influences on the

final product quality include the rate and amount of heat application, the humidity level in a baking chamber and the baking time.

2.4 Composite flour

2.4.1 Bread from composite flour

Bamidele *et al.* (1990) have studied the possibility of producing bread from wheat-plantain composite flour. It was found that the baking quality decreased with increasing level of supplementation and when unblanched plantain flour was used. The blend with 100 g/kg blanched plantain and 900 g/kg wheat flour was found to be internally and externally better than other blends and had acceptable bread quality.

Optimum mixing time and water absorption levels of composite wheat flours were evaluated by Defloor *et al.* (1993). It was found that substitution of wheat flour by wheat starch, cassava starch or cassava flour at 15 or 30% leads to a reduced breadmaking potential. Loaf volume data showed that the bread making potential of a substituted wheat flour is determined by the degree of substitution as well as the type of substitute. Clear differences of the substitutes occurs during baking, not at the fermentation stage of the dough.

Sharma *et al.* (1999) studied the effect of blending (50 to 250 g/kg) cowpea flour in wheat flour on baking and sensory characteristics of bread, chapatti, cookies and muffins. Loaf volume and overall acceptability scores of bread were reduced significantly beyond 150 g/kg incorporation of cowpea flour. There were significant changes in specific volume and overall acceptability scores of muffins, registering an initial improvement up to 50 g/kg and a significant decline thereafter.

Dhingra and Jood (2004) incorporated soybean (full-fat and defatted) and barley flours into wheat flour at 5, 10, 15 and 20% substitution levels. The breads prepared from the blends also varied in their loaf weight, loaf volume and sensory characteristics. The bread volume decreased with increasing amount of non-wheat flour substitution. The crumb color changed from creamish white to dull brown and a gradual hardening of crumb texture was observed as the level of soybean (full-fat and defatted) and barley flours increased. At the higher levels, the acceptability declined because of the compact texture of the crumb. The addition of 10% of soy flour (full-fat and defatted) or 15% of barley flour, full-fat soy flour or defatted soy and barley flour to wheat flour produced acceptable bread.

Mepba *et al.* (2007) studied the feasibility of partially replacing wheat flour with plantain flour in bread and biscuit making. Matured plantains (*Musa Paradisiaca*) were

pulped, blanched, dehydrated and pulverized. The wheat flour was substituted by plantain flour at levels of 5-30% and 0-100% for bread and biscuit making, respectively. Results showed that organoleptically acceptable breads and biscuits were formulated from wheat-plantain composite flours using up to 80:20 (w/w) and 60:40 (w/w) ratios of wheat:plantain flour as maximum acceptable levels of substitution for breads and biscuits, respectively

See *et al.* (2007) determined the physico-chemical and sensory characteristics of bread supplemented with four different levels (control, 5%, 10%, and 15%) of pumpkin flour. Loaf volume and specific volume of treated bread were significantly different to that of the control treatment. Sensory evaluation results indicated that bread with 5% pumpkin flour was rated the most acceptable and was not significantly different in terms of acceptability compared to the control.

Ammar *et al.* (2009) investigated the effects of using taro (*Colocasia Esculenta*) flour as partial substitution of wheat flour in balady bread (Egyptian bread) making with substitution levels of 5, 10, 15 and 20% on the organoleptic properties and chemical composition of the produced bread. It was found that substitution of wheat flour with taro flour up to 10 % produce bread similar to the control (wheat bread) in all the organoleptic properties.

Subajiny *et al.* (2010) studied the feasibility of partially replacing wheat flour with malted rice flour in bread making. The whole grains of a local rice variety (*Oryza sativa* L. subsp. *Indica* var. *Mottaikaruppan*) were steeped in distilled water (12 h and 30 °C) and germinated for three days to obtain high content of soluble materials and amylase activity in bread making. It was concluded that malted rice flour with 35% substitution level was the best according to the physical and sensory qualities of bread. Among different ratios of yeast and baking powder, 2:1 was the best. Bread improver containing amylases and oxidizing agents at the concentration of 40 g/kg was selected as the best concentration.

2.4.2 Bread from wheat-sorghum composite flour

Perten (1977) compared sorghum bread to wheat bread. The volume of bread made with sorghum alone was smaller than that of wheat flour bread, but the sorghum bread was preferred by many consumers. They concluded that bread made with 30% sorghum flour and 70% wheat flour was tolerable and was evaluated by consumers as “good to excellent” by an acceptability panel.

According to Dendy (1992) the world-wide research on sorghum-wheat composites showed that up to 30% sorghum flour could be used in conjunction with a wheat flour of reasonable strength to make quality bread.

Rao and Rao (1997) studied the effect of incorporation of sorghum flour to wheat flour on bread characteristics. Sorghum flours were incorporated into wheat flour at 5, 10, 15 and 20% levels. The bread volume decreased with increasing level of sorghum substitution. The crumb color changed from creamish white to dull brown and a gradual hardening of crumb texture was observed as the addition of sorghum increased. Replacement of wheat flour up to 15 and 10% with 75 and 85% extraction rate sorghum flours, respectively produced acceptable breads.

Elkhalifa and El Tinay (2002) prepared breads having 5, 10 and 15% addition of sorghum flour into wheat flour with or without addition of cysteine for preparation of breads. Results showed that 5% sorghum with 30 ppm cysteine gave acceptable bread using a straight-dough method. Chemical-dough development method gave high quality bread with 10% sorghum, along with 60 ppm cysteine.

Taylor *et al.* (2005) studied the essentials of sorghum flour in bread making. He has investigated two approaches: i) Modification of sorghum flour using the traditional technologies of malting and lactic acid fermentation. Compositing the modified sorghum flour with wheat flour at a level of 30% sorghum produced a pan-bread with much softer texture than with raw sorghum flour. Additionally, the breads had an attractive malt or sour-dough flavor and were less subject to staling. ii) Improving the quality of injera, a traditional Ethiopian leavened, fermented pancake. Decortication of sorghum, compositing with teff (*Eragrostis tef*) and cultivar selection enabled a wheat-free, leavened sorghum-based pancake with a flexible, soft texture and resistant to staling.

Another study was conducted Schober *et al.* (2007) to improve the quality and theoretical understanding of gluten-free sorghum bread. The addition of 2% hydroxypropyl methylcellulose improved bread with 70% sorghum flour and 30% potato starch. Nevertheless, a flat top and tendency toward a hole in the crumb remained. Sourdough fermentation of the total sorghum flour eliminated these problems. With sourdough fermentation, only small isolated patches of protein bodies embedded in matrix protein remained. In oscillatory temperature sweeps, sourdough fermentation caused a significantly higher resistance to deformation after gelatinization

of the above batter relative to batters without sourdough. Results suggested that a strong starch gel without interference of aggregated protein is desirable for this type of bread.

Abdelghafor *et al.* (2011) investigated the baking properties of composite flours containing whole and decorticated sorghum (*Sorghum Bicolor*) and wheat (*Triticum Aestivum*). They have also studied the physical characteristics and organoleptic quality of pan and balady breads made from those flours. Whole and decorticated sorghum flours were used to replace 0, 5, 10, 15, and 20% by weight of bread wheat flour. Sensory evaluation results showed that up to 20% wheat replacement with whole or decorticated sorghum flour produced acceptable pan and balady breads.

Onyango *et al.* (2011) has prepared gluten-free sorghum bread from cassava, maize, potato or rice starch and sorghum in the ratios 10:90, 20:80, 30:70, 40:60 and 50:50. Increasing starch content changed the batters' consistency from soft dough to thin pourable batter. Increasing starch content decreased crumb firmness and chewiness, while increased cohesiveness, springiness and resilience of all breads. Cassava-sorghum and rice sorghum breads had better crumb properties than maize sorghum or potato sorghum breads. Although the crumb properties of all breads declined (i.e. firmness and chewiness increased; cohesiveness, resilience and springiness decreased) on storage, the formulation containing 50% cassava starch retained the best overall texture.

Angioloni and Collar (2012) has carried out experiments on suitability of oat and sorghum in bread making. The research allowed up to 30% sorghum and up to 50% oat for wheat flour replacement. Overall acceptability of highly replaced wheat breads deserved higher scores for oat and sorghum composite breads (7/10) than control wheat breads (6/10). Oat, millet and sorghum represent a viable alternative to make aerated breads with lessened technological and sensory constraints based on non-viscoelastic cereals.

Yousif *et al.* (2012) has prepared bread wheat bread with varying levels of wholegrain white sorghum flour or red sorghum flour. Sensory evaluation indicated that sorghum addition did not reduce the sensory preference for the flat breads.

2.5 Effect of baking parameter on bread quality

Qazi *et al.* (2003) conducted an experiment to study the different fermentation time and baking on pytic acid content of whole wheat flour. The results of this study suggest that treatment of whole wheat flour for 45 min fermentation can reduce the

amount of phytic acid. Bread preparation from such treated flours dough will have high nutritional impact.

Baking technology for tasty bread with high whole meal oat content and good texture was developed by Flander *et al.* (2006). Bread was baked with a straight baking process using whole grain oat (51/100 g flour) and white wheat (49/100 g flour). The effects of gluten and water content, dough mixing time, proofing temperature-time and baking temperature on bread quality were investigated. Proofing conditions, gluten and water content had a major effect on specific volume and hardness of the oat bread. The sensory crumb properties were mainly affected by ingredients, whereas processing conditions exhibited their main effects on crust properties and richness of the crumb flavor.

Shittu *et al.* (2007) investigated the effect of baking temperature and time on some physical properties of bread from composite flour made by mixing cassava and wheat flour at ratio of 10:90 (w/w). A central composite rotatable experimental design was used while the baking temperature and time investigated ranged from 190 to 240 °C and 20 to 40 min, respectively. Loaf volume, weight and specific volume varied significantly from 440 to 920 cm³, 162 to 183 g and 3.31 to 5.32 cm³/g, respectively. The colour parameters such as L* (lightness) and brownness index (BI) of the crust varied significantly from 31 to 72 and 68 to 123, respectively. Moreover, Fresh crumb moisture, density, porosity and softness as well as the dried crumb hardness were also significantly affected by both the baking temperature and time.

Water absorption, dough properties, gluten and bread quality were affected by proofing temperature. Subjecting wheat gluten to high temperatures (55-75 °C) results in loss of baking quality. This loss of baking quality is due to denaturation/uncoiling of gluten by high temperatures (Beswa, 2008).

Jusoh *et al.* (2008) studied the impact of thermal processing parameters i.e. baking temperature or time on bread organoleptic and shelf life properties. Baking temperature and time cause significant differences in crust color, thickness, initial moisture content and firmness. Breads baked at high temperature have higher initial moisture content and experienced the lowest moisture loss during storage.

CHAPTER III

MATERIALS AND METHODS

This chapter includes experimental procedures and various methods used for the study of technological aspects for production of bread from wheat-sorghum composite flour. Methodologies related to the technological aspects as well as the chemical, physical, rheological properties and statistical analysis are explained here under. The study was carried out during the year 2012-13 at the College of Food Processing Technology and Bio-Energy, Anand Agricultural University, Anand, Gujarat, India.

3.1 Raw materials

Refined wheat flour

About 25 kg refined wheat flour (variety GW-496) was procured from the local market of Anand city. The flour was packed and kept in refrigerator at 7 ± 2 °C till used.

Sorghum flour

About 15 kg sorghum grains (variety GJ-38) was procured from the Main Sorghum Research Centre, Athwa, Navsari Agricultural University, Gujarat and milled in laboratory for further use (Plate 3.1). The flour was packed and kept in refrigerator at 7 ± 2 °C till used.

Sugar

Fine crystalline food grade sugar purchased from local market of Anand city was used for the entire experimental purpose.

Salt

Sodium chloride, a common salt, purchased from local market of Anand city was used for the entire experimental purpose.

Yeast

Fresh bakers yeast (*Saccharomyces Cerevisiae*) of good quality was procured from the local market of Anand city.

Shortening

Hydrogenated vegetable oil procured from local market of Anand city was used during the entire experimental period.

3.2 Experimental set up for preparation of bread

Refined wheat flour was blended with 20, 30, 40 and 50% sorghum flour. The composite flours were stored in air tight containers in a refrigerator until needed.

The process flow chart as depicted in fig. 3.1 was used for the preparation of bread for the experimentation. The process consists of different unit operations such as mixing, kneading, cutting, fermentation, proofing, moulding, baking, depanning, cooling, slicing and packing. The base formulation for the breads is shown in Table 3.1.

The bread was prepared by using straight dough method as procedure mentioned by Kamaliya and Kamaliya (2001). Preparation of flying ferment was the first step involved in mixing process of straight dough method. It was prepared by dissolving little sugar in luke warm water (37 °C), crumbled yeast was added to it and mixed properly. After 5 to 10 min yeast starts to float on the water. Little amount of flour was added to it to prepare thick paste. The paste was kept in warm atmosphere (32-38 °C) for 10 to 15 min. The paste is termed as flying ferment. Flour was sieved twice to remove impurities. Salt and remaining sugar were dissolved in the remaining water and strained. All dry ingredients were mixed using dough kneader (Plate 3.2). Flying ferment was added to dry mix. Mixing was continued with gradual addition of water. Shortening was added when mixing reaches half the way. After proper mixing dough became dry, elastic, smooth and velvety. Dough was allowed to ferment at 26.6 °C temperature and 75% relative humidity, for different time intervals as mentioned in experimental design. Dough was then divided into individual pieces of predetermined uniform weight and size. Dough pieces were rounded uniformly to prevent gas escaping from the cut surface. The dough was relaxed (intermediate proofing) for 10 min. Dough was moulded into cylindrical shape and placed into greased pan. The dough was relaxed (proofing) under suitable conditions (35-36 °C temperature and 80-85% relative humidity) for 55-65 min. The dough was then baked in baking oven (Plate 3.3) at various baking temperatures as mentioned in experimental design. Bread loaf was released from mould immediately after baking and allowed to cool. Loaf was sliced using stainless steel knife, packed in polyethylene pouches and used for further analysis. The above process was performed for four levels of composite flour as mentioned in experimental design.

3.3 Experimental design

Variety

Wheat (*Triticum Aestivum*) : GW496 Sorghum (*Sorghum Bicolor*) : GJ 38

Independent parameters

Refined wheat flour to sorghum flour ratio : 80:20, 70:30, 60:40, 50:50

Proofing / fermentation time (min) : 45, 55, 65, 75

Baking temperature (°C) : 165, 180, 195, 210



Plate 3.1: Sorghum grain and flour used for experimentation



Plate 3.2: Dough kneader

Table 3.1: Base formulation for bread

Ingredients	Quantity (bakers percentage)				
	Control Bread	Wheat-Sorghum Composite Bread			
		20%	30%	40%	50%
Refined wheat flour	100	80	70	60	50
Sorghum flour	Nil	20	30	40	50
Salt	2	2	2	2	2
Shortening	2	2	2	2	2
Yeast	2	2	2	2	2
Sugar	5	5	5	5	5
Water	60-65	60-65	60-65	60-65	60-65

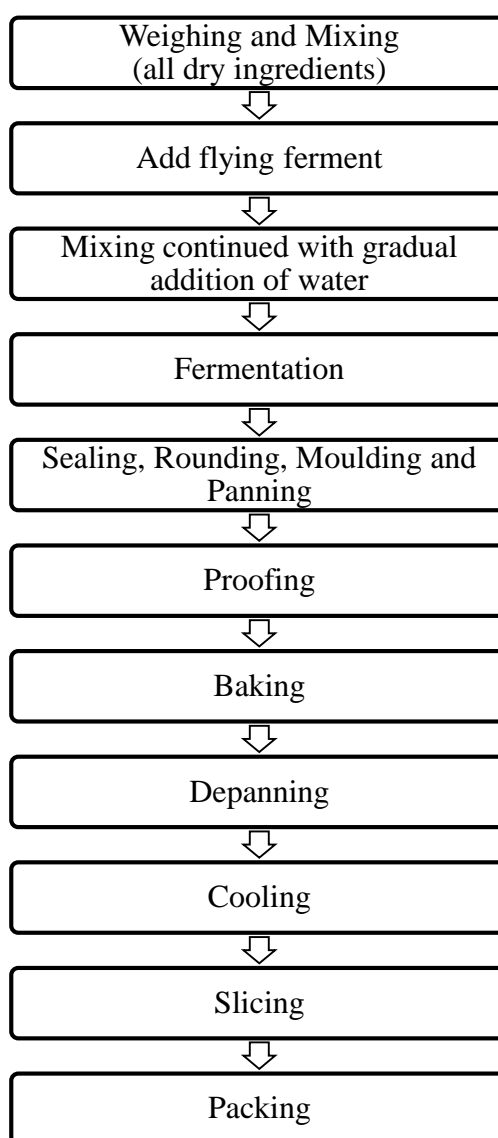


Fig. 3.1: Process flow chart for bread preparation

Quality of composite flour and dough

Bio-chemical quality

1. Moisture content
2. Protein
3. Fat
4. Carbohydrate
5. Ash
6. Fibre

Physico-chemical quality

1. Wet gluten
2. Dry gluten
3. Sedimentation value
4. Water absorption capacity
5. Bulk density
6. Tap bulk density

Rheological properties

1. Dough extensibility
2. Resistance to extension

Quality of bread

Physical properties

1. Volume
2. Weight
3. Specific volume
4. Height

Textural property

1. Firmness

Organoleptic properties

1. Crust colour
2. Shape and bake
3. Texture
4. Grain structure
5. Taste and aroma
6. Crumb colour
7. Overall acceptability

3.4 Quality analysis of composite flour and dough

3.4.1 Bio-chemical analysis of flour

Refined wheat flour, sorghum flour and blends of refined wheat-sorghum flours were analysed for moisture content, protein content, fat content, total carbohydrate, ash content and fibre content.

Moisture content

The method described in AOAC (1990) was used to determine the moisture content. A metallic dish was dried in hot air oven (Plate 3.4) at 110 °C for a period of an hour. It was quickly covered, cooled in desiccator and weighed (W_1). A 5 g sample was kept in thin layer on the metallic dish and weighed as quickly as possible to avoid loss of moisture (W_2). The sample was kept in hot air oven maintained at 100 ± 5 °C. The sample was dried for about 12 h until 2 to 3 consecutive weights remained constant and final weight was recorded (W_3). The moisture content (%) was calculated using the formula:

$$\text{M.C.(\%)} = \frac{[(W_2 - W_1) - (W_3 - W_1)] \times 100}{(W_2 - W_1)} \dots\dots\dots (3.1)$$

Where,

W_1 = Weight of empty metallic dish

W_2 = Weight of metallic dish with sample

W_3 = Weight of metallic dish with dried sample

Protein content

Crude protein content was estimated by the Auto-Kjeldahl method and the assembly used for protein estimation is shown in Plate 3.5. A Sample (0.5 g) was digested with concentrated sulphuric acid (H_2SO_4) containing pinch of catalyst mixture ($K_2SO_4:HgO:CuSO_4$). Then digested solution was distilled with 40% NaOH. Liberated ammonia was trapped for titration in 4% boric acid, using mixed indicator (methyl red: bromocresol green, 1:5). Distillate was titrated against 0.1 N HCl until the green colour turns to faint pink colour. The percent nitrogen was calculated using following formula and protein percentage in the sample was quantified by multiplying with factor of 6.25 (Ranganna, 1986).

$$\text{Nitrogen (\%)} = \frac{14.01 \times (\text{B.R.} - 0.1) \times N \times 100}{1000 \times W} \dots\dots\dots (3.2)$$

$$\% \text{ Protein} = \text{Nitrogen (\%)} \times 6.25 \dots\dots\dots (3.3)$$



Plate 3.3: Baking oven



Plate 3.4: Hot air oven

Where,

B.R. = Burette reading

N = Normality of HCl

W = Weight of sample

Fat content

5 g sample was weighed accurately in thimble and defatted with petroleum ether in soxhlet apparatus for 6-8 h at 60 °C. The resultant ether extract was evaporated and lipid content was calculated using following formula mentioned in AOAC (1990). The assembly used for fat estimation is shown in Plate 3.6.

