SCHOOL OF GRADUATE STUDIES

EFFECTS OF FAVA BEAN ROASTING TEMPERATURE, TIME, AND MILLING FRACTIONS ON WHEAT-FABABEAN COMPOSITE FLOUR PROPERTIES, AND BREAD QUALITY.

MSc THESIS

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Effect of Fava Bean Roasting Temperature, Time, And Milling Fractions on Wheat Faba Bean Composit Flour Properties, and Bread Quality.

MSc Thesis Submitted to the School of Graduate Studies, Wolkite University; in Partial Fulfillment of the Requirements for a Masters of Science Degree in Food Engineering

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DECLARATION

I hereby declare that this theis entitled Effect of Fava Bean Roasting Temperature, Time, and Milling Fractions on Wheat Faba Bean Composite Flour Properties, and Bread Quality was prepared by me, wth the guidance of my advisor. Except for the stated and referenced content, this paper is my own work.

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ABSTRACT

Legumes, like fava beans, are being used in food due to their protein and fiber content, potentially preventing malnutrition in underdeveloped nations and reducing food insecurity. This study sought to enhance the nutritional and acceptability of bread prepared from wheat and roasted fava bean (70:30) with various milling fractions of fava bean. Central Composite Design was used to optimize the roasting temperature and time with response to protein, fiber, tannin, and Phytic acid contents. The numerical model showed that roasting time of 20.69 minutes at temperature of 150.0 °C resulted in predicted values of 26.3%, 10.04%, 10.04 mg/g, and 652.702 mg/g respectively with a desirability of 0.626. The selection of faba bean milling fractions, large (0.6-0.4), mediume (0.4-0.3), and small (0.3-0.15) were based on preliminary investigation focusing on its final brad quality. The larger particle size produced higher protein (17.87%), lower carbohydrate (63.97%), whereas higher fiber (7.6%) content was found in medium particle sizes. The pasting temperature were icreases from (88.75°C) to (90.52°C) with increase in particle size. The setbak, peak time, and final viscosity were recorded from lage to small particlesizes (433 to 576Cp), (6.08-5.93min), and (957-1267Cp) respectively.

The highest degree of softness (252) and farinograph quality number (49) were founded in smallest and medium particle sizses respectively. The color parameters L, b*, a* showed darkness effect with the addition of bean at different particle size. The textural properties of bread made from medium and small particles were almost comparable, and the large particle sizes were recorded high firmness (10.99 N), gumminess (6.92 N), and low resilience (1.15) values. The highest loaf volume and sensorial score were conducted in small and medium particle sizes. From this faba bean roasting time 20.69 minutes at temperature of 150.0 °C with medium particle sizes, improve the nutritional, textural, and sensory acceptability of wheat bread.*

Key words: flour property, optimization, particle sizer, roasted faba bean, wheat flour

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LIST OF ABBREVIATIONS AND ACRONYMY

ANFs	Antinutritional Factor
ANOVA	Analysis Of Variance
AOAC	Association of Official Analytical Chemis
OAC	Oil Absorption Capacity
FC	Foam Capacity
FN	Falling Number Value
FQN	Farino graph quality number
FS	Foam Stability
PA	Phytic Acid
RSM	Response Surface Methodology
WSI	Water Solubility Index

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1. INTRODUCTION

1.1. Background

Legumes are dicotyledonous seeds that are rich in protein, carbohydrates, and fiber. The use of legume-based products in a variety of food applications has steadily increased in recent years due to their proteins, amino acids, and bioactive peptide contents (Keskin *et al*., 2022). Faba bean, a high-protein dietary source from legume crops, is produced globally, with China being the leading producer followed by Ethiopia (Dhull *et al*., 2022; Pasqualone et al., 2020). Ethiopia has been produced for centuries to provide protein supplements to the diet of rural households. The fava bean serves as a significant economic source of money for farmers, and foreign cash for the country (Teferi & Workineh, 2014). Fava beans from the legume crop that is low in saturated fatty acids and a great source of proteins and dietary fiber, as well as lysine (Dhull *et al*.,2022).