Total carbohydrate

Total carbohydrate (%) was measured by the following calculation:

$$\text{Total carbohydrate (\%)} = 100 - (\text{Moisture Content} + \text{Protein Content} + \text{Fat content} + \text{Ash content} + \text{Fibre Content}) \dots\dots\dots (3.4)$$

Ash content

Ash content was measured following procedure described by Kamaliya and Kamaliya (2001). The procedure is given below:

A 5 g of composite flours were added in dry and clean crucible. Flour was burned on burner flame for 1 hour. After that, burnt flour was heated in muffle furnace at 600 °C until the ash became white. Crucible was then quickly transferred to a desiccator and cooled prior to weighing. Process was repeated with an interval of 1 hour, until the difference between two consecutive weightings was less than 1 mg, recorded mass was the lowest mass obtained. The ash was calculated as follows:

$$\text{Ash (\%)} = \frac{W_a - W_c}{W_f} \times 100 \dots\dots\dots (3.5)$$

Where,

W_a = Weight after ashing with crucible

W_c = Weight of empty crucible

W_f = Weight of fresh sample taken

Fibre content

Fibra plus instrument (Plate 3.7) was used for estimation of crude fibre content. Sample was treated with 1.25 % H₂SO₄ followed by 1.25% NaOH and washed thoroughly with distilled water after each treatment. Neutral residue left over was dried and weighed and then ignited in to muffle furnace. From the loss in weight of the

residue, the percentage of crude fibre was calculated using following formula given by Ranganna (1986).

$$\text{Crude Fibre (\%)} = \frac{W_r - W_a}{W_s} \times 100 \quad \dots\dots\dots (3.6)$$

Where,

W_r = mass of residue, g

W_a = mass of ash, g

W_s = mass of sample, g

3.4.2 Physico-chemical quality of composite flour and dough

Physico-chemical properties of major raw ingredients and their blends used for bread preparation were analysed according to standard methodology. Some methods are appended below.

Wet gluten content

Wet gluten content (%) was determined according to the procedure described by Kamaliya and Kamaliya (2001) and briefed as follow:

Composite flours were firstly prepared by mixing flour in a homogeneous mix. Starch was washed off from dough ball in big beaker half filled with water turbid water was thrown away and gluten was put in fresh water. Process was repeated for around 15-25 min (time required for satisfactory washing) until the liquid squeezed from gluten does not produce cloudiness in fresh water. Gluten was let stand in clean water for 40 min and dried between fingers until it begins to stick and finally weighed directly on balance, without using paper.

$$\text{Wet gluten (\%)} = \frac{\text{Wt of wet gluten} \times 100}{\text{Wt of flour}} \quad \dots\dots\dots (3.7)$$

Dry gluten content

Dry gluten content (%) was determined according to the procedure described by Kamaliya and Kamaliya (2001) and briefed as follow:

Composite flours were firstly prepared by mixing flour in a homogeneous mix. Wet gluten was prepared following the previous protocol. Small ball of wet gluten was placed into tin plate with proper identification, and plate was kept in oven at 200 °C for 30 min. Samples were cooled in air for 30 min and weighed.

$$\text{Dry gluten (\%)} = \frac{\text{Wt of dry gluten} \times 100}{\text{Wt of flour}} \quad \dots\dots\dots (3.8)$$



(a) Digestion assembly

(b) Distillation unit

Plate 3.5: Assembly for protein estimation



Plate 3.6: SOCS plus equipment used for measuring the fat content



Plate 3.7: Fibra plus equipment used for measuring the fibre content

Sedimentation value

Sedimentation value (ml) was measured according to the procedure described by Kamaliya and Kamaliya (2001) and briefed as follow:

Composite flours were firstly prepared by mixing flour in a homogeneous mix. 50 ml of distilled water was added to a 100 ml graduated glass cylinder and exactly 4 g of the flour was placed into the glass cylinder using a paper cone. The mixture was shaken for 30 seconds and stand for 5 min. 25 ml of lactic acid solution were then added with pipette, the content of the cylinder was mixed by inverting and returning the cylinder to an upright position 10 times. The cylinder was not shaken (Plate 3.8).

Immediately after mixing, the cylinder was placed in an upright position in front of light and timing was noted using stopwatch. After an interval of exactly 5 min, volume of the solid phase of the material in the cylinder was read. This volume in ml was the sedimentation value recorded.

Water absorption capacity

Water absorption capacity (%) was measured according to the procedure described by Kamaliya and Kamaliya (2001) and briefed as follow:

Composite flours were prepared by mixing flour in a homogeneous mix. 50 g of flour were carefully weighed and placed in porcelain bowl. 25 ml of water at 26.5 °C was allowed to run into the bowl from a burette. Flour and water were mixed with a spatula; water was added until well-kneaded ball-dough of medium soft consistency was formed. Number of ml of water required was recorded. When the final kneaded-dough was too soft, the process was repeated and new dough was made with less water.

$$\text{Water absorption capacity (\%)} = \frac{\text{Water absorbed by flour} \times 100}{\text{Wt of flour}} \quad \dots\dots (3.9)$$

Bulk Density

Bulk density (g/ml) was measured as methodology described by Dadey (1994) using graduated cylinder and weight balance.

Tap Bulk Density

Tap bulk density (g/ml) was measured using Bulk Density Apparatus and methodology described in the manual (Make: DBK Instruments, Mumbai) (Plate 3.9).

Apparent Porosity

Apparent Porosity (%) was measured as methodology described by Ranganna (1986) and calculation was made as below:

$$\text{Apparent porosity (\%)} = 1 - \frac{\text{BD}}{\text{Tap BD}} \quad \dots\dots\dots (3.10)$$



Plate 3.8: Sedimentation value measurement



Plate 3.9: Bulk density apparatus

Where,

BD = Bulk density (g/ml)

Tap BD = Tap bulk density (g/ml)

3.4.3 Rheological properties of dough

Resistance to extension and extensibility for flours were determined as rheological properties.

Resistance to extension and extensibility

Resistance to extension (g) and extensibility (mm) both were measured according to the technique explained in manual guide of the TA-HDI Texture Analyzer (Make: Stable Micro Systems, UK) (Plate 3.10). Dough was analyzed for resistance to extension and extensibility using Kieffer rig. The test was performed using mode: measured force in tension, option: return to start, pre-test speed: 2 mm/s, test speed: 3.3 mm/s, post-test speed: 10 mm/s, load cell: 25 kg and data acquisition rate: 200 PPS.

Dough was prepared and made as a rod, using the Texture Analyzer accessory. The sample was put on the platform, above the probe (initial situation). The probe was forced for stretching. The force used for stretch the dough was recorded by the Texture Analyzer (stretching). The probe stretched the dough so much that the dough breaks (breaking). The force used for stretch the dough till it breaks was set by the Texture Analyzer as the resistance to extension (g) and the distance before breaking was set by the Texture Analyzer as the extensibility (mm) (Plate 3.11).

3.5 Quality analysis of bread

3.5.1 Physical analysis of bread

Specific volume

Weight of loaf was measured after one hour of baking. Volume (cm³) was determined by rapeseed displacement method. Loaves were placed in a container of known volume into which rapeseeds were run until the container was full. The volume of seeds displaced by the loaf was considered as the loaf volume. Specific volume (cm³/g) was then calculated by dividing volume by weight (Flander *et al.*, 2006).

Height

Bread loaf was sliced from center. Height (cm) of the central slice was measured.

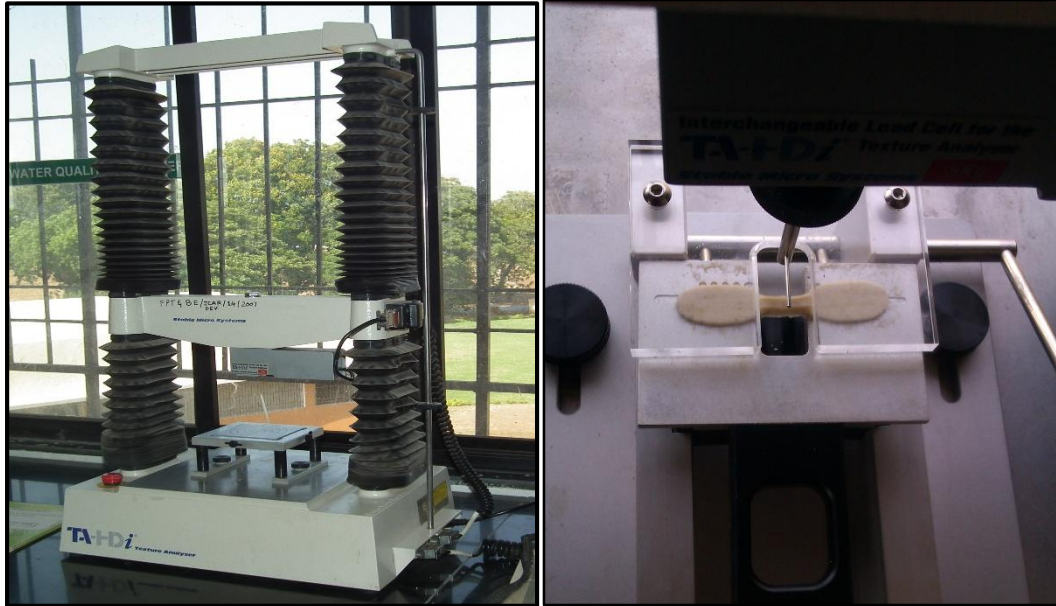


Plate 3.10: Texture Analyzer (Stable Micro System), and probe working in tension used for research work

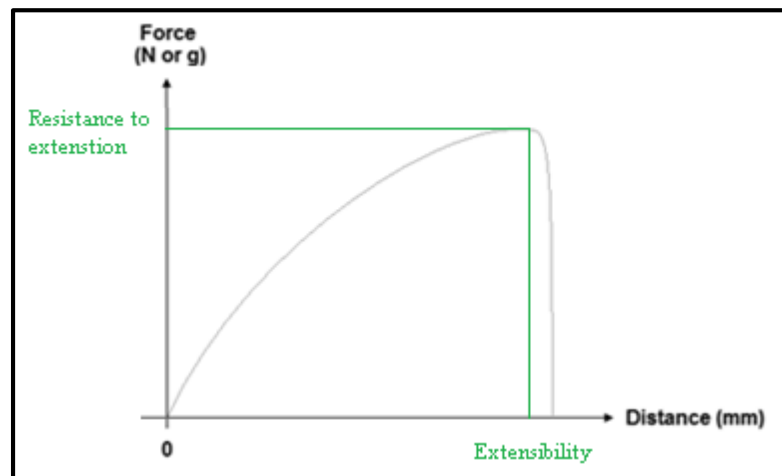


Plate 3.11: Texture analyzer typical graphic result

3.5.2 Textural analysis of bread

Firmness

Firmness is the force required to compress the material by a given amount. It is defined as the peak force during the first compression cycle (First bite). Crumb firmness was measured using the TA-HDI Texture Analyzer (Make: Stable Micro Systems, UK) (Plate 3.10). The determination of crumb firmness follows the standard procedure provided in the TA-HDI Texture Analyzer software. In this test, a P/75 flat probe was used. For this experiment, the firmness value at 40% compression was taken. The test was performed using mode: probe diameter: 20 mm, load cell: 100 kg, pre-test speed: 2 mm/s, test speed: 1 mm/s, post-test speed: 2 mm/s, acquisition rate: 250 PPS and trigger force: 0.196 N.

3.5.3 Organoleptic analysis of bread

A sensory judging panel was constituted with seven panelist from among the faculty members of the institute. The experimental samples were served to the judges. The panelists were instructed to rate each sample on ten point scale which included crust color, shape and bake, texture, grain structure, taste and aroma, crumb color and overall acceptability rating. The sensory criteria are given in Appendix-1. The final score for each attribute was obtained by averaging the score of all panelist.

3.6 Statistical analysis

The mean values generated from analysis of each of quality attribute obtained from three replications during the experimentation were subjected to statistical analysis using Factorial Completely Randomized Design (CRD) as per the procedure given by Steel and Torrie (1980). ANOVA tables were prepared and the significance of influence of each parameter on the specific characteristics was tested at 5% level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter represents the results and discussion of the experiment entitled “Technological aspects for production of bread from wheat-sorghum composite flour” conducted at College of Food Processing Technology and Bio Energy, Anand Agricultural University, Anand. Initially, wheat-sorghum composite flour and dough was analyzed for chemical, physical and rheological characteristics and then bread was prepared from composite flour with varying technical parameters and analyzed for various physical, textural and organoleptic characteristics. The data obtained are represented with statistical analysis.

4.1 Proximate chemical composition of refined wheat flour, sorghum flour and their blends

Refined wheat flour, sorghum flour and their blends were analyzed for their proximate chemical composition like moisture content, protein content, fat content, carbohydrate, ash content and fiber content as per the methods explained in the previous chapter. The results obtained are presented in Appendix - II.

4.1.1 Moisture content

The moisture content was significantly ($p < 0.05$) affected by the change in proportion of sorghum flour incorporated into the blends. When the proportion of sorghum flour in the blends was increased, the moisture content of the composite flour decreased (Fig. 4.1). The maximum value (13.18%) was obtained for the pure wheat flour and the minimum value (9.50%) for the pure sorghum flour.

4.1.2 Protein content

The protein content was significantly ($p < 0.05$) affected by the change in proportion of sorghum flour incorporated into the blends. On increasing the proportion of sorghum flour in the blends, the protein content of the composite flour decreased (Fig. 4.2). On increasing the proportion of sorghum flour in the sample, the protein content significantly ($p < 0.05$) decreased. The maximum value (15.30%) was obtained for the pure wheat flour and the minimum value (12.33%) for the pure sorghum flour.

As it has already been dealt in previous chapters, protein content is one of the main issues in bakery industry. Although the results obtained are high in the case of all composite flours and control samples, still the protein content cannot be linked directly with the gluten constitution. Indeed the gluten is made by specific proteins (glutein and

gliadin). Albumin and globulin are also present among the proteins, and these two are respectively soluble in water and salty solution.

4.1.3 Fat content

The fat content was significantly ($p < 0.05$) affected by the change in proportion of sorghum flour incorporated into the blends. When the proportion of sorghum flour in the blends was increased, the fat content of the composite flour increased (Fig. 4.3). The maximum value (3.92%) was obtained for the pure sorghum flour and the minimum value (3.07%) for the pure wheat flour.

4.1.4 Carbohydrate

The carbohydrate content was significantly ($p < 0.05$) affected by the change in proportion of sorghum flour incorporated into the blends. When the proportion of sorghum flour in the blends was increased, the carbohydrate content of the composite flour decreased (Fig. 4.4). The maximum value (69.64%) was obtained for the pure sorghum flour and the minimum value (63.56%) for the pure refined wheat flour sample.

4.1.5 Ash content

The ash content was significantly ($p < 0.05$) affected by the change in proportion of sorghum flour incorporated into the blends. When the proportion of sorghum flour in the blends was increased, the ash content of the composite flour increased (Fig. 4.5). The maximum value (2.10%) was obtained for the pure sorghum flour and the minimum value (1.06%) for the pure wheat flour.

4.1.6 Fiber content

The fiber content was significantly ($p < 0.05$) affected by the change in proportion of sorghum flour incorporated into the blends. When the proportion of sorghum flour in the blends was increased, the fiber content of the composite flour decreased (Fig. 4.6). The maximum value (3.83%) was obtained for the pure wheat flour and the minimum value (2.52%) for the pure sorghum flour.

Fig. 4.1 moisture content
Fig. 4.2 protein content
Fig. 4.3 fat content

Fig. 4.4 total carbohydrate

Fig. 4.5 ash content

Fig. 4.6 fiber content

4.2 Physico-chemical characteristics of refined wheat flour, sorghum flour and their blends

Refined wheat flour, sorghum flour and their blends were analyzed for various physico-chemical characteristics as depicted in Appendix - III.

4.2.1 Wet and dry gluten content

Wet and dry gluten contents were significantly ($p < 0.05$) affected by the change in proportion of sorghum flour incorporated into the blends. Highest values of wet gluten (57.58%) and dry gluten (32.07%) were obtained for pure wheat flour, while the lowest values of wet gluten (12.33%) and dry gluten (2.73%) were obtained for a blend with 50% sorghum flour (Fig. 4.7).

The pure sorghum flour had 0% wet and dry gluten contents. It is explained by the fact that the sorghum does not have the gluten constitution (gliadin and glutenin). Tests done by incorporating from 20 to 50% of sorghum flour in the composite flour resulted in decreasing of wet and dry gluten content values. Gluten analysis is important since gluten is essential for the stable structure of baked products. It is responsible for dough elasticity, bread volume and soft texture.

4.2.2 Sedimentation value

Sedimentation value decreased significantly ($p < 0.05$) when the proportion of sorghum flour was increased into the blends. The maximum value (22.64 ml) was obtained for the pure wheat flour and the minimum value (15.43 ml) for pure sorghum flour (Fig. 4.8).

4.2.3 Water absorption capacity

The water absorption capacity of composite flour decreased significantly ($p < 0.05$) on increasing the proportion of sorghum flour into the blends. The maximum value (112.00%) was obtained for the pure wheat flour and the minimum value (63.67%) for pure sorghum flour (Fig. 4.9).

4.2.4 Bulk density

The bulk density almost linearly decreased significantly ($p < 0.05$) with increase in proportion of sorghum flour in the blend. The highest bulk density (0.53 g/ml) was obtained for the pure wheat flour and the lowest (0.26 g/ml) was for the pure sorghum flour (Fig. 4.10).

Fig. 4.7 wet & dry gluten

Fig. 4.8 sedimentation value

The bulk density is linked with issues regarding the packaging of the flour. According to the bulk density value, an identical mass of flour can fit in different volumes. Decreasing of bulk density makes the same weight of flour taking more volume. By increasing the proportion of sorghum, the composite flour takes more volume.

4.2.5 Tap bulk density

Tap bulk density is nothing but the modified bulk density after taping. Tap Bulk density decreased significantly ($p < 0.05$) when the proportion of sorghum flour was increased in the composite flour. The highest tap bulk density (1.67 g/ml) was obtained for the pure wheat flour and the lowest (0.93 g/ml) was for the pure sorghum flour (Fig. 4.10).

4.2.6 Apparent porosity

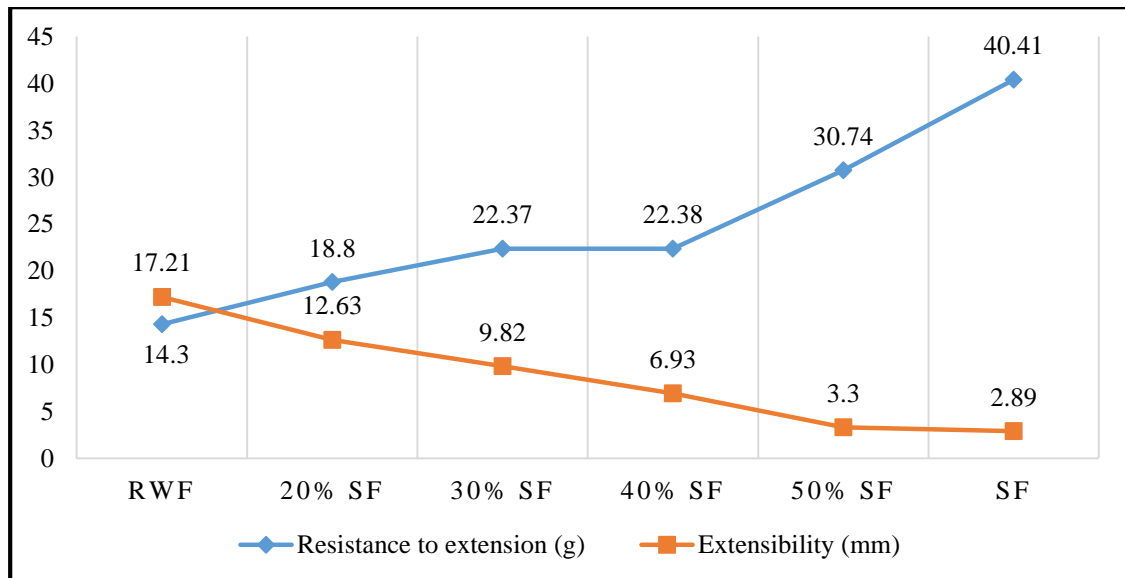
Apparent porosity increased when the proportion of sorghum flour was increased in the composite flour. The highest apparent porosity (0.72%) was found for the pure sorghum flour, while the lowest apparent porosity (0.68%) was for the pure wheat flour (Fig. 4.10). The composite flour became more porous as the proportion of sorghum flour in composite flour was increased. From the ANOVA it can be seen that effect on apparent porosity was non-significant.

Fig. 4.9 WAC

Fig. 4.10 BD, tap BD and AP

4.3 Rheological characteristics of refined wheat flour, sorghum flour and their blends

Dough prepared from refined wheat flour, sorghum flour and their blends were analyzed for the resistance to extension and the extensibility as their rheological properties. The tests were carried out using Keiffer Ring, which is exclusively designed for the parameters mentioned above. The test generally conveys the nature of the gluten formed in the dough. The results obtained are presented in the Appendix - IV.



RWF = Refined wheat flour, SF = Sorghum flour

Fig. 4.11: Effect of sorghum flour level on resistance to extension and extensibility

4.3.1 Resistance to Extension and Extensibility

Results obtained show that the rheological properties of composite flour dough were significantly ($p < 0.05$) affected by the level of sorghum flour incorporation into the sample (Appendix - IV).

As for the resistance to extension, the sample having pure sorghum flour showed the maximum value (40.41 g) whereas the pure wheat flour sample showed the minimum value (14.30 g). Resistance to extension increased when the proportion of sorghum flour incorporated into the sample was increased, while the extensibility of the blend found to be reducing on increasing the proportion of sorghum flour incorporated into the sample (Fig. 4.11). The maximum value (17.21 mm) was obtained for the pure wheat flour and the minimum value (2.89 mm) for the pure sorghum flour

4.4 Effect of sorghum flour level, fermentation time and baking temperature on physical properties of bread

The three different refined wheat flour level with sorghum flour (80:20, 70:30, 60:40 and control), four different fermentation time (45, 55, 65 and 75 min) and four different baking temperature (165, 180, 195 and 210 °C) were tried for production of bread. It was very difficult to prepare bread with 50:50 ratio of refined wheat flour and sorghum flour without addition of additives. So, we have not gone for bread with this ratio. Prepared bread was analyzed for various physical properties like volume, weight, specific volume and height. The results obtained are discussed according to the treatment given to the breads (Table 4.1).

4.4.1 Effect on volume of bread

The data on the effect of sorghum flour level, fermentation time and baking temperature on volume (cm³) of experimental bread are presented in Table 4.1. The same are represented graphically in Fig.4.12.

It was observed that the volume of bread was varied from 376.67 cm³ to 526.67 cm³ at 165 °C, 393.33 cm³ to 538.33 cm³ at 180 °C, 393.33 cm³ to 548.33 cm³ at 195 °C and 376.67 cm³ to 548.33 cm³ at 210 °C. Plate 4.1 shows volume comparison of control and composite flour bread. As we increase the level of sorghum flour there was decrement in the volume of bread. It could be because of dilution effect on gluten with the addition of non-wheat flour to wheat flour and less retention of CO₂ gas caused the depression in loaf volume (Sharma and Chauhan, 2000). In this study, it is evident from graphs that the reduction in volume is almost linear with the increase in level of sorghum flour. Another reason for the decrease in loaf volume could be the presence of relatively high concentrations of low molecular weight thiols, especially reduced glutathione, which activates proteolytic enzymes, thereby causing a detrimental effect on loaf volume (Indrani and Rao, 1992). Beswa (2008) studied that high levels of finger millet flour also resulted in a decrease in loaf volume. It was also observed that, on increasing the fermentation time and baking temperature, the volume of bread was also slightly increased (Fig. 4.12), but Beswa (2008) stated that extreme decrease in temperature had negative effect on volume of bread. While Shittu *et al.* (2007) mentioned that increasing in proofing (fermentation) time will increase loaf volume and specific volume. A significant reduction in loaf volume was observed (Dhingra and Jood, 2004; Ereifej and Shibli, 1993 and Ptitchkina *et al.*, 1998) as the level of substitution of non-wheat flours increased.

Table 4.1: Effect of sorghum flour level, fermentation time and baking temperature on physical properties of bread

RWF : SF Ratio	Fermentati on Time (min)	Volume of Bread (cm³)	Weight of Bread (g)	Specific Vol. of Bread (cm³/g)	Height of Bread (cm)
Baking Temperature: 165 °C					
Control	45	501.67	174.96	2.87	5.77
80:20		461.67	182.90	2.53	5.37
70:30		376.67	176.95	2.13	4.77
60:40		406.67	176.95	2.30	4.37
Control	55	515.00	178.13	2.89	5.93
80:20		458.33	178.12	2.57	5.47
70:30		388.33	174.83	2.22	4.97
60:40		403.33	178.16	2.26	4.57
Control	65	518.33	173.48	2.99	6.17
80:20		453.33	176.91	2.56	5.60
70:30		413.33	176.18	2.35	5.10
60:40		408.33	180.94	2.26	4.67
Control	75	526.67	167.84	3.14	6.33
80:20		446.67	176.95	2.52	5.77
70:30		423.33	173.70	2.44	5.03
60:40		418.33	179.41	2.33	4.43
Baking Temperature: 180 °C					
Control	45	518.33	171.48	3.02	5.87
80:20		396.67	166.78	2.38	5.43
70:30		428.33	183.89	2.33	5.13
60:40		423.33	181.69	2.33	4.77
Control	55	526.67	176.50	2.98	5.93
80:20		403.33	169.32	2.38	5.53
70:30		430.00	184.84	2.33	5.53
60:40		428.33	180.25	2.38	4.87
Control	65	531.67	175.77	3.02	6.03
80:20		425.00	177.14	2.40	5.77
70:30		438.33	184.29	2.38	5.77
60:40		428.33	182.04	2.35	5.27
Control	75	538.33	175.92	3.06	6.23
80:20		441.67	175.64	2.51	6.03
70:30		393.33	181.76	2.16	5.63
60:40		433.33	179.88	2.41	4.87
Baking Temperature: 195 °C					
Control	45	533.33	178.11	2.99	6.17
80:20		451.67	175.17	2.58	5.67
70:30		393.33	175.40	2.24	5.10
60:40		421.67	176.97	2.38	4.70
Control	55	538.33	179.83	2.99	6.33
80:20		458.33	176.97	2.59	5.87
70:30		406.67	172.99	2.35	5.23
60:40		431.67	177.64	2.43	4.93
Control	65	541.67	180.03	3.01	6.43

80:20		468.33	179.82	2.60	6.00
70:30		403.33	178.29	2.26	5.33
60:40		436.67	176.42	2.48	5.23
Control	75	548.33	179.10	3.06	6.53
80:20		478.33	180.26	2.65	6.10
70:30		408.33	179.94	2.27	5.13
60:40		441.67	175.68	2.51	4.97
Baking Temperature: 210 °C					
Control	45	541.67	175.73	3.08	6.50
80:20		465.00	179.76	2.59	6.03
70:30		376.67	176.90	2.13	4.97
60:40		451.67	178.59	2.53	5.07
Control	55	548.33	176.00	3.12	6.60
80:20		475.00	177.25	2.68	6.27
70:30		386.67	173.14	2.23	5.13
60:40		421.67	174.50	2.42	4.87
Control	65	545.00	174.29	3.13	6.67
80:20		471.67	173.14	2.72	6.33
70:30		403.33	178.29	2.26	5.33
60:40		415.00	174.78	2.37	5.33
Control	75	548.33	180.61	3.04	6.77
80:20		481.67	179.23	2.69	6.03
70:30		391.67	174.81	2.24	5.03
60:40		418.33	170.79	2.45	4.47

RWF = Refined wheat flour, SF = Sorghum flour

It can be seen from ANOVA that the processing parameters such as sorghum flour level, baking temperature and fermentation time and their interactions had significant effect on volume of experimental bread at 5% level of significance (Table 4.2).

Table 4.2: ANOVA for effect of sorghum flour level, fermentation time and baking temperature on volume of bread

SOURCE	D.F.	M.S.	F cal	F tab	SEm	CD (5%)	Test
Ratio (R)	3	19.829	1620.27	2.68	1.6	4.47	*
Time (T)	3	1.643	134.29	2.68	1.6	4.47	*
R × T	9	0.485	39.61	1.95	3.19	0.09	*
Temperature (Temp)	3	0.864	70.62	2.68	1.6	4.47	*
R × Temp	9	0.131	10.69	1.95	3.19	0.09	*
T × Temp	9	0.091	7.42	1.95	3.19	4.47	*
R × T × Temp	27	0.026	2.12	1.57	0.06	0.18	*
CV (%)	2.00						

4.4.2 Effect on weight of bread

The data on the effect of sorghum flour level, fermentation time and baking temperature on weight (g) of experimental bread are presented in Table 4.1. The same are represented graphically in Fig.4.13.

It was observed that the weight of bread was varied from 167.84 g to 182.90 g at 165 °C, 166.78 g to 184.84 g at 180 °C, 172.99 g to 180.26 g at 195 °C and 170.79 g to 180.61 g at 210 °C. During the experimentation dough was cut manually so there was not a linear trend in weight of bread. But however the weight of bread increased with the increase in the sorghum flour. It might be because of less retention of gas in the blended doughs, hence providing denser bread texture. The results in this study were comparable with those reported by earlier workers (Ereifej and Shibli, 1993; Sharma and Chauhan, 2000).

It can be seen from ANOVA that the processing parameters such as sorghum flour level, fermentation time and their interactions had significant effect while baking temperature had no significant effect on weight of experimental bread at 5% level of significance (Table 4.3).

Table 4.3: ANOVA for effect of sorghum flour level, fermentation time and baking temperature on weight of bread

SOURCE	D.F.	M.S.	F cal	F tab	SEm	CD (5%)	Test
Ratio (R)	3	31.699	8.23	2.68	0.28	0.79	*
Time (T)	3	47.254	12.28	2.68	0.28	0.79	*
R × T	9	142.639	37.05	1.95	0.57	1.56	*
Temperature (Temp)	3	2.083	0.54	2.68	0.28	NS	NS
R × Temp	9	13.4	3.48	1.95	0.57	1.56	*
T × Temp	9	32.91	8.55	1.95	0.57	0.79	*
R × T × Temp	27	19.576	5.09	1.57	1.13	3.17	*
CV (%)	1.11						

4.4.3 Effect on specific volume of bread

The data on the effect of sorghum flour level, fermentation time and baking temperature on specific volume of experimental bread are presented in Table 4.1. The same are represented graphically in Fig.4.14.

Fig. 4.12 volume

Plate 4.1 volume

Fig. 4.13 weight

Fig. 4.14 specific volume

The specific volume, which is the ratio of two properties (i.e. volume of bread to weight of bread), has been generally adopted as a more reliable measure of loaf size. The specific volume of bread was varied from 2.13 cm³/g to 3.14 cm³/g at 165 °C, 2.18 cm³/g to 3.06 cm³/g at 180 °C, 2.22 cm³/g to 3.06 cm³/g at 195 °C and 2.11 cm³/g to 3.13 cm³/g at 210 °C.

Specific volume of bread decreased significantly with increasing sorghum substitution level, which is in agreement with the data obtained by Abdel-Aal *et al.* (1993); Abdelghafor *et al.* (2011); Aluko and Olugbemi's (1989); Morad *et al.* (1984); Perten *et al.* (1980); Dhingra and Jood (2004); Indrani and Rao (1992) and Ereifej and Shibli (1993) for replacement of refined wheat flour. This can be attributed to lower levels of gluten network in the dough and consequently less ability of the dough to rise; due to the weaker cell wall structure. The poor quality and quantity of gluten in cereal-pulse blended breads may be responsible for retention of CO₂ gas in the fermented dough and low specific loaf volume.

During the study it was found that specific volume slightly increased with the increase in fermentation time. The significant effect of proofing time on specific volume of wheat sourdough bread has also been reported by Clarke *et al.* (2003) and Flander *et al.* (2006).

It can be seen from ANOVA that the processing parameters such as sorghum flour level, baking temperature and fermentation time and their interactions had significant effect on specific volume of experimental bread at 5% level of significance (Table 4.4).

Table 4.4 ANOVA for effect of sorghum flour level, fermentation time and baking temperature on specific volume of bread

SOURCE	D.F.	M.S.	F cal	F tab	SEm	CD (5%)	Test
Ratio (R)	3	5.28	3820.6	2.68	5.37	0.02	*
Time (T)	3	0.083	59.93	2.68	5.37	0.02	*
R × T	9	0.056	40.46	1.95	1.07	3.00	*
Temperature (Temp)	3	0.044	31.57	2.68	5.37	0.01	*
R × Temp	9	0.007	4.9	1.95	1.07	3.00	*
T × Temp	9	0.01	7.13	1.95	1.07	0.02	*
R × T × Temp	27	0.013	9.47	1.57	2.12	6.00	*
CV (%)	1.45						

4.4.4 Effect on height of bread

The data on the effect of sorghum flour level, fermentation time and baking temperature on height of experimental bread are presented in Table 4.1. The same are represented graphically in Fig.4.15.

It was observed that the height of bread was varied from 4.37 cm to 6.33 cm at 165 °C, 4.77 cm to 6.23 cm at 180 °C, 4.70 cm to 6.53 cm at 195 °C and 4.47 cm to 6.77 cm at 210 °C. As we increase the level of sorghum flour there was decrement in the height of bread. Seguchi *et al.* (2001) reported that bread height gradually decrease by increasing level of mushroom powder. The results are also correlated with the results obtained by other authors (Mepba *et al.*, 2007 and Schober *et al.*, 2005). In this study it is evident from graph that the reduction in height is almost linear with the increase in level of sorghum flour. These findings are in principal agreement with Cauvain (1998), who described wheat less bread doughs as more fluid than wheat doughs and closer in viscosity to cake batters. It was observed that as we increase fermentation time and baking temperature, the height of bread was also slightly increased for a particular wheat-sorghum flour ratio. See *et al.* (2007) reported similar results in terms of oven spring in bread supplemented with pumpkin flour. Oven spring (cm) was calculated by the difference between loaf height before and after baking. As the level of pumpkin flour increased there was linear reduction in height of baked breads.

It can be seen from ANOVA that the processing parameters such as sorghum flour level, baking temperature and fermentation time and their interactions had significant effect on height of experimental bread at 5% level of significance (Table 4.5).

Table 4.5: ANOVA for effect of sorghum flour level, fermentation time and baking temperature on height of bread

SOURCE	D.F.	M.S.	F cal	F tab	SEm	CD (5%)	Test
Ratio (R)	3	19.829	1620.2	2.68	1.6	4.47	*
Time (T)	3	1.643	134.29	2.68	1.6	4.47	*
R × T	9	0.485	39.61	1.95	3.19	0.09	*
Temperature (Temp)	3	0.864	70.62	2.68	1.6	4.47	*
R × Temp	9	0.131	10.69	1.95	3.19	0.09	*
T × Temp	9	0.091	7.42	1.95	3.19	4.47	*
R × T × Temp	27	0.026	2.12	1.57	0.06	0.18	*
CV (%)	2.00						

Fig. 4.15 height

4.5 Effect of sorghum flour level, fermentation time and baking temperature on textural properties of bread

The variation in textural properties in terms of firmness of bread prepared from different flour level combination is presented in Table 4.6. The sorghum flour level and various processing parameters had a significant ($p < 0.05$) effect on bread firmness (Table 4.7).

4.5.1 Effect on firmness of bread

Firmness of bread was from 978.92 g to 1638.26 g at 165 °C, 980.65 g to 1766.56 g at 180 °C, 958.68 g to 1725.76 g at 195 °C and 913.01 g to 1828.40 g at 210 °C (Fig. 4.16).

Table 4.6: Effect of sorghum flour level, fermentation time and baking temperature on firmness of bread

RWF : SF Ratio	Fermentation Time (min)	Firmness of Bread (g)
Baking Temperature: 165 °C		
Control	45	1004.25
80:20		1178.96
70:30		1467.12
60:40		1638.26
Control	55	989.48
80:20		1318.21
70:30		1502.38
60:40		1571.55
Control	65	978.92
80:20		1268.96
70:30		1553.41
60:40		1578.59
Control	75	984.85
80:20		1078.53
70:30		1437.73
60:40		1628.65
Baking Temperature: 180 °C		
Control	45	991.46
80:20		1073.38
70:30		1556.52
60:40		1766.56
Control	55	984.25
80:20		1241.99
70:30		1550.95
60:40		1651.04
Control	65	983.14
80:20		1177.81
70:30		1457.21
60:40		1585.51
Control	75	980.69
80:20		1269.73
70:30		1463.93

60:40		1542.56
Baking Temperature: 195 °C		
Control	45	976.70
80:20		1152.46
70:30		1508.37
60:40		1642.92
Control	55	965.07
80:20		1186.99
70:30		1517.09
60:40		1725.76
Control	65	963.65
80:20		1236.41
70:30		1515.37
60:40		1692.47
Control	75	958.68
80:20		1216.34
70:30		1486.10
60:40		1654.18
Baking Temperature: 210 °C		
Control	45	936.86
80:20		1279.76
70:30		1581.04
60:40		1793.40
Control	55	928.95
80:20		1185.69
70:30		1563.22
60:40		1828.40
Control	65	923.92
80:20		1088.05
70:30		1515.37
60:40		1727.20
Control	75	913.01
80:20		1051.53
70:30		1493.46
60:40		1662.30

RWF = Refined wheat flour, SF = Sorghum flour

The results showed that, as the amount of sorghum flours increased, the hardness of bread crumb increased. It was reported that since wheat flours contain gluten protein, which by suitable development gives the bread its unique and much desired texture; the inclusion of sorghum flours dilutes wheat gluten and consequently weakens its strength. The presence of starch in baking affects crumb characteristics (Taha, 2000). It was also observed that increasing in proofing time has positive effect on firmness while increasing in baking temperature has negative effect on bread firmness. Plate 4.2 shows the textural characteristics of control and composite flour bread.

Fig. 4.16 firmness

Seetharaman *et al.* (2002) reported that crumb firmness has a positive relationship with baking temperature and time. Increasing the baking temperature and time cause an increment in crumb firmness since crumb firming is closely related to starch properties in bread. Variation in starch properties e.g. starch gelatinization, pasting viscosities, amylose solubility and amylopectin recrystallization depends on different thermal conditions applied to it. These properties influence the crumb firming values. The significant effect of proofing time on hardness of wheat sourdough bread has also been reported by Clarke *et al.* (2003). Flander *et al.* (2006) reported that from some processing factors, proofing temperature and time had the greatest effects on bread quality.