Due to the nutritional composition, fortification of wheat with legumes increases its nutritional content and has health advantages (Fizzello *et al*., 2014). From bakery products, bread is one of the ancient and most broadly consumed foodstuffs worldwide by people of all ages, and its main ingredient is wheat flour, which is high in carbohydrates but low in fiber, fat, and minerals (Codină *et al*., 2019). Cereal proteins are also low in some essential amino acids, particularly lysine Rizzello *et al*., (2014). Blending wheat flour with locally available legumes can enhance the nutritional content of wheat products. (Fadzelly, 2014), as well as facilitating its usage and reducing the amount of wheat flour (Hasmadi *et al*., (2020).

Depending on the flour combinations, fortification of wheat flour with legume flour may impact the nutritional, physical, functional, and rheological qualities of the final product (Awolu *et al*., 2015). The functional qualities of composite flour are primarily determined by nutritional composition, which is affected by the quality and amount of wheat gluten as well as the product's nature (Hasmadi *et al*., 2020). The pasting characteristics of flour are important to understand the process ability of the product (Mohammed *et al.*, 2012). Rheological properties of flour are used to identify the effect of flour composition on dough qualities (Zafar *et al*., 2020). Moreover, blending wheat flour with legumes has a limitation due to beany flavor. However, using convectional processing methods such as roasting may be beneficial in masking the "beany" off-flavor (Young *et al.*, 2020).

Different studies reported the impacts of roasting on the beany flavor of legumes, the inclusion of wheat flour with roasted yellow peas at 150°C for 25 minutes was reported by Kotsiou *et al*., (2021) for bread formulations without compromising dough rheology, bread texture, or shelf-life, resulting in end goods with a nice taste profile and shelf-life. The effects of roasting as a pre-milling treatment on whole yellow split peas milled into flour for pan bread were studied, which lowers odors and tastes when yellow peas are roasted (Young *et al.*, 2020).

In addition to undesirable flavor, legume intake is restricted by acceptability, digestibility, and consumption due to ant-nutritional compounds like phytates and tannins (Mugabo *et al*., 2017). Avezum *et al*., (2023) reported the processing of legumes to reduce ANFs is necessary before combination with wheat flour to increase its consumption and protein quality, and roasting time and temperature can breakdown the ANFs of legumes (Farinde *et al*., 2018). On the other hand roasting may be degrade nutrient and and unexpected flavoure due to high temperature and thime, although it require the optimume roasting temperature and time for total nutritional value as a result examining the correct temperature and time can help to preserve proteins, and minerals with reducing in anti-nutritional components and improving sensory characteristics. And previous studies indicated roasting of legumes and milling treatment have a significant effect on the properties of wheat-legume flour (Kotsiou *et al*., 2021; Young *et al*., 2020).

However, to the best of my knowledge, there is no research reported on the effects of roasting temperature and time on faba bean as well as its milling fraction on wheat flour addition. Hence the aim of this research was to investigate nutritional and antinutrional content of faba bean and the sensory aspects of roasted broad bean-wheat flour blends as well as the influence of milling fractions on the functional, pasting, and rheological properties of wheat flour.

1.2. Statement Of Problem

The consumption and production of animal protein require a large amount of land and water, which contributes to food insecurity and climate change. Nevertheless, increasing the number of alternative protein sources is necessary to achieve a sustainable food supply chain and prevent malnutrition. Ethiopia is frequently adjusted to improve the nutritional quality of foods to satisfy the calorie requirements of a normal individual. It is common practice to use locally accessible raw materials with wheat flour to increase the nutritional content of bakery goods. The possibility of combining wheat flour with higher nutritional value flour has attracted the attention of manufacturers involved in the creation of novel baking goods based on nutrient-dense ingredients.

Bread is a popular food and universally consumed product and its major ingredient is wheat flour. While animal consumption has been undergoing a gradual decline by low-income people in recent years due to its high cost, it is necessary to fortify wheat flour with locally available raw materials like legumes to substitute for malnutrition (Farinde *et al*., 2018). Legumes have higher protein content and have the potential to combat the problems of protein energy malnutrition, especially in developing countries, where lysine is scarce in cereals *(Rahate et al*., 2021). From legume fava beans are important due to their high nutritional value, and long storage times (Kebebu *et al*., (2013).

In addition to nutritional content, new researchers have come in to eliminate anti-nutritional components through the use of methods of processing to boost the bioavailability of legumes (Mugabo *et al*., 2017; Farinde *et al*., 2018; Avezum et al., 2023). Because of legumes protein has a crucial role in the quality of bread to compensate for wheat dough which may affect the properties of wheat flour dough and the final product. Despite the anti-nutritional value the milling fraction of légume flour affects the bread quality, and there were no standards exist for the particle size of legume flour in contrast with wheat flour which is well defined in the wheat flour milling industry (Limsangouan & Isobe, 2009).

Therefore, this study allow for the production of wheat-roasted faba bean composite flour and products as wel as optimum faba bean roasting temperature, and time on nutritional and anti nutritional contentof faba bean faba bean and its milling fraction on properties, proximate, mineral, of wheat flour with better sensory attributes by improving the nutritional content of its product.

1.3. Research Question

- Does the roasting time and temperatures affect the anti-nutritional and nutritional content of fava bean?
- How does roasted fava bean milling fractions affect the rheological, pasting, and functional properties of wheat flour?
- Does wheat faba bean composite flour affect the bread quality?

1.4. Objective

1.4.1. General Objective

Effects of fava bean roasting temperature, time, and milling fractions on wheat- faba bean composite flour properties, and bread quality.

1.4.2. Specific Objectives.

- To study the effects of roasting time and temperature on the Protein, fiber and ant-nutritional (Phytic and tannin) content of fava bean.
- To evaluate the functional, pasting, and rheological properties of wheat-roasted fava bean composite flour at different milling fraction.
- To evaluate the milling fraction effect on bread quality (texture, volume, and sensory attributes)

1.5. Significance of The Study

In Ethiopia, faba beans are used as a traditional food and consumed in limited amounts. Today, legumes (faba beans) have an advantage in reducing malnutrition. This research may increase its role in the food industry by combining wheat with roasted faba to improve nutritional qualities and the final wheat flour product by considering optimization of temperature, time, and milling fractionof faba bean and it is important to increase protein digestibility in the final product's texture, taste, and functional attributes.

1.6. Scope of the Study

In this study, the nutritional and antinutritional content of faba bean was investigated based on roasting temperature and time, and composite flour was produced by optimumizing tempature and time based on high nutritional (protein and fiber)and low antinutritional(phytic acid and tannin) values with different milling fractions, as well as the impact of millig fraction on wheat flour properties (functional, pasting, and reheological), proximate, mineral, and final bread qualities (texture, loaf volume, and sensory attributes).

2. LITERATURE REVIEW

2.1. Overview of Vaba Bean Production In Ethiopia

Fava bean/ broad bean (Vicia faba L.) is a popular breakfast meal in the Middle East, the Mediterranean area, China, and Ethiopia. According to the food and Agriculture Organization (FAO) report, Ethiopia was the biggest producer of fava beans after China, and it is consumed as a vegetable, green or dry, fresh, or cooked/canned (Dhull *et al*., 2022). It's an important pulse crop in Ethiopia's highlands and mid-highlands. It was the first crop farmed in the country in terms of both geographical coverage and annual production volume (Merga *et al*., 2019). According to Gereziher *et al*., (2018) report the current production of fava bean with an annual production of 8,389,438.97 tones with an average yield of 1893 kg ha^{-1} and grows in several eco-geographical regions of the country including Arsi and Bale highlands, the Central Highlands of Ethiopia, Hadiya, Sidama, and Gamogofa (Teferi & Workineh, 2014).