Table 4.7: ANOVA for effect of sorghum flour level, fermentation time and baking temperature on firmness of bread

SOURCE	D.F.	M.S.	F cal	F tab	SEm	CD (5%)	Test
Ratio (R)	3	4795247	1923.19	2.68	7.21	20.17	*
Time (T)	3	3852.976	1.55	2.68	7.21	NS	NS
R × T	9	24359.24	9.77	1.95	14.42	40.34	*
Temperature (Temp)	3	25361.51	10.17	2.98	7.21	20.17	*
R × Temp	9	8280.169	3.32	1.95	14.42	40.34	*
T × Temp	9	10987.61	4.41	1.95	14.42	20.17	*
R × T × Temp	27	9577.981	3.84	1.57	28.83	80.68	*
CV (%)	3.74						

4.6 Effect of sorghum flour level, fermentation time and baking temperature on organoleptic properties of bread

The data of effect of sorghum flour level, fermentation time and baking temperature on various organoleptic parameters are presented in Table 4.8. Prepared bread was analyzed for various organoleptic properties like crust color, shape and bake, texture, grain structure, taste and aroma, crumb color and overall acceptability. The influence of composite flour and technological parameters were found significant ($p < 0.05$) for most of the sensory attributes.

Table 4.8: Effect of sorghum flour level, fermentation time and baking temperature on organoleptic properties of bread

RWF : SF Ratio	Fermentation Time (min)	Crust Color	Shape and Bake	Texture	Grain Structure	Taste and Aroma	Crumb Color	Overall Acceptability
Baking Temperature: 165 °C								
Control	45	6.67	5.33	7.33	7.67	7.67	7.67	7.06
80:20		5.33	4.33	6.00	6.00	6.67	5.33	5.61
70:30		4.00	4.67	5.00	5.33	4.67	4.00	4.61
60:40		3.00	4.00	2.33	2.67	2.67	3.00	2.94

Results and Discussion

Control	55	7.33	5.67	7.67	7.33	7.67	8.00	7.28
80:20		5.33	4.67	5.67	5.67	6.00	5.33	5.44
70:30		4.33	4.33	5.33	6.00	5.00	4.33	4.89
60:40		2.67	5.33	3.00	3.00	3.33	2.67	3.33
Control	65	7.00	6.33	8.00	7.67	8.33	8.33	7.61
80:20		6.00	5.33	6.00	6.33	6.33	6.00	6.00
70:30		4.67	3.67	5.00	5.33	4.67	4.67	4.67
60:40		3.33	6.00	3.33	3.00	3.00	3.33	3.67
Control	75	7.00	6.67	7.67	8.00	7.67	7.00	7.33
80:20		5.33	5.33	6.00	6.00	6.67	5.33	5.78
70:30		4.67	4.33	5.33	6.00	4.67	4.67	4.94
60:40		2.67	6.00	3.00	2.33	2.67	2.67	3.22
Baking Temperature: 180 °C								
Control	45	7.33	5.67	7.33	7.33	8.00	7.33	7.17
80:20		6.33	4.33	6.33	6.33	6.00	6.33	5.94
70:30		5.33	5.00	5.00	5.00	5.00	5.33	5.11
60:40		3.00	5.67	2.67	3.33	3.00	3.00	3.44
Control	55	7.00	5.33	8.33	8.00	8.33	7.00	7.33
80:20		6.00	5.33	6.33	5.67	6.33	6.00	5.94
70:30		5.00	5.67	5.00	5.00	4.67	5.00	5.06
60:40		3.00	5.67	3.00	2.33	3.33	3.00	3.39
Control	65	6.33	6.33	8.33	8.33	8.00	6.33	7.28
80:20		5.33	5.00	5.67	6.00	6.00	5.33	5.56
70:30		5.00	4.67	5.00	5.33	5.00	5.00	5.00
60:40		4.00	6.67	3.00	3.33	3.00	4.00	4.00
Control	75	6.67	6.67	8.67	8.33	8.00	6.67	7.50
80:20		6.00	5.33	6.00	6.33	6.00	6.00	5.94
70:30		4.33	5.33	5.33	5.00	5.00	4.33	4.89
60:40		3.00	5.33	3.33	3.00	2.67	3.00	3.39
Baking Temperature: 195 °C								
Control	45	7.00	6.33	7.33	7.33	7.67	7.00	7.11
80:20		6.67	5.00	6.33	6.33	6.33	6.67	6.22
70:30		5.33	4.00	5.00	4.67	5.00	5.33	4.89
60:40		3.00	5.00	3.33	3.33	3.00	3.00	3.44
Control	55	7.33	6.67	7.67	8.00	8.67	7.33	7.61
80:20		6.33	5.00	6.33	6.33	6.00	6.33	6.06
70:30		5.33	4.33	4.33	4.33	4.67	5.33	4.72
60:40		4.33	4.00	3.00	3.33	4.33	4.33	3.89
Control	65	6.67	6.00	8.00	8.00	8.33	7.00	7.33
80:20		6.67	5.00	6.67	5.33	6.00	6.67	6.06
70:30		5.33	5.33	5.33	5.00	5.00	5.33	5.22
60:40		3.33	4.00	3.00	3.00	3.00	3.33	3.28
Control	75	7.67	6.00	8.00	8.00	8.00	6.67	7.39
80:20		6.67	5.00	6.00	6.33	5.67	6.67	6.06
70:30		5.67	4.67	5.67	5.67	5.33	5.67	5.44
60:40		4.67	3.33	3.33	3.33	3.00	4.67	3.72
Baking Temperature: 210 °C								
Control	45	8.00	6.67	7.67	8.00	8.33	7.33	7.67
80:20		7.33	5.33	6.67	5.67	7.00	7.33	6.56
70:30		4.67	5.67	5.00	4.33	5.00	4.67	4.89
60:40		4.00	2.67	3.00	3.00	3.00	4.00	3.28
Control	55	7.67	6.00	8.00	8.33	8.00	7.67	7.61
80:20		7.67	4.67	6.33	6.00	7.33	7.67	6.61
70:30		5.33	5.00	5.00	5.00	5.00	5.33	5.11

60:40		4.67	3.00	3.33	3.00	3.00	4.67	3.61
Control	65	8.00	6.67	7.67	7.67	8.00	8.33	7.72
80:20		8.33	5.33	5.67	6.67	7.33	8.33	6.94
70:30		5.33	5.33	5.33	5.00	5.00	5.33	5.22
60:40		4.33	3.00	3.00	2.67	3.00	4.33	3.39
Control	75	8.67	6.33	8.33	8.33	8.67	8.67	8.17
80:20		8.00	5.67	6.67	6.67	6.33	8.00	6.89
70:30		5.67	4.67	5.00	5.00	4.67	5.67	5.11
60:40		4.67	3.00	3.33	3.33	3.00	4.67	3.67

RWF = Refined wheat flour, SF = Sorghum flour

4.6.1 Effect on crust color of bread

The sensory scores for crust color varied from 3.67 to 7.33, 3.00 to 7.33, 3.00 to 7.67 and 4.00 to 8.67 for baking temperature 165, 180, 195 and 210 °C respectively (Fig. 4.17). The similar results for crust color were reported by Pawse (2009) for pigeon pea husk supplemented breads. As the proportion of sorghum flour in blends was increased, the crust color of the breads changed from creamy white to dull brown. These results are in conformity with findings of Dhingra and Jood (2004) who developed bread from barley and soy flour. The darker crust color may be because of the greater amount of the maillard reaction between reducing sugars and proteins (Raidi and Klein, 1983). These results are in agreement with those reported by Summer and Nielsen (1976), who concluded that incorporation of 20% sorghum flour in bread formulation darkened the external loaf color i.e. crust. Beswa (2008) reported that as the finger millet flour substitution level was increased the resultant composite breads became dark in color.

It can be seen from ANOVA that the processing parameters such as sorghum flour level, baking temperature and fermentation time had significant effect on crust color of experimental bread at 5% level of significance, while effect of their interactions were found non-significant (Table 4.9).

Table 4.9: ANOVA for effect of sorghum flour level, fermentation time and baking temperature on crust color of bread

SOURCE	D.F.	M.S.	F cal	F tab	SEm	CD (5%)	Test
Ratio (R)	3	121.625	220.3	2.68	0.11	0.3	*
Time (T)	3	21.514	38.97	2.68	0.11	0.3	*
R × T	9	1.426	2.58	1.95	0.21	0.6	*
Temperature (Temp)	3	0.514	0.93	2.68	0.11	NS	NS
R × Temp	9	0.315	0.57	1.95	0.21	NS	NS
T × Temp	9	0.833	1.51	1.95	0.21	NS	NS
R × T × Temp	27	0.412	0.75	1.57	42	NS	NS
CV (%)	13.36						

Fig. 4.17 crust color

4.6.2 Effect on shape and bake of bread

The sensory scores for shape and bake varied from 3.67 to 6.67, 4.33 to 6.67, 3.33 to 6.67 and 2.67 to 6.67 for baking temperature 165, 180, 195 and 210 °C respectively (Fig. 4.18). The difference in score among the bread may raise due to addition of sorghum flour. Increasing level of sorghum flour resulted in decrease of symmetry of shape and uniformity of bake sensory score. This result is in agreement with the results reported by Pawse (2009) and Kamaliya (2005) who tried to develop high fiber bread.

It can be seen from ANOVA that the processing parameters such as sorghum flour level, baking temperature and fermentation time had significant effect on shape and bake of experimental bread at 5% level of significance, while effect of their interactions were found non-significant (Table 4.10).

Table 4.10: ANOVA for effect of sorghum flour level, fermentation time and baking temperature on shape and bake of bread

SOURCE	D.F.	M.S.	F cal	F tab	SEm	CD (5%)	Test
Ratio (R)	3	25.319	42.27	2.68	0.11	0.31	*
Time (T)	3	3.389	5.66	2.68	0.11	0.31	*
R × T	9	6.838	11.42	1.95	0.22	0.63	*
Temperature (Temp)	3	0.903	1.51	2.68	0.11	NS	NS
R × Temp	9	0.537	0.9	1.95	0.22	NS	NS
T × Temp	9	0.921	1.54	1.95	0.22	NS	NS
R × T × Temp	27	0.846	1.41	1.57	0.44	NS	NS
CV (%)	15.10						

4.6.3 Effect on texture of bread

The texture was related to the external appearance of the bread top i.e. smoothness or roughness of the crust. The sensory scores for texture of bread varied from 2.33 to 8.00, 2.67 to 8.67, 3.00 to 8.00 and 3.00 to 8.33 for baking temperature 165, 180, 195 and 210 °C respectively (Fig. 4.19). As we increased the level of sorghum flour, the bread became more tuff and hard, which simply resulted in low sensory scores. The data correlated with the data obtained for bread rheology (firmness). The deterioration in the crust texture of breads with puffed Bengal gram beyond a 20% substitution has also been observed (Rathna and Neelakantan, 1995). Similar deterioration in the texture of wheat bread on supplementation was observed by other workers (Sharma *et al.*, 1999; Carson *et al.*, 2000). Addition of more fiber produces bread of poor quality in terms of texture and appearance was reported by Pawse (2009) and Dubois (1956). Beswa (2008) reported that an increase in both finger millet level

of substitution and temperatures had a negative effect on the acceptability of crust appearance of different composite breads.

It can be seen from ANOVA that the processing parameters such as baking temperature, fermentation time and their interactions had non-significant effect on texture of experimental bread while effect of sorghum flour ratio on texture was significant at 5% level of significance (Table 4.11).

Table 4.11: ANOVA for effect of sorghum flour level, fermentation time and baking temperature on texture of bread

SOURCE	D.F.	M.S.	F cal	F tab	SEm	CD (5%)	Test
Ratio (R)	3	194.464	289.43	2.68	0.12	0.33	*
Time (T)	3	0.602	0.9	2.68	0.12	NS	NS
R × T	9	0.306	0.46	1.95	0.24	NS	NS
Temperature (Temp)	3	0.714	1.06	2.68	0.12	NS	NS
R × Temp	9	0.454	0.68	1.95	0.24	NS	NS
T × Temp	9	0.315	0.47	1.95	0.24	NS	NS
R × T × Temp	27	0.309	0.46	1.57	0.47	NS	NS
CV (%)	14.75						

4.6.4 Effect on grain structure of bread

The grain structure was related to the internal appearance of the bread as well as the gritty sensation in the mouth. The sensory scores for grain structure of bread varied from 2.33 to 8.00, 2.33 to 8.33, 3.00 to 8.00 and 2.67 to 8.33 for baking temperature 165, 180, 195 and 210 °C respectively (Fig. 4.20). As the level of sorghum flour increased, the grain structure became poorer. Pawse (2009) reported similar results for bread prepared from pigeon pea husk supplementation. Grain structure score also decreased with increase in the substitution of barley and soy flour in wheat flour as compared with the control bread (Dhingra and Jood, 2004).

It can be seen from ANOVA that the processing parameters such as baking temperature, fermentation time and their interactions had non-significant effect on grain structure of experimental bread while effect of sorghum flour ratio on grain structure was significant at 5% level of significance (Table 4.12).

Fig. 4.18 Shape & bake

Fig. 4.19 texture

Fig. 4.20 grain

Table 4.12: ANOVA for effect of sorghum flour level, fermentation time and baking temperature on grain structure of bread

SOURCE	D.F.	M.S.	F cal	F tab	SEm	CD (5%)	Test
Ratio (R)	3	201.299	301.95	2.68	0.12	0.33	*
Time (T)	3	0.09	0.14	2.68	0.12	NS	NS
R × T	9	0.757	1.14	1.95	0.24	NS	NS
Temperature (Temp)	3	0.868	1.3	2.68	0.12	NS	NS
R × Temp	9	0.387	0.58	1.95	0.24	NS	NS
T × Temp	9	0.289	0.43	1.95	0.24	NS	NS
R × T × Temp	27	0.475	0.71	1.58	0.47	NS	NS
CV (%)	14.76						

4.6.5 Effect on taste and aroma of bread

The taste and aroma are the major contributing factors in deciding the acceptability of any food product. The sensory scores for taste and aroma of bread varied from 2.67 to 8.33, 2.67 to 8.33, 3 to 8.67 and 3.00 to 8.67 for baking temperature 165, 180, 195 and 210 °C respectively (Fig. 4.21).

Taste scores decreased significantly as the level of sorghum flour increased. When the proportion of sorghum flours increased in breads, the softness and mouth feel of bread scores decreased significantly (Abdelghafor *et al.*, 2011). Dhingra and Jood (2004) concluded that the taste score decreased with increased level of substitution with soy flour as compared with control bread. Pawse (2009) reported that addition of pigeon pea husk in blends resulted in depression effect in terms of taste and found non-acceptable. In the contrary Rao and Rao (1997) developed wheat bran bread and found that aroma and taste got improved with the addition of wheat bran into blends. A similar decrease in the aroma and flavor of breads with increase in the supplementation levels of fenugreek flour was also noticed by Sharma and Chauhan (2000). A decrease in the acceptability of mouth feel of composite breads was noticed when the finger millet level of substitution was increased. There was no improvement shown by increasing temperatures on the acceptability of mouth feel (Beswa, 2008).

It can be seen from ANOVA that the processing parameters such as baking temperature, fermentation time and their interactions had non-significant effect on taste and aroma of experimental bread while effect of sorghum flour ratio on taste and aroma was significant at 5% level of significance (Table 4.13).

Fig. 4.21 taste & aroma

Table 4.13: ANOVA for effect of sorghum flour level, fermentation time and baking temperature on taste and aroma of bread

SOURCE	D.F.	M.S.	F cal	F tab	SEm	CD (5%)	Test
Ratio (R)	3	219.236	273.33	2.68	0.13	0.36	*
Time (T)	3	0.833	1.04	2.68	0.13	NS	NS
R × T	9	0.949	1.18	1.95	0.26	NS	NS
Temperature (Temp)	3	0.556	0.69	2.68	0.13	NS	NS
R × Temp	9	0.375	0.47	1.95	0.26	NS	NS
T × Temp	9	0.102	0.13	1.95	0.26	NS	NS
R × T × Temp	27	0.316	0.39	1.57	0.52	NS	NS
CV (%)	15.98						

4.6.6 Effect on crumb color of bread

The sensory scores for crumb color of bread varied from 2.67 to 8.33, 3 to 7.33, 3.00 to 7.33 and 4.00 to 8.67 for baking temperature 165, 180, 195 and 210 °C respectively (Fig. 4.22). As the level of sorghum flour increased the crumb color became darker. Abdelghafor *et al.* (2011) reported that the crumb color of the breads made with 5 and 10% substituted decorticated sorghum flour was similar to the control (100% wheat flour); whereas at higher levels of substitution, samples were significantly darker. These results are in agreement with those reported by Summer and Nielsen (1976), who concluded that incorporation of 20% sorghum flour in bread formulation darkened the internal loaf color i.e. crumb. The decreasing trend in the scores of crumb color were similar to that of pigeon pea husk bread prepared by Pawse (2009). Beswa (2008) also studied that higher temperature resulted in a smaller breads with thick crust and dark crumb color.

It can be seen from ANOVA that the processing parameters such as sorghum flour level, fermentation time and baking temperature had significant effect on crumb color of experimental bread at 5% level of significance, while effect of their interaction were found non-significant (Table 4.14).

Table 4.14: ANOVA for effect of sorghum flour level, fermentation time and baking temperature on crumb color of bread

SOURCE	D.F.	M.S.	F cal	F tab	SEm	CD (5%)	Test
Ratio (R)	3	128.479	224.25	2.68	0.11	0.31	*
Time (T)	3	17.396	30.36	2.68	0.11	0.31	*
R × T	9	2.836	4.95	1.95	0.22	0.61	*
Temperature (Temp)	3	0.701	1.22	2.68	0.11	NS	NS
R × Temp	9	0.141	0.25	1.95	0.22	NS	NS
T × Temp	9	1.058	1.85	1.95	0.22	NS	NS

R × T × Temp	27	0.485	0.85	1.57	0.44	NS	NS
CV (%)	13.43						

4.6.7 Effect on overall acceptability of bread

The sensory scores for overall acceptability of bread varied from 2.94 to 7.61, 3.39 to 7.50, 3.28 to 7.61 and 3.28 to 8.17 for baking temperature 165, 180, 195 and 210 °C respectively (Fig. 4.23). The overall acceptability was calculated as an average value of some important characteristics of sensory evaluation. As we increase the level of sorghum flour there was decrement in the overall acceptability of bread. Fermentation time and baking temperature also affect the overall acceptability of bread.

Result of overall acceptability was correlated with the data obtained by (Anglani, 1998; Carson *et al.*, 2000; Hugo *et al.*, 2000; Hugo *et al.*, 2003; Summer and Nielsen, 1976; Perten, 1977 and Taha, 2000). Aremu *et al.* (1995) also reported the organoleptic properties of bread of wheat flour of full fat or defatted fermented cocoa bean powder, the organoleptic acceptability dropped with increasing percentage of cocoa supplementation.

In this study, overall bread quality at the different levels of sorghum flours substitution was found to be acceptable. However, acceptability increased as the level of sorghum flour, decreased. Cardenas *et al.* (1993) and Abdel-Aal *et al.* (1993) also reported high acceptability of wheat breads as compared to composite breads.

It can be seen from ANOVA that the processing parameters such as sorghum flour level, fermentation time and baking temperature had significant effect on overall acceptability of experimental bread at 5% level of significance, while effect of their interaction were found non-significant (Table 4.15).