2.1.1. Nutritional and Health Bbenefits of Fava Bean

Legumes are important foods due to their high nutritional value, ease of preservation, low cost of production, and poor man's protein compensator (Boukid & Castellari, 2022). Legumes are low in Sulphur containing amino acids such as tryptophan, cysteine, and methionine but are rich in lysine content, whereas cereals are vice versa (Khan *et al*., 2015). Though legume proteins can be improved by cereals, they are complementary to each other (Rahate *et al.*, 2021). And also Legumes are a good source of protein, dietary fiber, and lower levels of fat (2–5%) (Xu & Chang, 2007).

Faba beans are high quality protein, and the third most important legume after soya (Glycine max) and pea (Pisum sativum) (Rahate *et al*., 2021), and the protein content of fava bean varies from 20% to 41%; due to varietal differences in the growing season, and planting site, dietary fiber in whole fava bean ranged from 15% to 30%, having hemicellulose as the major component, and globulins (60%), albumins (20%), glutens (15%), and polyamines (8%), and also Carbohydrate content ranges from 51% to 68% in which major quantity is represented by starch (41–58%) and bioactive compounds (antioxidants, phenols, and γ-aminobutyric acid), which have several reported health benefit, which has advantageous for the prevention of cardiovascular diseases, low-density lipoprotein (LDL) cholesterol levels (Delgado *et al.*, 2021; Dhull *et al*., 2022). Hence fortification of legume flour with cereal is going to be interesting in different studies not only from a nutritional point of view and also to benefit human health.

According to (Sharan et al., 2020) the amino acid content of fava beans compared to the adults' requirements for dietary intake along with cereals in suitable quantities to achieve the daily requirement of essential amino acids. (Rahate et al., 2021a) report health benefits of fava bean, which can be used in formulating food products specifically for pregnant women due to its vitamin, 423µg folates as compared to soybeans (250µg) and peas (274µg) which is important for preventing the opportunity of the occurrence of spinal Bifida (related to spines of newborn babies) and anencephaly (baby born with underdeveloped brain and skull) and also proteins from the Fava bean are important to protects against several chronic diseases like cancer, diabetes type 2, cardiovascular diseases, etc.

Due to the various benefits and balanced nature of amino acids in pulses with other ingredients such as cereals, to enrich their quality and nutrients, used to make bread, biscuits, meat with pulses, dairy products, etc. Pulse flours have been utilized successfully in the formation of meat products such as burgers, sausages, nuggets, and so on (Sofi *et al*., 2017). As Table 2.1 shows, fava beans are also used for the production of bread, pasta, and other gluten-free products blended with other cereals, and it is a potential source of proteins for the human diet, can produce nutritional and functional ingredients, such as flours, concentrates, and isolates, that are useful in industrial food applications (Sharan *et al*., 2020).

2.1.2 Faba Bean for Food Applications and Its Products

Table 2. 1 Faba bean (broad bean) based food products (Source: (Rahate et al., 2021))

Food	Utilization	Effects
Bread	Raw, germinated faba bean	The pale color of the crust crumb grain and loaf volume degradation effect
	Protein isolates (5-8%)	
	20% germinated faba bean protein	Weakened dough properties, decreased Weakened dough properties, decreased effects on loaf volume.
	30% germinated faba bean protein isolate	Increase in protein content by 5%, increased protein digestibility, nutritional indexes, and reduced glycemic indexes.
Pasta	10–30% faba bean flour	Acceptable cooking and sensory properties.
	35% faba bean flour	Higher hardness and brittleness due to high drying temperature.
	10–50% raw faba bean	Flour Higher mineral availability, lower GI
	10–50% fermented faba	Bean flour Nutritional indexes further enhanced by fermentation, increased resistant starch.
Gluten free	100% hulled and DE hulled faba	Increased protein content of Products bean flour.
	30% raw faba bean and 70% corn flour	Increased protein content; mineral bioavailability

2.1.3. Milling of Legume Flour

Legume milling involves eliminating the seed coat, splitting, which cleaves the cotyledons and produces splits, and flour milling, which produces the ground floor (Limsangouan & Isobe, 2009). Kerr *et al*., (2000) studied in 2.0, 1.0, or 0.5-mm screen for cowpea flour, and found particle size influenced the functional properties of flour that was hammer milled from cowpeas.

According to Bourré *et al*., (2019) study, the baking properties of a yellow pea, navy bean, and red lentil flours, flours differing in particle size distributions produced by using different size milling screens (1.27, 1.00, 0.79, 0.5 mm), and founded finer flours lower water absorption capacity, and higher peak and final viscosities. Bread made with finer flours had better bread color and less crumb structure. Shafi *et al*., (2017) studied on different sieve particle sizes (≤ 0.212 mm) and (≤ 0.125 mm) of wheat-water chestnut blend and found different sieve sizes significantly varied in proximate composition, mineral content, physio-chemical, functional, and pasting properties.

2.1.4. Effect of Processing Method on Anti-Nutritional Factors (Phytic Acid And Tannin) Content of Legumes

The use of legumes to achieve future demand must take into account the presence of ant nutritional substances and their influence on nutritional quality (Bou *et al*., 2022). Recent research has raised concerns regarding the healthfulness of plant-based diets due to the presence of substances known as "anti-nutrients," which include lectins, oxalates, phytates, phytoestrogens, and tannins (Oladele *et al*., 2009). Although legume seeds are a good source of protein, calories, minerals, and vitamins, their use in food is limited by the presence of several anti-nutritional factors (Farinde *et al*., 2018). Kotsiou *et al*., (2021), found that roasting Yalow split pea at 150°C for 25 minutes in bread formulations resulted in a final product with an acceptable taste profile and shelf-life, and also Young *et al*., (2020) investigated the effects of roasting yellow peas at 120°C for 30 minutes on odors and tastes.

According to (Abbas & Ahmad, 2018) tannin is mostly found in seed coats and it is a water-soluble phenol. The existence of tannins in legumes inhibits protein availability and digestibility by forming reversible and irreversible tannin-protein complexes between protein carbonyl groups and tannin hydroxyl groups (Petroski & Minich, 2020), and also tannin-rich diets may contribute to iron-deficiency anemia in developing and low-income nations due to their anti-nutritional effects (Rahate *et al*., 2021). And also Phytic acid is a compound present in salt form and stored in the form of phosphorus in legumes, which reduces the absorption of micronutrients like P, Ca, Mg, Fe, and Zn, as well as macronutrients like lipids and proteins. Additionally, it inhibits digestive enzymes like amylase, pepsin, and trypsin (Shi et al., 2018; Shi *et al*., 2018; Bou *et al*., 2022). Phytic acid present in various legume plants like soybeans and common beans contains the maximum amount of Phytic acid ranging from 1.20 to 1.75, and 0.55 to 1.69 g per 100 g, respectively, whereas peas range from 0.72 to 1.23g per 100 g (Rahate *et al*., 2021c).

To increase the nutritional content of legumes and make them more acceptable for human consumption, anti-nutrients must be eliminated by processing methods (Rahate *et al*., 2021). (Kim A Millar & Gallagher, 2019) studied the nutritional content and ant nutritional components of fava beans, green peas, and yellow peas, however, fava beans have more protein than green and yellow peas, but they also include more anti-nutritional elements including tannins and Phytic acid. The role of processing methods in lowering the amounts of anti-nutritional elements in legumes, and also reported 15 to 30% reduction in the digestibility of fava beans is observed in the incorporation of fava beans in the diet and also affects the digestibility and absorption of carbohydrates (Rahate *et al*., 2021).

The roasting process has a significant role in reducing the anti-nutrient factors of cereals and legumes, improves color, and texture, and reduces the tannin and phenolic content of lentil flour (Cominelli *et al*., 2022), hence heat treatments improve the nutritional value and quality of legume grains so that the heat treatments are used to enhance the protein quality of legume grains by inactivating the tannin content (Abbas & Ahmad, 2018). and severa1 studies report different processing methods reduce tannin and Phytic acid contents of legumes, in bean varieties (Kim A Millar & Gallagher, 2019), soaking, boiling, and roasting for desi and Kabuli chickpea varieties (Sharma *et al*., 2018).