Table 4.15: ANOVA for effect of sorghum flour level, fermentation time and baking temperature on overall acceptability of bread

SOURCE	D.F.	M.S.	F cal	F tab	SEm	CD (5%)	Test
Ratio (R)	3	135.396	926.72	2.68	5.51	0.15	*
Time (T)	3	2.428	16.62	2.68	5.51	0.15	*
R × T	9	0.42	2.87	1.95	0.11	0.31	*
Temperature (Temp)	3	0.388	2.65	2.68	5.51	NS	NS
R × Temp	9	0.082	0.56	1.95	0.11	NS	NS
T × Temp	9	0.106	0.73	1.95	0.11	NS	NS
R × T × Temp	27	0.147	1.01	1.57	0.22	NS	NS
CV (%)	6.94						

Fig. 4. 22 crumb color

Fig. 4. 23 overall acceptability

4.7 Optimized technology for production of bread from wheat-sorghum composite flour

The effect of different sorghum flour level, fermentation time and baking temperature have been explained. To optimize the whole process of bread production, sensory characteristics of bread were considered. It was found sorghum flour incorporation into wheat flour is acceptable up to 30%. Bread prepared from composite flour of ratio 70:30 (wheat:sorghum) had maximum acceptability score (i.e. >5.00) while on increasing sorghum flour level more than 30%, product was not acceptable by sensory panel. The acceptable level of sorghum incorporation was again optimized with respect to baking parameters for maximum volume, weight, specific volume, height, overall acceptability and minimum firmness of the bread.

From the results discussed above in this chapter, the optimized conditions obtained were:

Sorghum flour level	: 30%
Fermentation time	: 75 min
Baking temperature	: 195 °C

Final optimized sample of composite bread was prepared employing the above mentioned optimized conditions. The physical, textural and organoleptic parameters of optimized bread is depicted in table 4.18.

Table 4.16: Physical, textural and organoleptic parameters of composite bread prepared using optimized condition

Volume	408.33 cm ³
Weight	179.94 g
Specific volume	2.27 cm ³ /g
Height	5.13 cm
Firmness	1486.10 g
Overall acceptability	5.44

CHAPTER V

SUMMARY AND CONCLUSION

Composite flours are extensively used in the bakery industry to develop designer food products, having specific nutritional or functional properties. The major or mandatory ingredients in bread making are flour, water and yeast. Due to the high cost, geographical scarcity and high demand of wheat flour, efforts are being directed toward the provision of alternative source of flour. The present investigation was undertaken to substitute wheat flour with underutilized millet, sorghum. Challenges and opportunities of minor cereals with poor viscoelastic value deserve a special attention in bread making applications due to their unique nutritional components.

Sorghum is a potentially important source of nutraceuticals such as antioxidant phenolics and cholesterol-lowering waxes. It is also a rich source of B-complex vitamins. Wheat flour was substituted by sorghum flour in four different combinations. The developed composite flour was analyzed for bio-chemical, physical and rheological parameters in order to study the impact of sorghum flour incorporation on characteristics of composite flour and dough. They are of importance in terms of product formulation and optimization, quality control, machining properties of the dough, scale-up of the process and automation. The quality of the bread made up from composite flour was also affected by technological parameter like fermentation time and baking temperature. This was aimed to give relevant information to food processors and nutritionists to formulate commercial products based on wheat-sorghum blends.

With a view to develop a comprehensive technology for the production of acceptable quality wheat – sorghum composite bread, a research project was undertaken with following objectives;

- To study proximate chemical composition of composite flour
- To study the physico-chemical and rheological properties of composite flour and dough
- Optimization of baking parameters for development of bread from composite flour
- To study organoleptic, physical and bio-chemical quality of the bread prepared from composite flour

Refined wheat flour, sorghum flour and their blends i.e. 100% refined wheat flour (RWF), 100% sorghum flour (SF), RWF:SF = 80:20, 70:30, 60:40 and 50:50; were analyzed for bio-chemical, physico-chemical and rheological properties. Bread was prepared by sponge and dough method with varying fermentation time (45, 55, 65,

and 75min) and baking temperature (165, 180, 195 and 210 °C). The quality of bread prepared from composite flour blends was also evaluated. The above parameters were optimized for the acceptable quality of bread from composite flour with respect to different fermentation time and baking temperature.

The following conclusions could be drawn from the present investigation:

1. The flour blends significantly affected the chemical, physical and rheological properties of composite flour and dough made up.
2. The moisture content, protein content and fiber content of the composite flour were decreased significantly, on increasing the proportion of sorghum incorporated in the composite flour.
3. Fat content, carbohydrate and ash content increased significantly with increasing the proportion of sorghum incorporated.
4. Wet and dry gluten contents, sedimentation value, water absorption capacity, bulk density and tap bulk density of composite flour decreased significantly on increasing the proportion of sorghum incorporated in the composite flour.
5. The apparent porosity increased significantly on increasing the proportion of sorghum incorporated in the blends.
6. Rheological measures made with the texture analyzer showed that the extensibility decreased and the resistance to extension increased on increasing the proportion of sorghum incorporated in the blend.
7. The dough was prepared from composite flour (RWF:SF = control, 80:20, 70:30 and 60:40) and was fermented for different time interval (45, 55, 65 and 75 min). The dough pieces were then baked (165, 180, 195 and 210 °C). The prepared bread was analyzed for physical, textural and organoleptic quality.
8. The sorghum flour level in composite flour, fermentation time, baking temperature and their interaction had significant effect on volume of bread. The volume of bread varied from 376.67-526.67 cm³, 393.33-538.33 cm³, 393.33-548.33 cm³ and 376.67-548.33 cm³ at 165, 180 195 and 210 °C respectively.
9. It was found that for control bread highest volume (548.33 cm³) achieved at 75 min fermentation and 210 °C baking. For bread with 80:20 ratio of RWF and SF, highest volume (481.67 cm³) was attained at 75 min fermentation and 210 °C baking. For bread with 70:30 ratio, highest volume (438.33 cm³) was attained at 65 min fermentation and 180 °C baking. For bread with 60:40 ratio, highest volume (451.67 cm³) was attained at 45 min fermentation and 210 °C baking.

10. The sorghum flour level in composite flour, fermentation time and their interactions had significant effect on weight of bread, while baking temperature had non-significant effect. The weight of bread was varied from 167.84-182.90 g, 166.78-184.84 g, 172.99-180.26 g and 170.79-180.61 g at 165, 180 195 and 210 °C respectively.
11. It was found that for control bread highest weight (180.61 g) achieved at 75 min fermentation and 210 °C baking. For bread with 80:20 ratio of RWF and SF, highest weight (182.90 g) was attained at 45 min fermentation and 165 °C baking. For bread with 70:30 ratio, highest weight (184.84 g) was attained at 55 min fermentation and 185 °C baking. For bread with 60:40 ratio, highest weight (182.04 g) was attained at 65 min fermentation and 180 °C baking.
12. The sorghum flour level in composite flour, fermentation time, baking temperature and their interaction had significant effect on specific volume of bread. The specific volume of bread was varied from 2.13-3.14 cm³/g, 2.18-3.06 cm³/g, 2.22-3.06 cm³/g and 2.11-3.13 cm³/g at 165, 180 195 and 210 °C respectively.
13. It was found that for control bread highest specific volume (3.14 cm³/g) achieved at 75 min fermentation and 165 °C baking. For bread with 80:20 ratio of RWF and SF, highest specific volume (2.71 cm³/g) was attained at 65 min fermentation and 210 °C baking. For bread with 70:30 ratio, highest specific volume (2.44 cm³/g) was attained at 75 min fermentation and 165 °C baking. For bread with 60:40 ratio, highest specific volume (2.53 cm³/g) was attained at 45 min fermentation and 210 °C baking.
14. The sorghum flour level in composite flour, fermentation time, baking temperature and their interaction had significant effect on height of bread. The height of bread was varied from 4.37-6.33 cm, 4.77-6.23 cm, 4.70-6.53 cm and 4.47-6.77 cm at 165, 180 195 and 210 °C respectively.
15. It was found that for control bread highest height (6.77 cm) achieved at 75 min fermentation and 210 °C baking. For bread with 80:20 ratio of RWF and SF, highest height (6.33 cm) was attained at 65 min fermentation and 210 °C baking. For bread with 70:30 ratio, highest height (5.77 cm) was attained at 65 min fermentation and 180 °C baking. For bread with 60:40 ratio, highest height (5.33 cm) was attained at 65 min fermentation and 210 °C baking.

16. The sorghum flour level in composite flour, baking temperature and their interaction had significant effect on firmness of bread, while fermentation time did not affect significantly. The firmness of bread was varied from 978.92-1638.26 g, 980.65-1766.56 g, 958.68-1725.76 g and 913.01-1828.40 g at 165, 180 195 and 210 °C respectively.
17. It was found that for control bread lowest firmness (913.01 g) achieved at 75 min fermentation and 210 °C baking. For bread with 80:20 ratio of RWF and SF, lowest firmness (1051.53 g) was attained at 75 min fermentation and 210 °C baking. For bread with 70:30 ratio, lowest firmness (1437.73 g) was attained at 75 min fermentation and 165 °C baking. For bread with 60:40 ratio, lowest firmness (1542.56 g) was attained at 75 min fermentation and 180 °C baking.
18. Processing parameters such as sorghum flour level, baking temperature and fermentation time had significant effect on organoleptic properties of bread, while their interaction did not affect these properties significantly.
19. The highest scores of crust color (8.67), shape and bake (6.67), texture (8.67), grain structure (8.33), taste and aroma (8.67), crumb color (8.67) and overall acceptability (8.17) of bread was found for control bread when fermented 75 at min and baked at 210 °C, while the lowest score (2.67, 2.67, 2.33, 2.33, 2.67, 2.67 and 2.94 respectively) was for bread prepared with flour composition 60:40 ratio when fermented at 45 min and baked at 165 °C
20. The acceptable level of sorghum flour incorporation into wheat flour is 30%. The overall acceptability of wheat-sorghum composite bread was 5.44, when the dough fermented at 75 min and baked at 195 °C.
21. From the present study, it can be concluded that sorghum represents the feasible ingredient in manufacturing of composite bread. Incorporation of sorghum in composite flour improves the bread quality in terms of its nutritional value and organoleptically acceptable bread could be formulated with 70:30 ratio of wheat-sorghum flour.

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APPENDIX - I

SENSORY EVALUATION SCORE CARD FOR WHEAT-SORGHUM COMPOSITE BREAD

Name:

Date:

Characteristic	Possible Score	Sample Score			
		1	2	3	4
Crust Color	10				
Shape & Bake	10				
Texture	10				
Grain	10				
Taste & Aroma	10				
Crumb Color	10				
Overall Acceptability	10				

Characteristic	Crust Color	Bake & Shape	Texture & Grain	Taste & Aroma	Crumb Color
Desirable	Golden brown, smooth	Even baking, proper Shape	Soft, silky but firm smooth grain	Normal, pleasant	Creamish white
Undesirable	Brownish white or dark, rough	Dark or light in top relation to rest of the crust, improper shape	Cheesy, drummy, coarse	Off flavor, off taste	Brown, dark brown

Sensory Score Rating	
10	Excellent
9	Best
8	Very good
7	Good
6	Satisfactory
5	Intermediate
4	Fair
3	Poor
2	Very poor
1	Worst

Comments:

Sign

APPENDIX - II

Bio-chemical characteristics of refined wheat flour, sorghum flour and their blends

Properties (%)	RWF	20% SF	30% SF	40% SF	50% SF	SF	F Cal	SEm	CD (5%)	CV (%)	Test
Moisture content	13.18	11.94	11.16	10.82	9.66	9.50	185.34	0.10	0.32	1.60	*
Protein	15.30	14.58	14.17	13.81	13.33	12.33	137.98	0.09	0.27	1.09	*
Fat	3.07	3.13	3.22	3.37	3.56	3.92	189.26	0.02	0.07	1.18	*
Carbohydrate	63.56	65.62	67.03	67.70	69.24	69.64	193.32	0.16	0.51	0.42	*
Ash	1.06	1.35	1.34	1.45	1.59	2.10	180.42	0.03	0.08	3.03	*
Fibre	3.83	3.37	3.08	2.84	2.63	2.52	214.56	0.03	0.10	1.90	*

RWF = Refined wheat flour, SF = Sorghum flour

APPENDIX - III

Physico-chemical characteristics of refined wheat flour, sorghum flour and their blends

Properties	RWF	20% SF	30% SF	40% SF	50% SF	SF	F Cal	SEm	CD (5%)	CV (%)	Test
Wet gluten (%)	57.58	39.43	26.50	19.57	12.33	0.00	2473.74	0.41	1.26	2.74	*
Dry gluten (%)	32.07	16.96	11.63	4.73	2.73	0.00	292.13	0.70	2.15	10.62	*
SV (ml)	22.64	20.28	19.15	18.31	17.45	15.43	77.77	0.28	0.86	2.56	*
WAC (%)	112.00	80.33	78.00	71.33	67.67	63.67	355.45	0.92	2.84	2.02	*
BD (g/ml)	0.53	0.42	0.40	0.36	0.31	0.26	53.99	0.01	0.04	5.96	*
Tap BD (g/ml)	1.67	1.48	1.37	1.24	1.06	0.93	129.35	0.02	0.07	3.22	*
AP (%)	0.68	0.71	0.71	0.71	0.71	0.72	1.82	0.01	NS	2.55	NS

RWF = Refined wheat flour, SF = Sorghum flour

SV = sedimentation value, WAC = water absorption capacity, BD = Bulk density, Tap BD = Tap bulk density, AP = Apparent porosity

APPENDIX - IV

Rheological characteristics of refined wheat flour, sorghum flour and their blends

Properties	RWF	20% SF	30% SF	40% SF	50% SF	SF	F Cal	SEm	CD (5%)	CV (%)	Test
Resistance to extension (g)	14.30	18.80	22.37	22.38	30.74	40.41	105.0 7	0.91	2.81	6.36	*
Extensibility (mm)	17.21	12.63	9.82	6.93	3.30	2.89	194.4 2	0.40	1.23	7.87	*