2.2. Overview of Wheat Production in Ethiopia

Wheat is the grain used in bread preparation due to its high gluten level. Bread is a universally consumed product and its versatility means it continues to evolve to reflect consumer needs. While bread consumption has been undergoing a gradual decline in recent years, due to its high cost it continues to make a substantial contribution to the diets of many cultures (Millar *et al*., 2019) .

Ethiopia is a major wheat producer in Sub-Saharan Africa, producing 4.2 million quintals on 1.7 million hectares, which ranks fourth after teff, maize and sorghum in area coverage and third after maize and teff in total production on the other hand, the production of wheat and dominated by the country’s numerous smallholder farmers that cultivate more of wheat for consumption and less of it for the market (Anteneh & Asrat, 2020). And its production accounts for approximately 20% of total African wheat production (Shikur, 2022). Ethiopia's 2020 trade shows a significant mismatch between export and import, with a $3.5B export and $11.1B import expenditure . The production of food has slowed due to population growth, leading to requirement on imported wheat. Wheat self-sufficiency ratios have declined from 99% in the 1960s to 70% in 2022. Ethiopia annually imports 1.6 million tonnes of wheat at a cost of $700 million from 2019 to 2022.The country's lack of foreign exchange reserves has limited commercial grain purchases, making it a major food aid recipient. Wheat consumption is increasing at 9.0% per annum, as compared to local production increase of only 7.8 % making the demand to exceed the supply (Feyissa & Worku, 2023).

2.3 Roasting Technology and Its Principle

Roasting legume seeds improves nutritional value by converting complex proteins, carbs, and lipids into peptides, simple sugars, and fatty acids. Pulses are interesting to the food processing industry because they are high in protein, fiber, and have functional qualities (Seied *et al*., 2023). Roasting technique improve releasing pleasant aromas, and resulting in more efficient, sustainable, and adaptable legume roasting solutions (Turfani *et al*., 2017). Modern food sector innovations include roasting machinery using Infrared waves, microwave roasting for lower processing time and energy consumption, and Forced Convection Continuous Tumble Roasting (FCCT) for energy efficiency. Microwave roasting improves oil pressing efficiency in grains like chickpea, flaxseed, peanuts, and millets, while FCCT alters cereal grain microstructure. These process involves heat transfer, Millard reaction, moisture removal, and structural changes, and causes physical and chemical changes within the legume, while the Millard reaction develops the characteristic roasted products (Sruthi *et al.,* 2021).

2.4 Baking Technology and Its Principle

Bread making is the ancient food processing (Alkandari *et al.*, 2021), has undertaken significant technical developments, transferring from ancient wood-fired ovens to contemporary, automated industrial bakeries. Bread baking technology has advanced with the introduction of specific equipment and machines. Commercial bakeries today employ mixers, proofing chambers, automated dividers, slicers, and modern oven technology, thought these instruments allow constant dough quality, temperature management, and effective heat transmission, resulting in increased efficiency and uniformity in baking (Das *et al*., 2023).

According to Cappelli, A., and Lupori, L, (2021) echnological advancements in bread baking have led to increased production volumes, quality control, and improved product consistency. Researchers have developed innovative techniques and formulations, such as enzymes and emulsifiers, to enhance texture, shelf life, and nutritional profile, and the bread baking principle lead to change in flour, water, yeast, and other ingredients into a structured, aerated, and flavorful final product. Heat and mass transfer phenomena are take place all together during bread baking which causes physical, chemical, and biological processes that turn basic components into a tasty loaf of bread (Bogl, 2018).