RWF = Refined wheat flour, SF = Sorghum flour

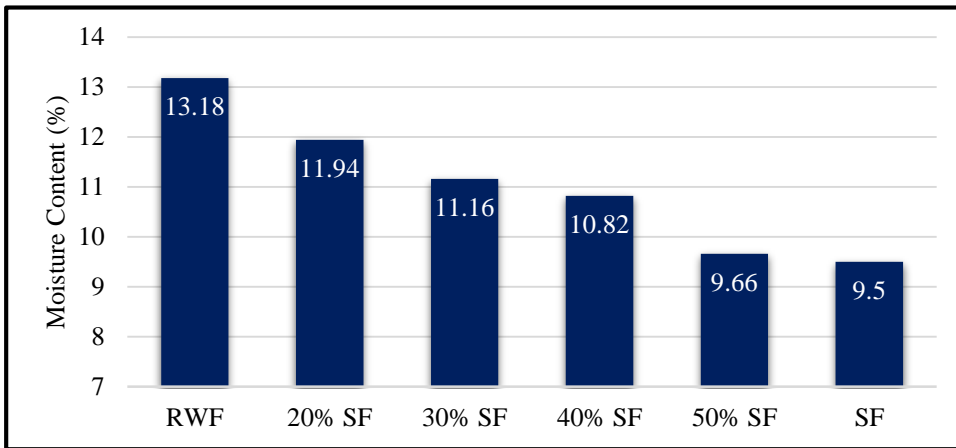


Fig. 4.1: Effect of sorghum flour level on moisture content

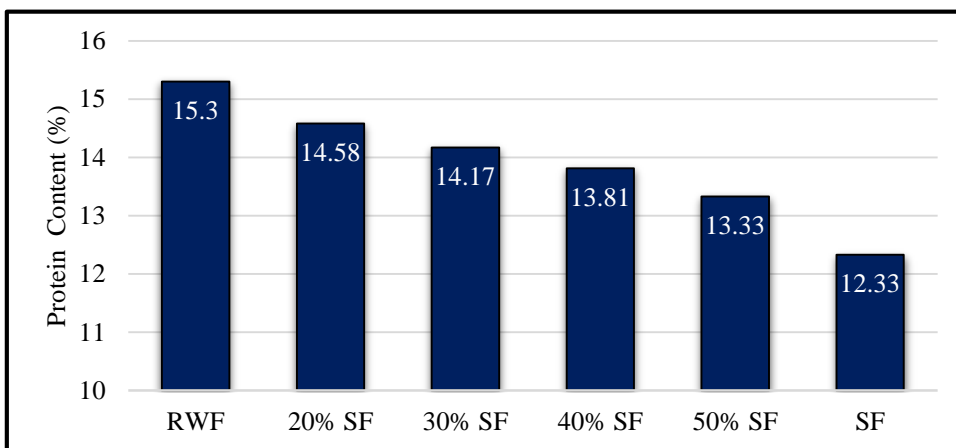


Fig. 4.2: Effect of sorghum flour level on protein content

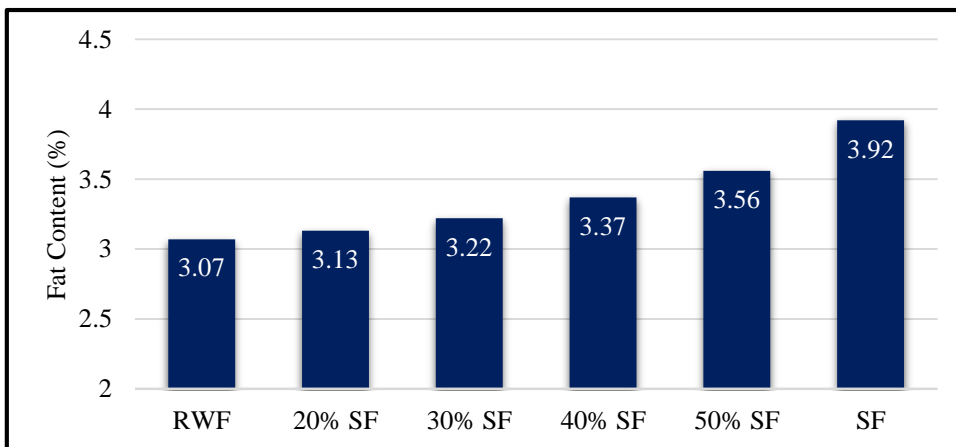


Fig. 4.3: Effect of sorghum flour level on fat content

RWF = Refined Wheat Flour, SF = Sorghum Flour

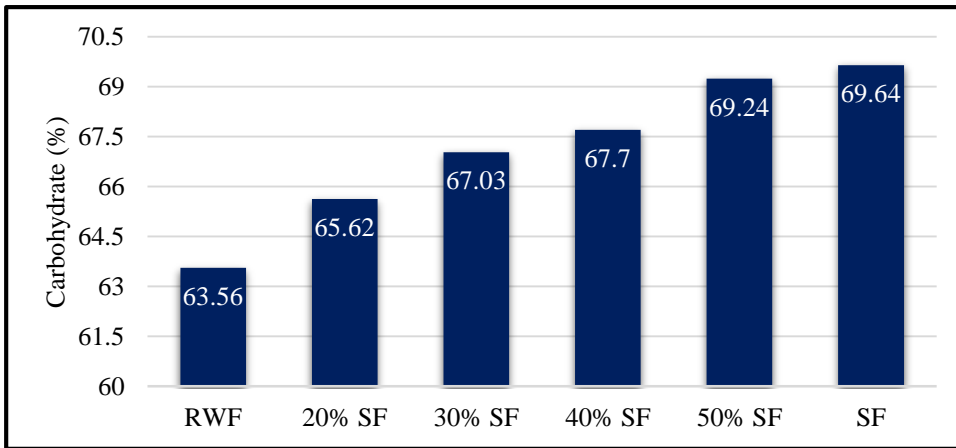


Fig. 4.4: Effect of sorghum flour level on carbohydrate

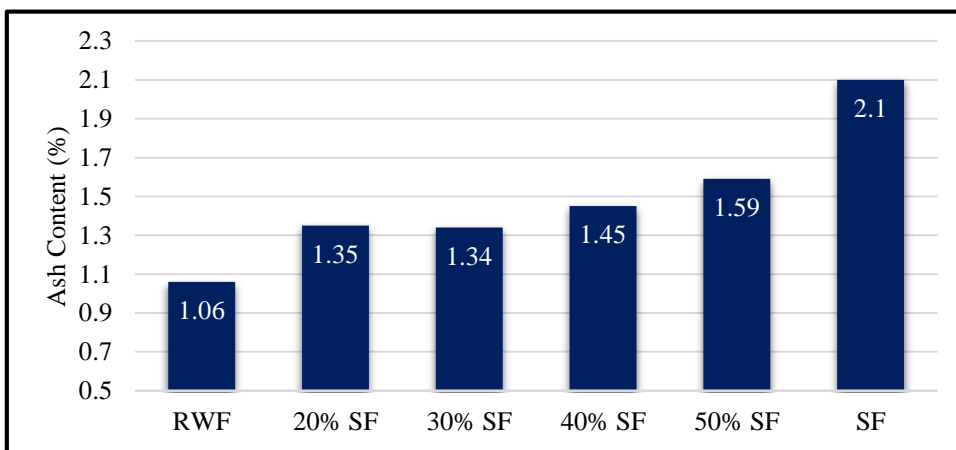


Fig. 4.5: Effect of sorghum flour level on ash content

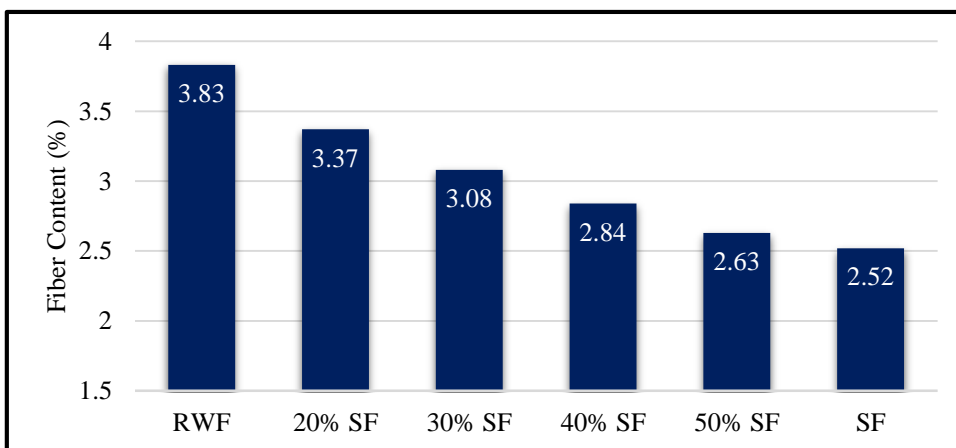


Fig. 4.6: Effect of sorghum flour level on fiber content

RWF = Refined Wheat Flour, SF = Sorghum Flour

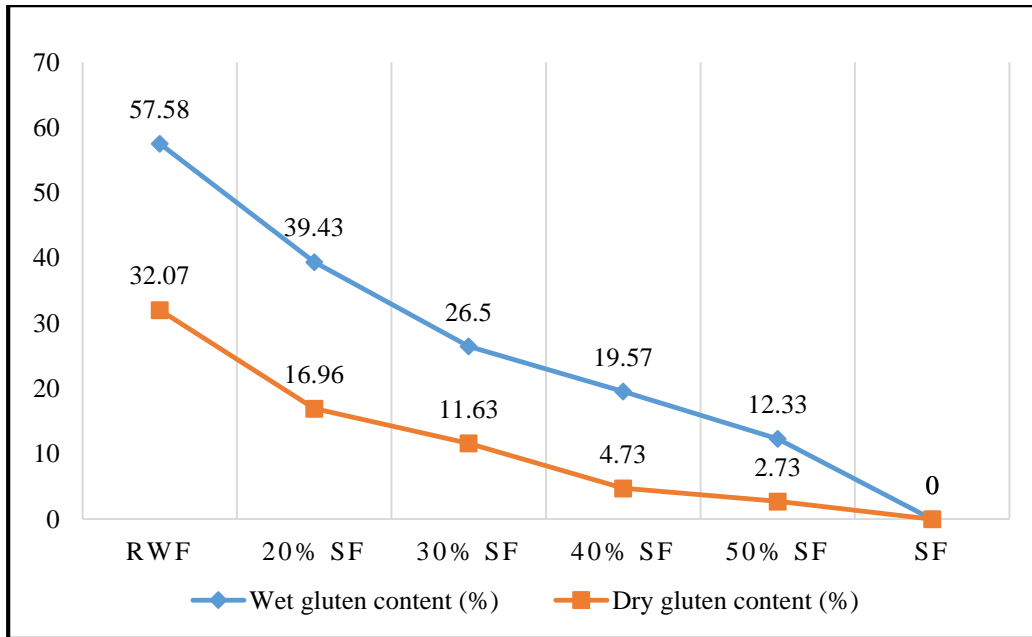


Fig. 4.7: Effect of sorghum flour level on wet & dry gluten content

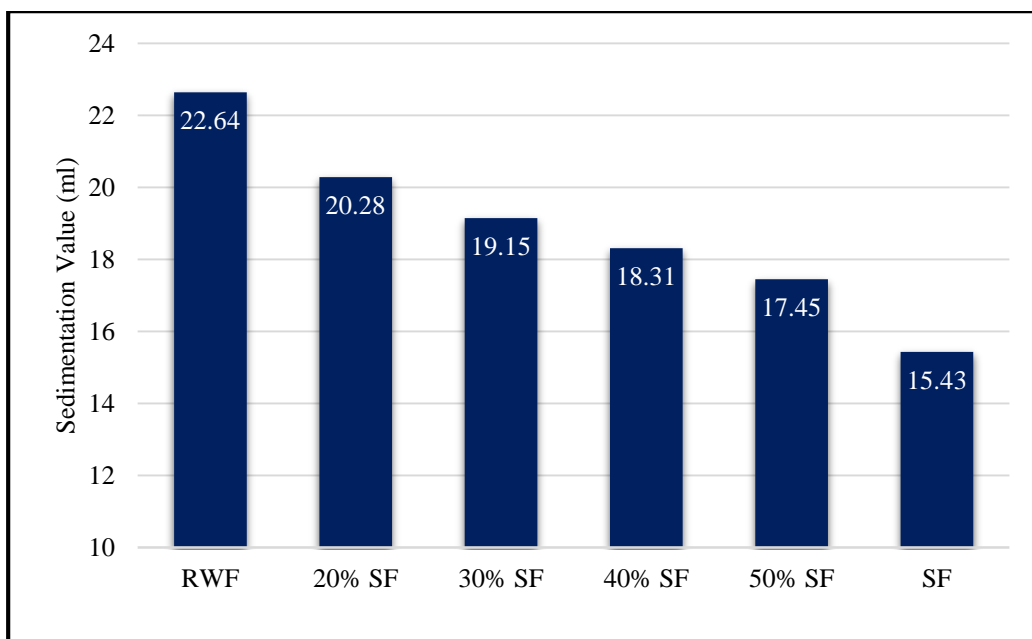


Fig. 4.8: Effect of sorghum flour level on sedimentation value

RWF = Refined Wheat Flour, SF = Sorghum Flour

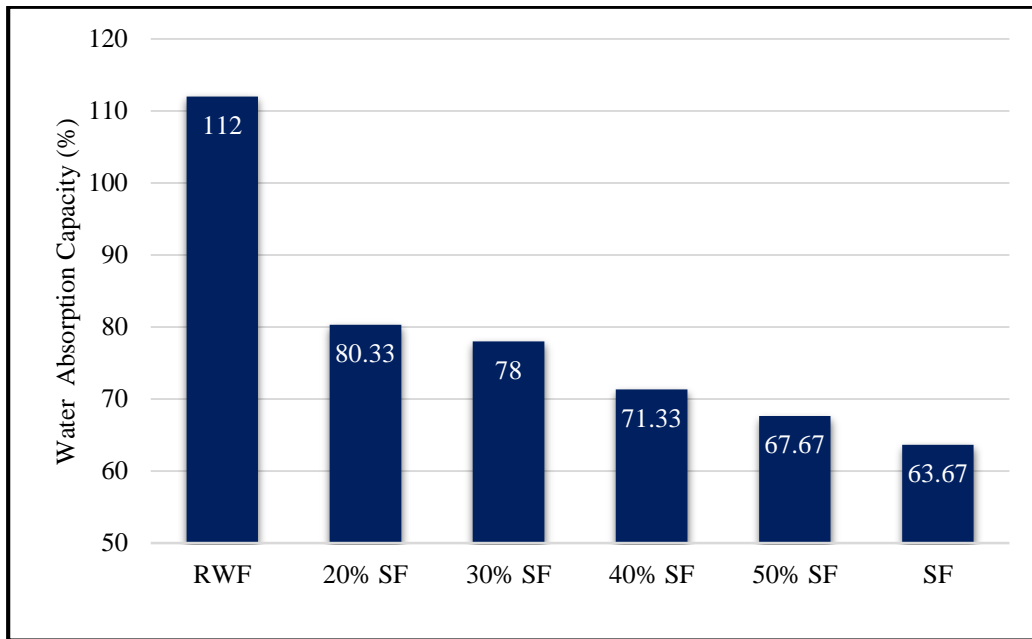


Fig. 4.9: Effect of sorghum flour level on water absorption capacity

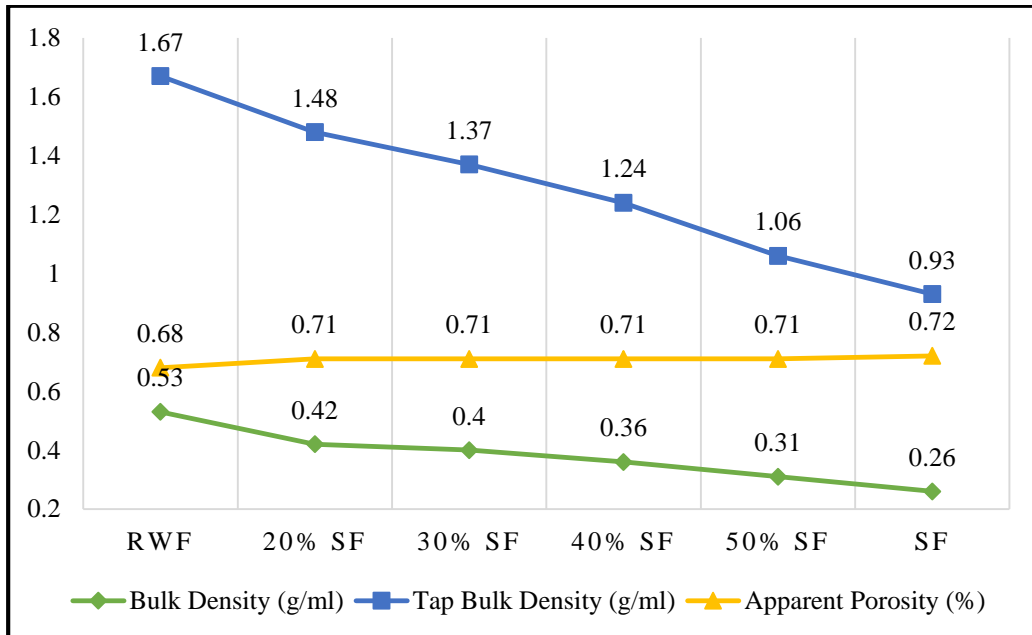


Fig. 4.10: Effect of sorghum flour level on bulk density, tap bulk density and apparent porosity

RWF = Refined Wheat Flour, SF = Sorghum Flour

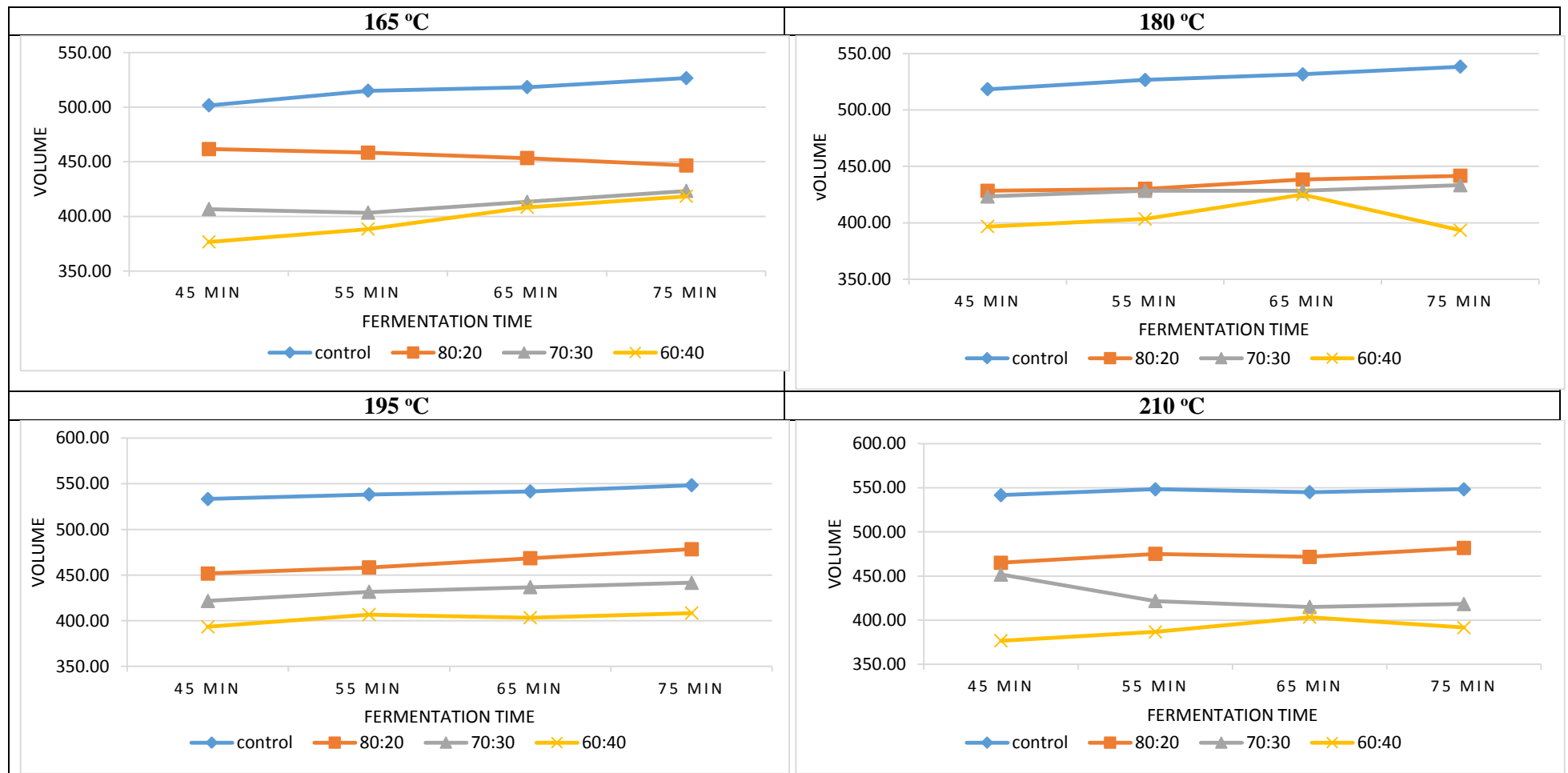


Fig. 4.12: Effect of sorghum flour level, fermentation time and baking temperature on volume of bread (cm³)

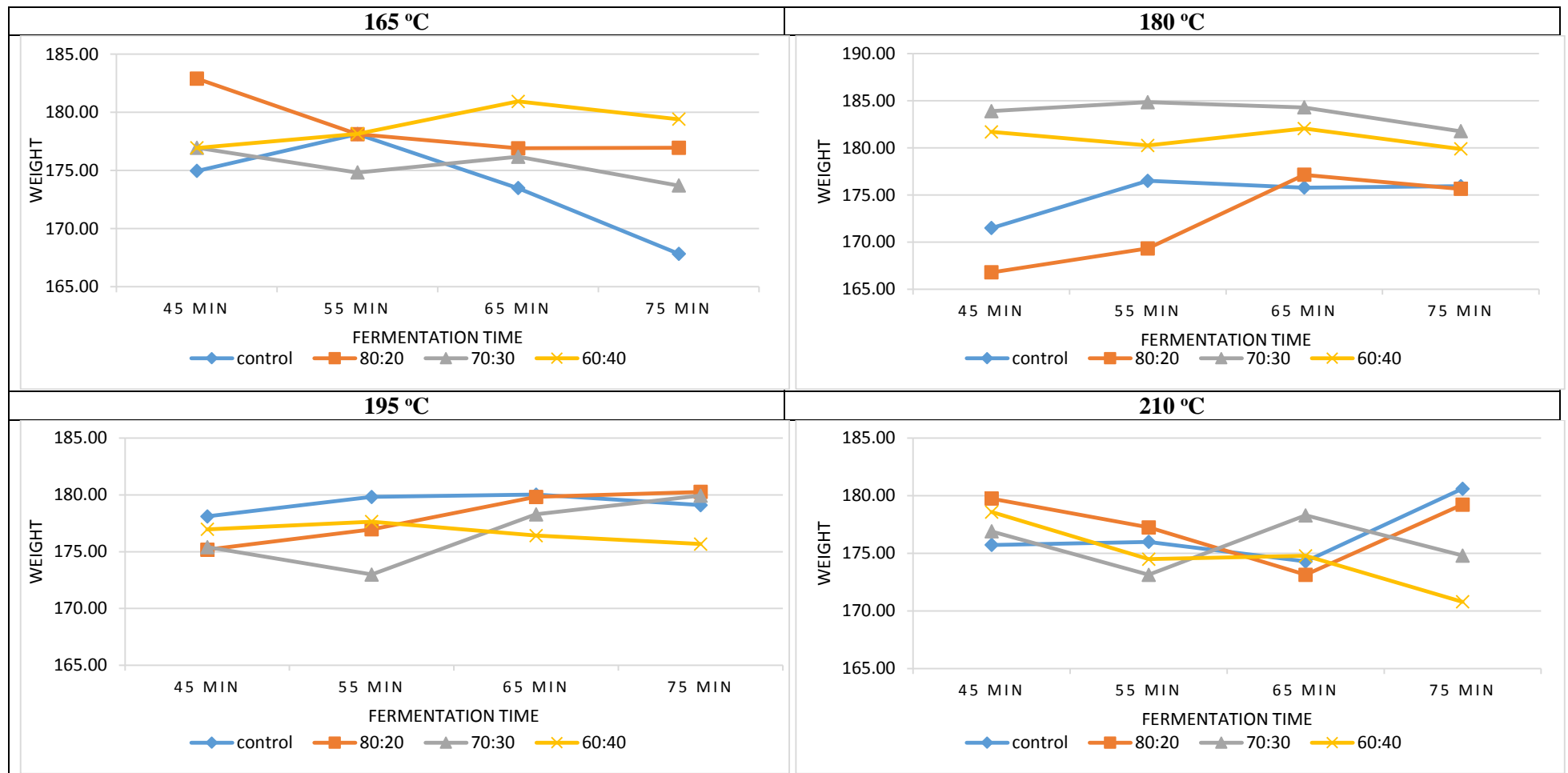


Fig. 4.13: Effect of sorghum flour level, fermentation time and baking temperature on weight of bread (g)

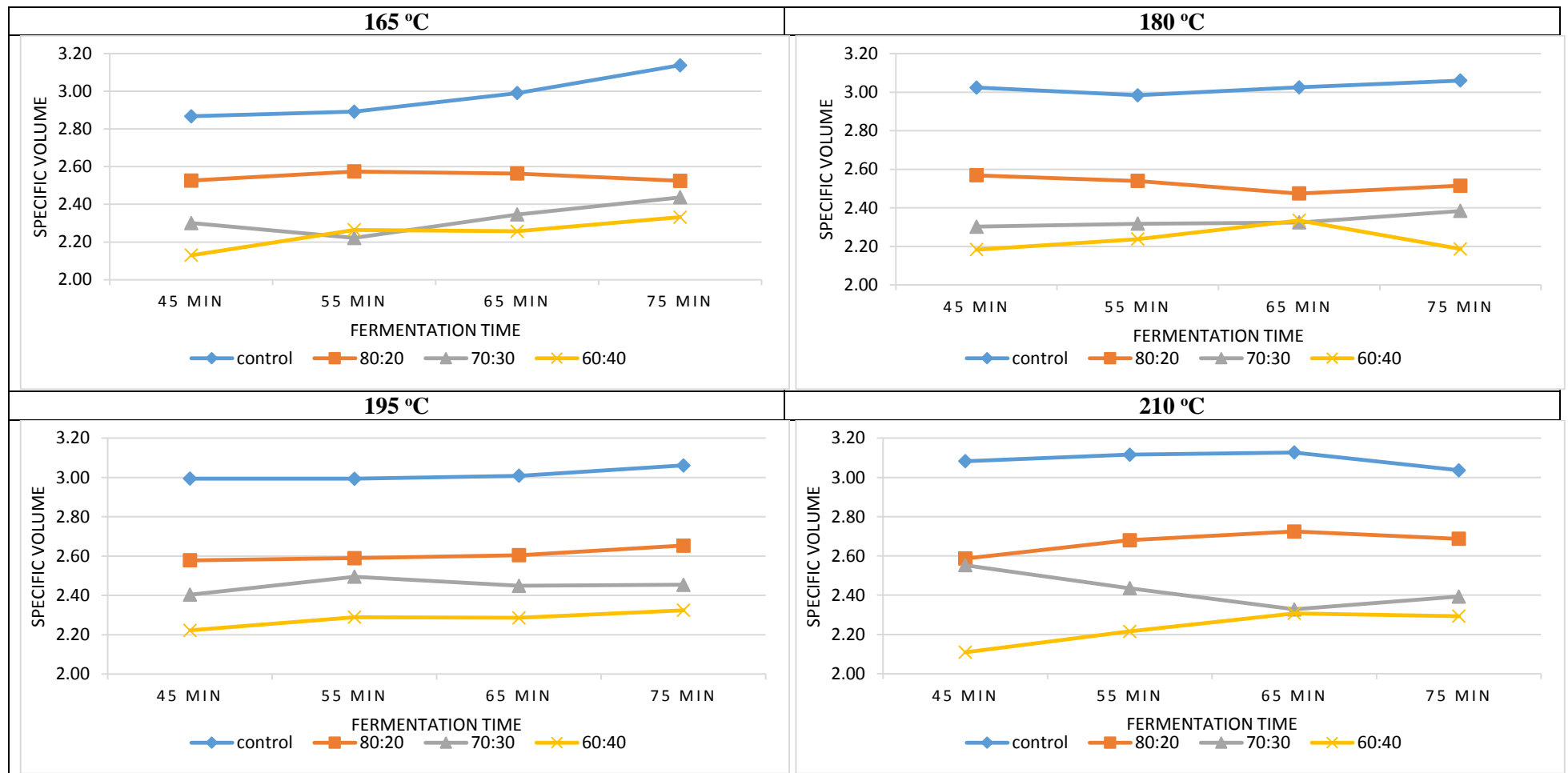


Fig. 4.14: Effect of sorghum flour level, fermentation time and baking temperature on specific volume of bread (cm³/g)

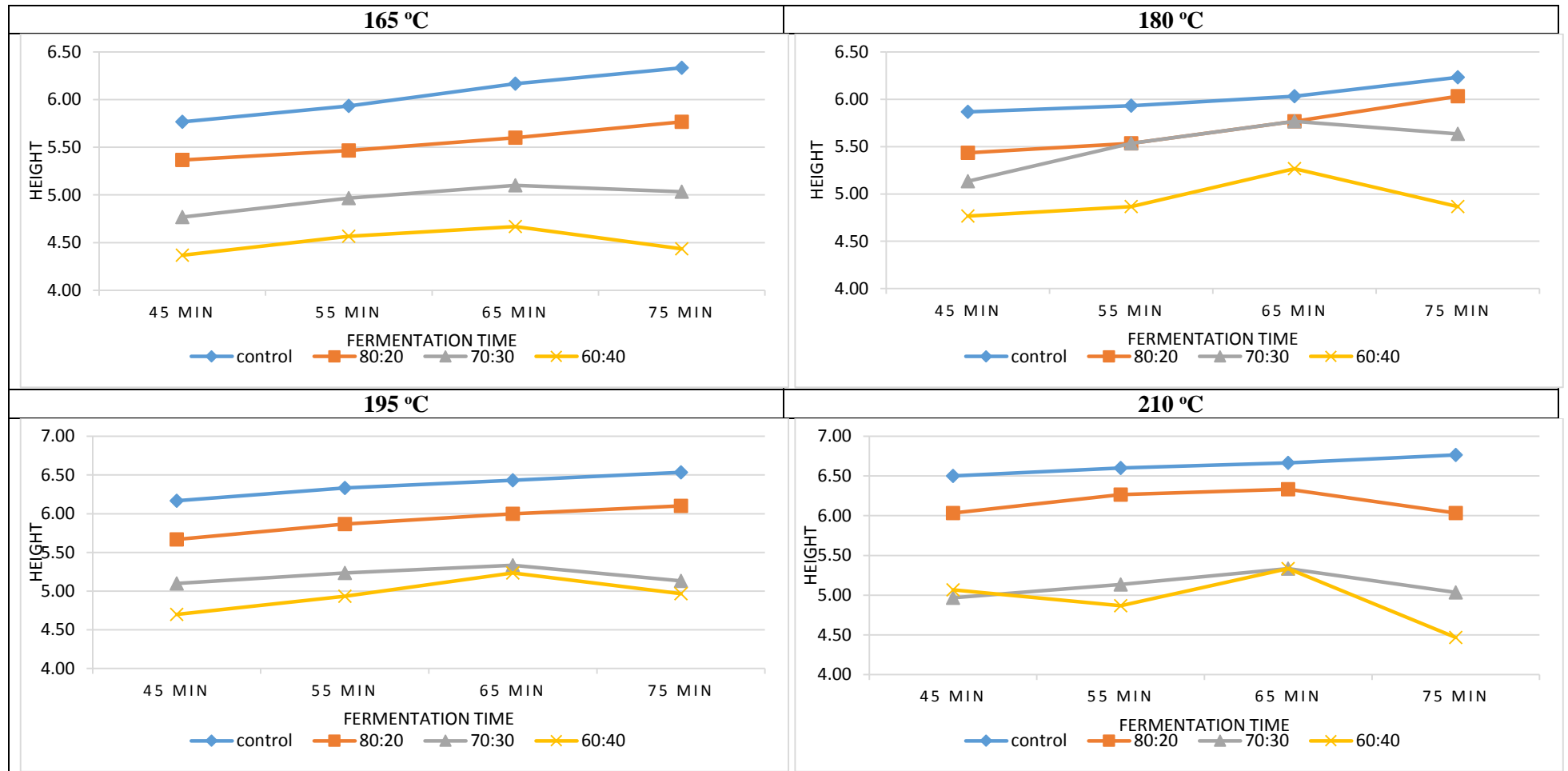


Fig. 4.15: Effect of sorghum flour level, fermentation time and baking temperature on height of bread (cm)

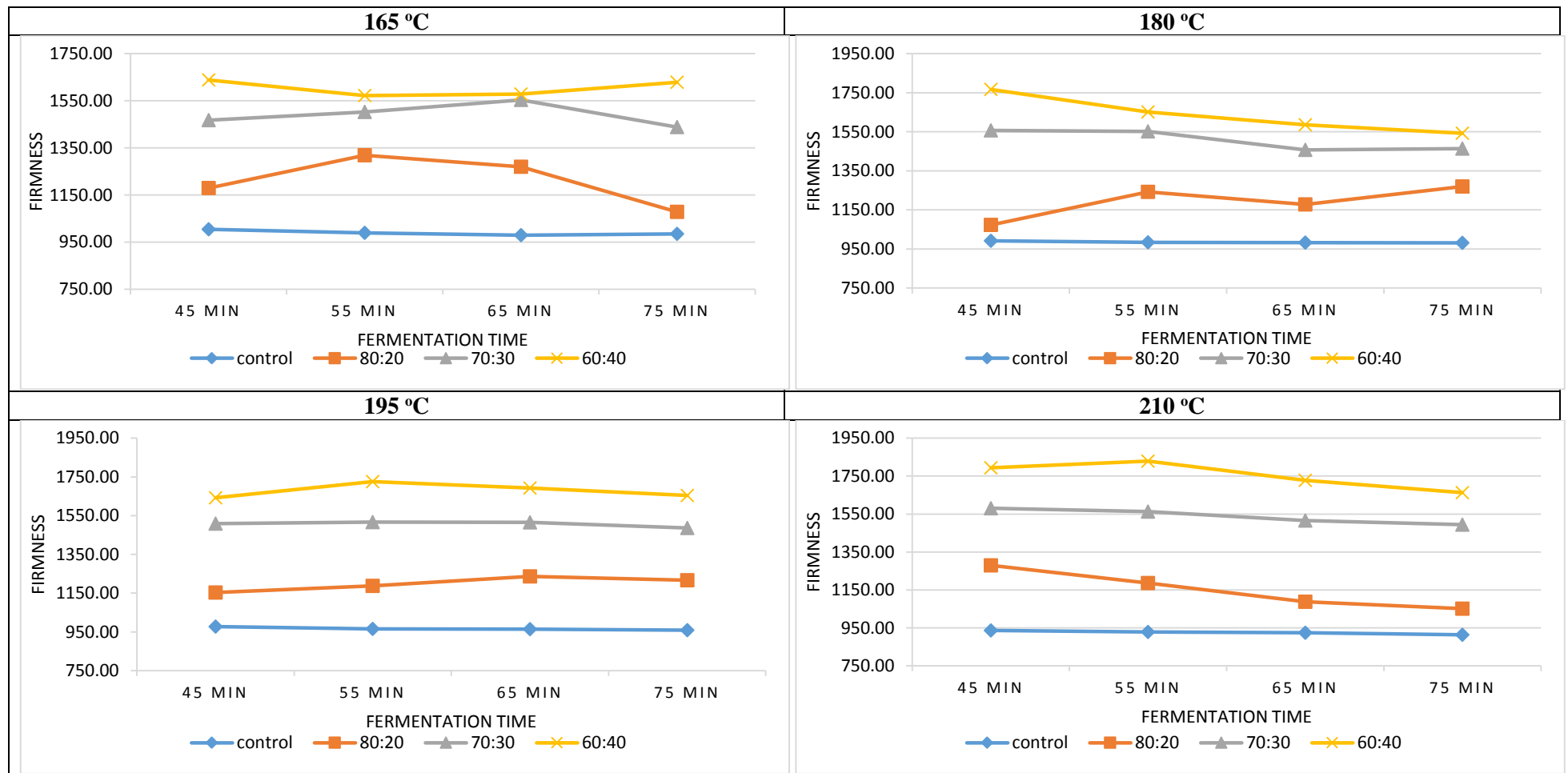


Fig. 4.16: Effect of sorghum flour level, fermentation time and baking temperature on firmness of bread (g)

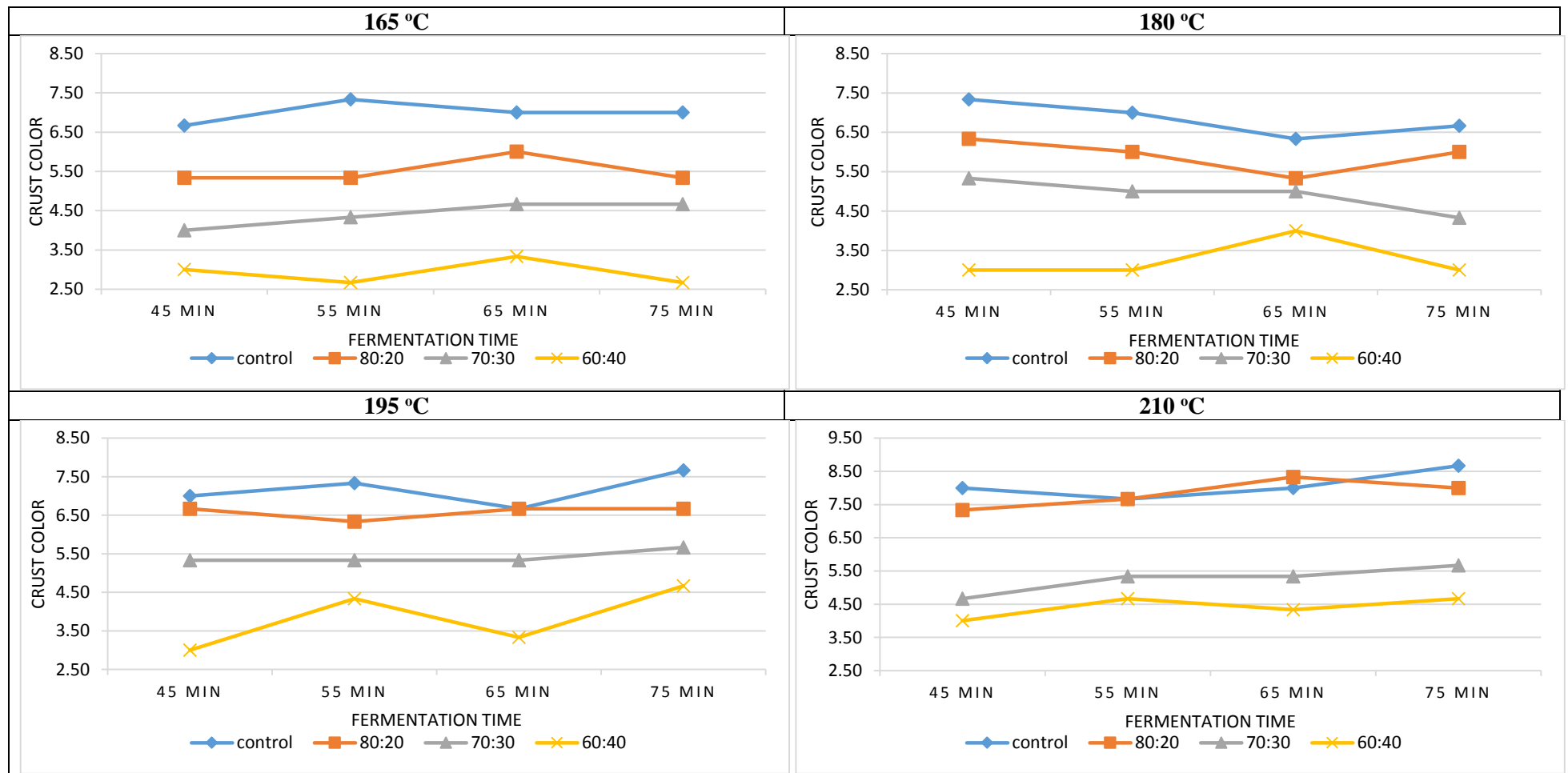


Fig. 4.17: Effect of sorghum flour level, fermentation time and baking temperature on crust color of bread

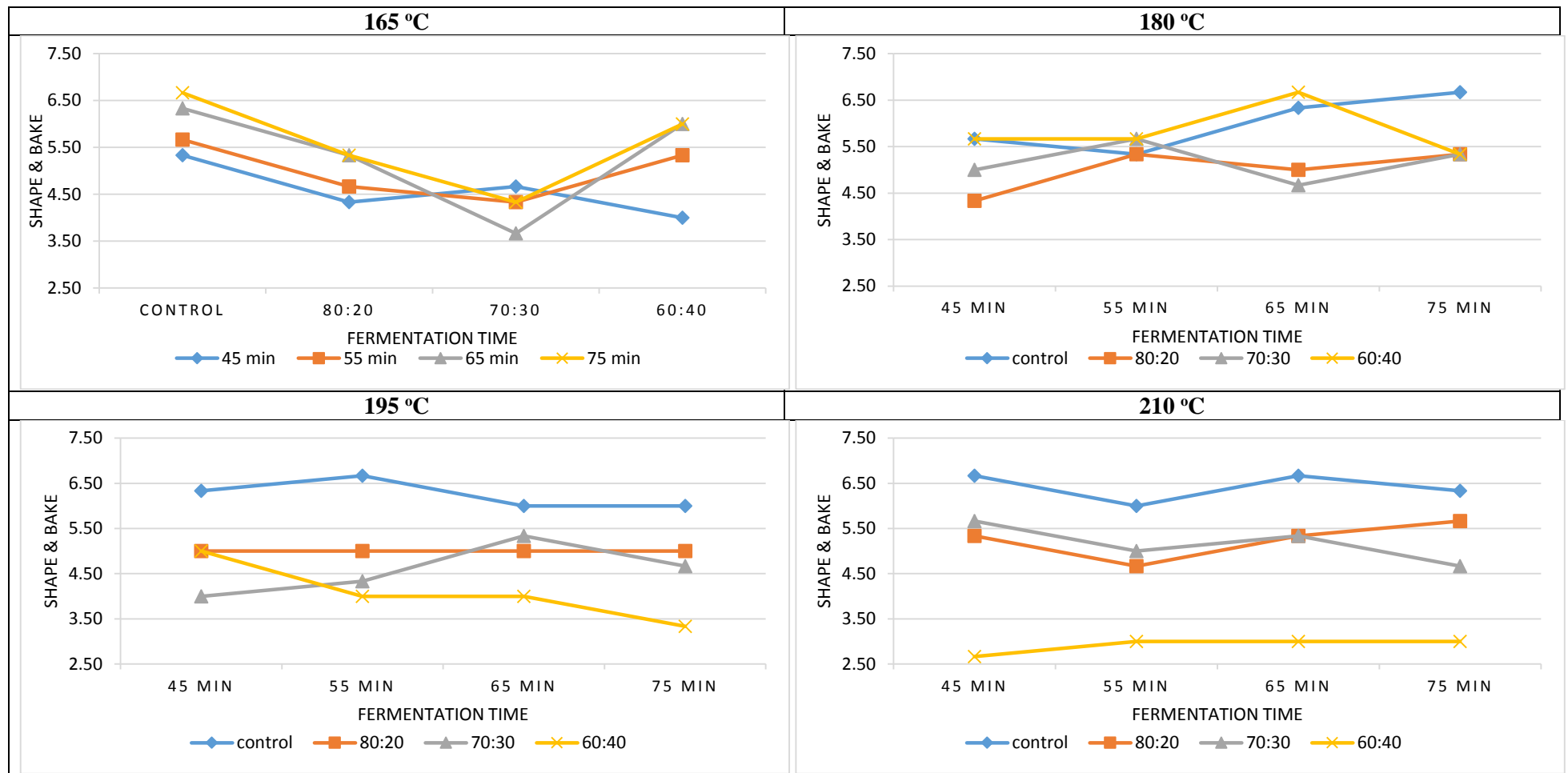


Fig. 4.18: Effect of sorghum flour level, fermentation time and baking temperature on shape and bake of bread

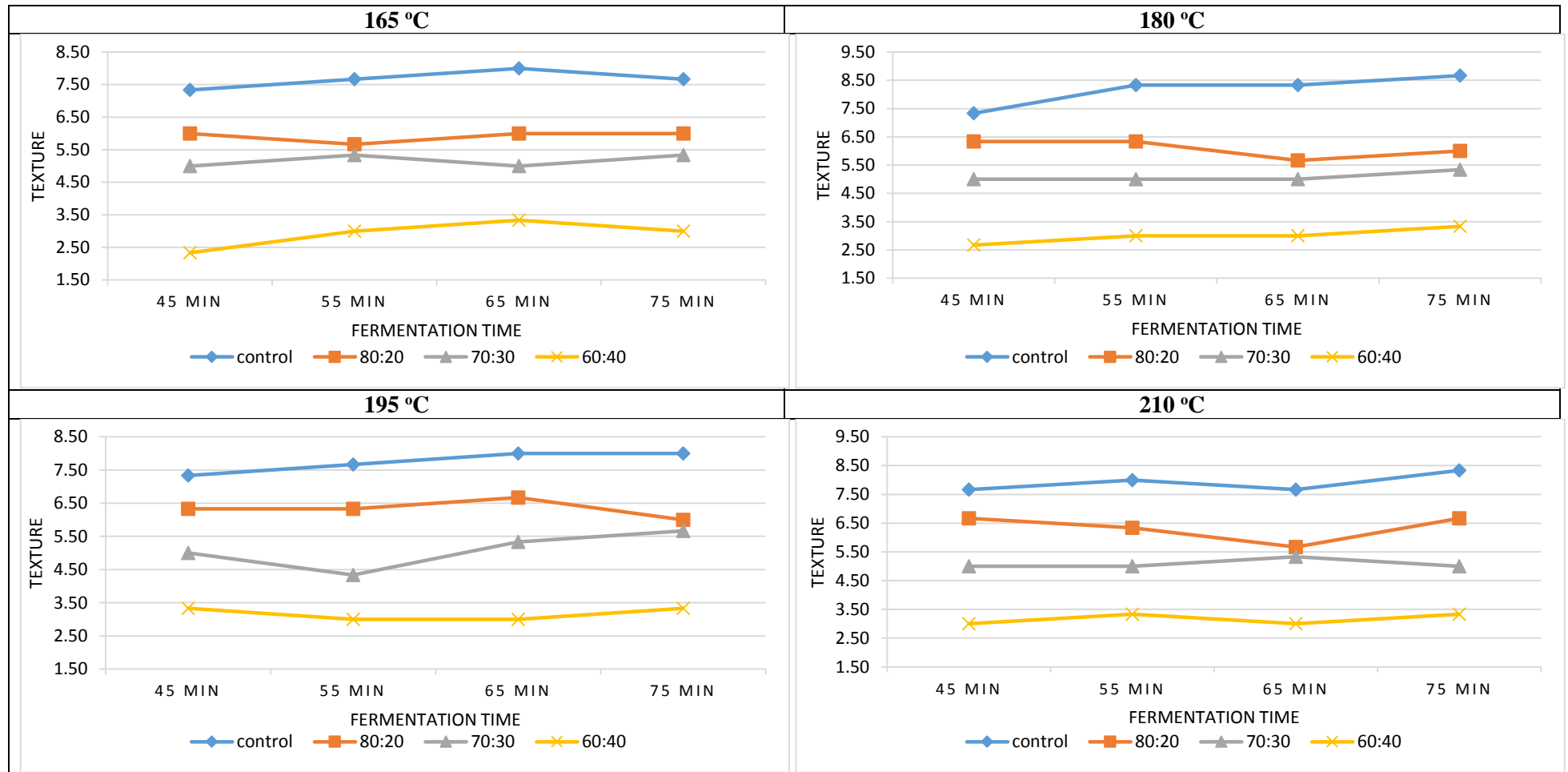


Fig. 4.19: Effect of sorghum flour level, fermentation time and baking temperature on texture of bread

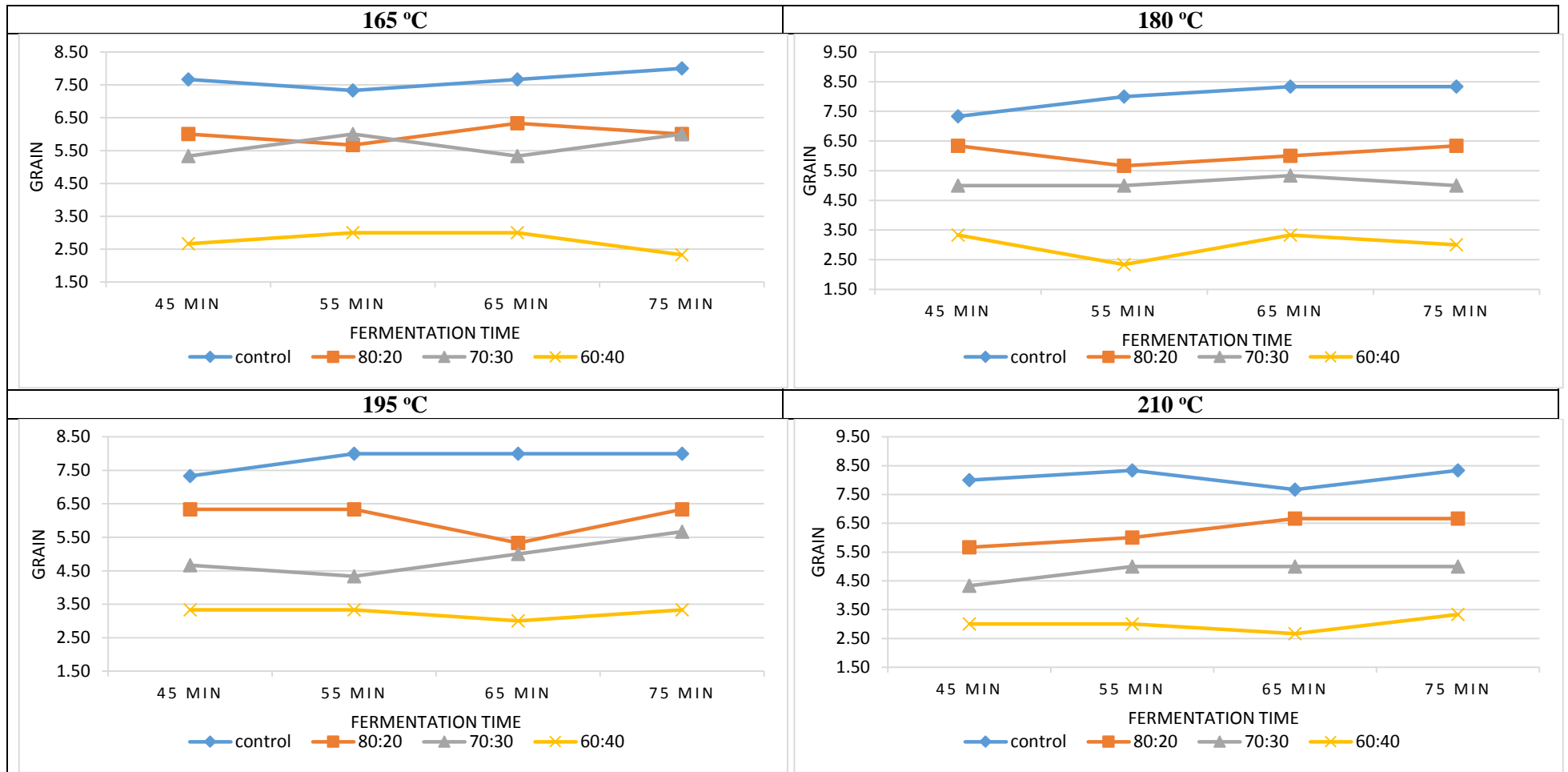


Fig. 4.20: Effect of sorghum flour level, fermentation time and baking temperature on grain structure of bread

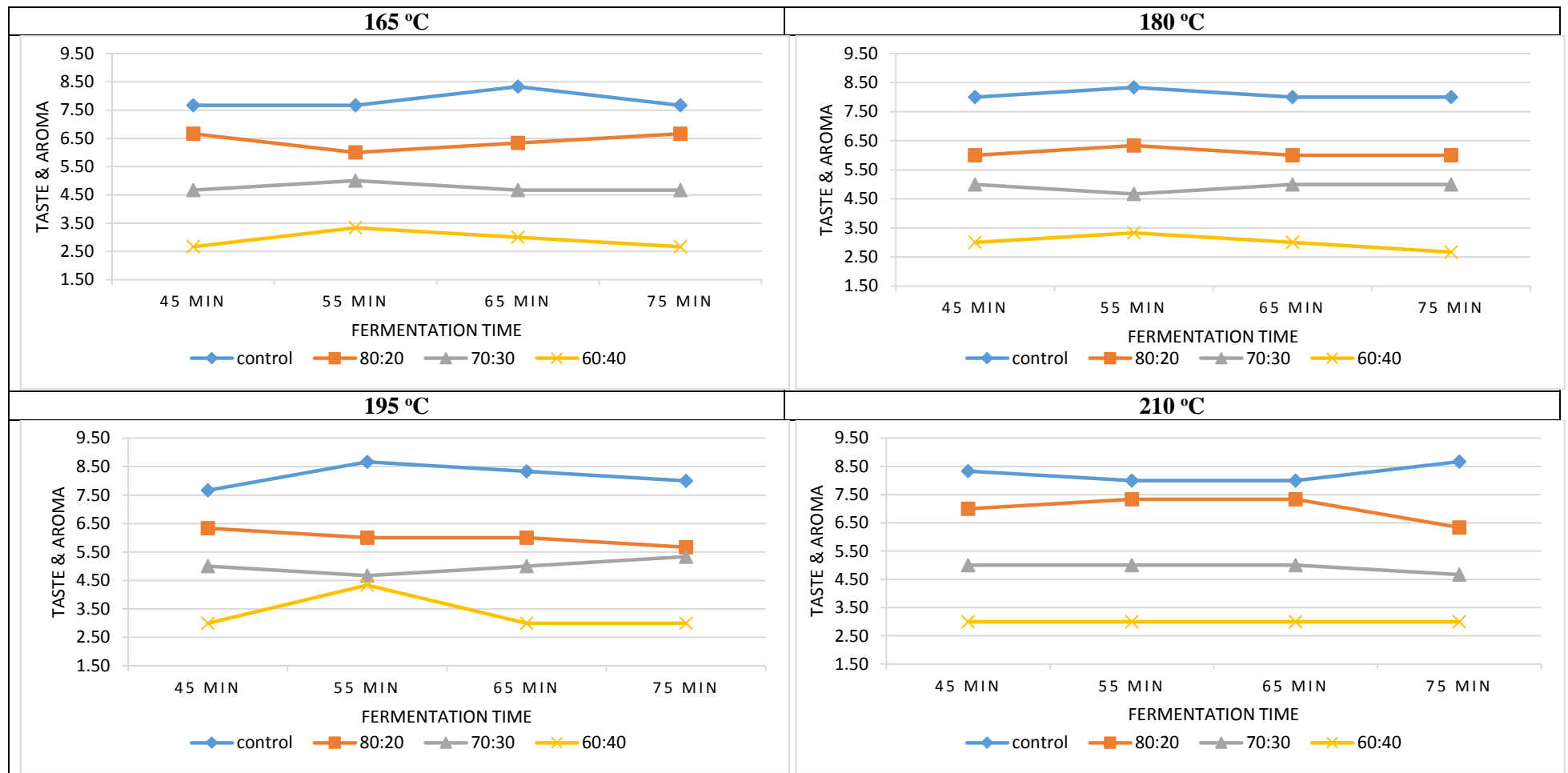


Fig. 4.21: Effect of sorghum flour level, fermentation time and baking temperature on taste and aroma of bread

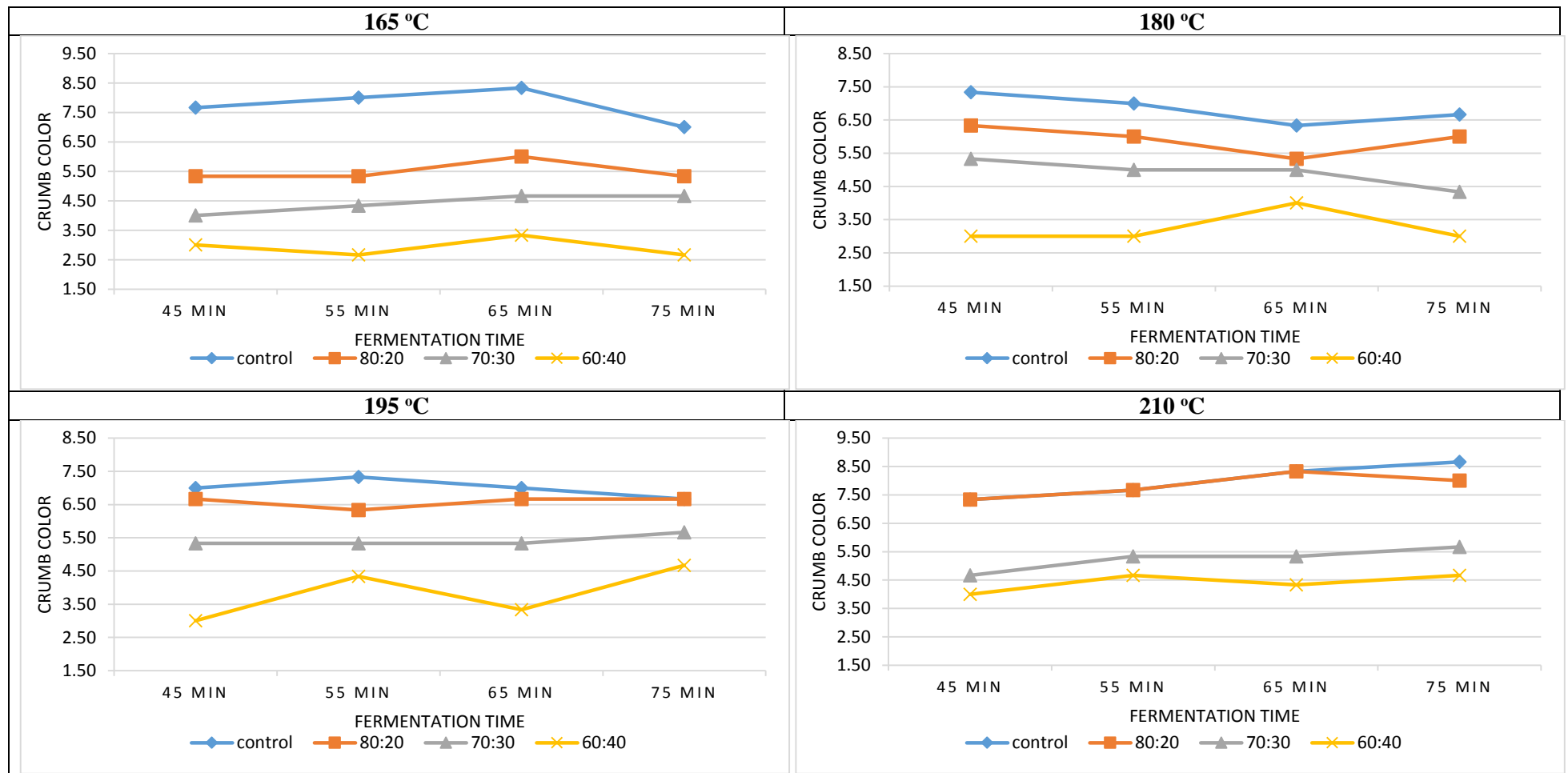


Fig. 4.22: Effect of sorghum flour level, fermentation time and baking temperature on crumb color of bread

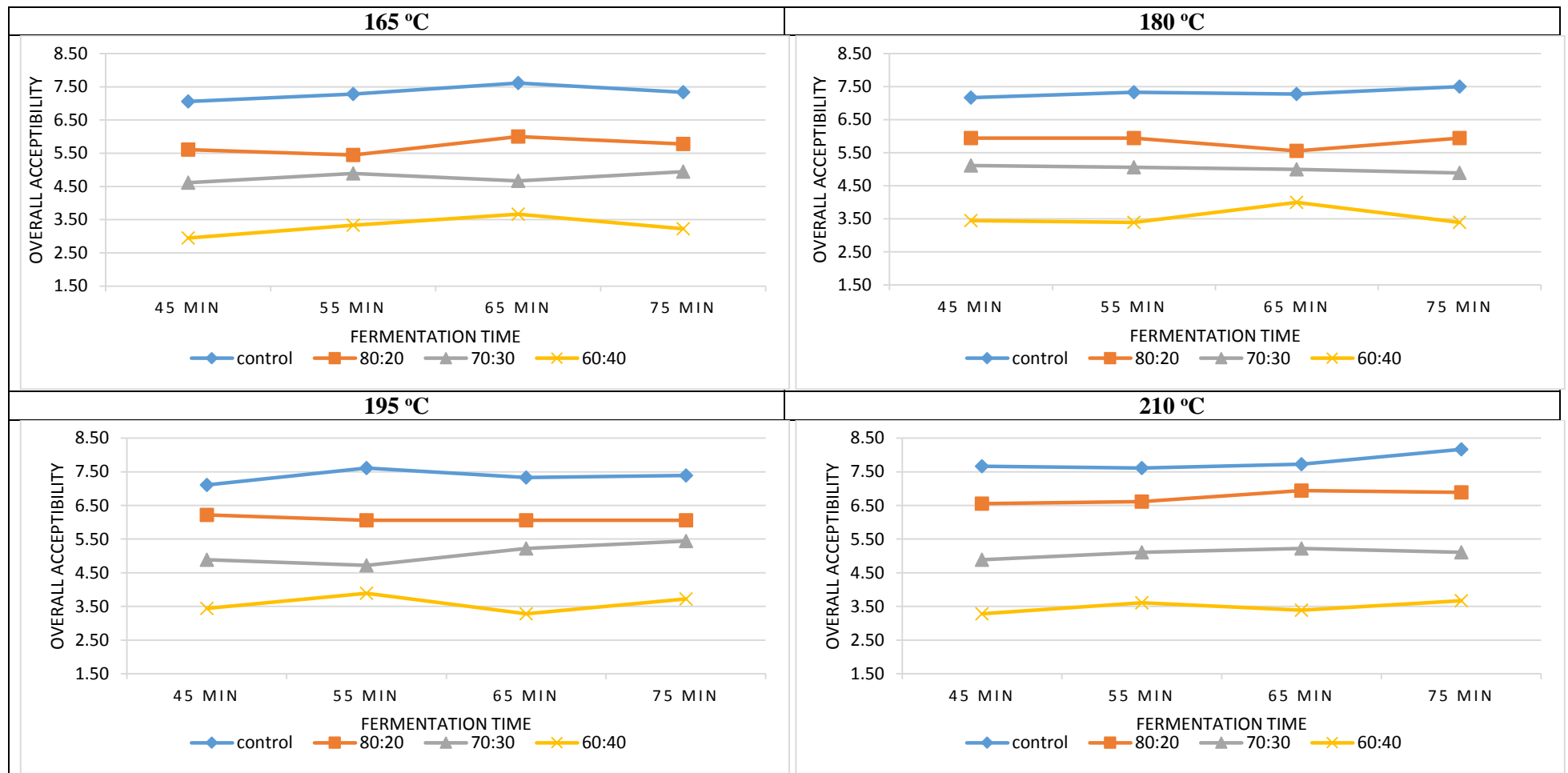


Fig. 4.23: Effect of sorghum flour level, fermentation time and baking temperature on overall acceptability of bread



RWF:SF = 80:20

70:30

60:40

Control

Plate 4.1: Volume comparison of control and composite breads



RWF:SF = 60:40

70:30

80:20

Control

Plate 4.2: Textural characteristics of control and composite flour breads