Baking process includes gluten production in wheat flour, yeast fermentation, gelatinization of starch granules, oven browning reactions, and enzyme activity in flour and additional components and help to get the proper texture, structure, and flavor of the finished product (Das *et al*., 2023). Heat and mass transfer phenomena are taking place simultaneously during bread baking which causes physical, chemical, and biological processes that turn basic components into a tasty loaf of bread (Bogl, 2018). This process includes gluten production in wheat flour, yeast fermentation, gelatinization of starch granules, oven browning reactions, and enzyme activity in flour and additional components and help to get the proper texture, structure, and flavor of the finished product, and enzymes also help break down complex carbs and proteins (Mondal & Datta, 2008).

2.4. Functional Properties

The functional properties of a food ingredient have a great impact on the utilization and acceptability of proteins in food systems. The functionality of foods is a characteristic of the food ingredients that affect the end product in terms of how it tastes looks and feels (Wani & Kumar, 2014). From functional properties absorption of oil by food products is appropriate for enhancing flavor, mouth feels, and shelf life when used in food preparation (Chinaza G Awuchi, 2019). The highest value of oil absorption capacity is related to the hydrophobicity in blends (Awolu *et al*., 2015).

Swelling capacity is important in keeping the structure of different food products like bakery products during and after processing (Chandra *et al*., 2014). According to Adegunwa *et al*.,(2014), the swelling capacity of wheat flour is increased when millet flour is combined, which is similar to wheat-germinated and native broad bean flour (Aprodu *et al*., 2019). The formation of an amylose-lipid complex hinders the starch from swell and delays the gelatinization process (Chandra *et al*., 2014). The lower resistance to swelling drops the pasting temperature needs lower energy to activate the gelatinization process is an advantage in the backing application (Marchini *et al*., 2022) and the higher swelling power (SP) in flour indicated good organoleptic characteristics in terms of mouthfeel. The higher SP value indicates the weaker bonding forces in their starch granules (Eriksson et al., 2014). Foaming properties are essential for the maintenance of the texture and structure of different food products (Shad *et al*., 2011)

Water absorption capacity is an important function of protein in many food items such as dough, soups, and baked goods. Water adsorbed on the surface of macromolecular colloids such as proteins, pectins, starches, and cellulose is called water absorption capability. (Mohammed *et al*., 2012) studied on chickpea and wheat composite flour discovered that as the percentage of chickpeas in the composite flour increased, so did the water absorption capacity, maybe owing to a rise in total protein and non-starch polysaccharides content. On the other hand, composite flour made of millet flour, whole wheat flour, and defatted soy flour decreases water absorption capacity as the millet flour content increases (Vijayakumar and Mohankumar, 2009), possibly because of a lower degree of protein interaction with water. The maximum water absorption capacity is well- accepted in baking applications (Iwe *et al*., 2016; Ohizua *et al*., 2017).

2.6. Pasting Property

The pasting properties of starch refer to the change that occurs during the application of heat in the presence of water and it is an important property that influences the quality of starch-based food products which affect texture and digestibility (Iwe *et al*., 2016). It is the ability of starches to swell freely before their physical breakdown and shows the strength of the pastes formed during gelatinization (Asaam *et al*., 2018). The pasting character predicts the processing qualities (cooking temperature and time, thickening ability, temperature, pressure, shear induce viscosity breakdowns, gelling, and retrogradation tendencies over the storage durations) of starch-based raw material food ingredients. The pasting character is fundamentally determined by the starch granule composition and its nature and is influenced by the non-starch flour components. Pasting properties are determined by using Rapid Visco Analyzers (Shimelis *et al.*, 2006).

Peak viscosity (PV) is the maximum viscosity during the heating application test and indicates the maximum swelling capacity of starch granules and is related to the final product quality (Ohizua *et al.,* 2017). The starch granular swelling and leaching of soluble carbohydrates mostly amylose are the main factors that determine the viscosity development during the pasting process (Awolu *et al*., 2015).

Pasting temperature is the minimum temperature required for starch granules to swell in composite flour (Awolu, 2017). In the previous study, the increase in pasting temperature of wheat–chickpea blends varies from 62 to 66.5 °C and the high pasting temperature may be due to the higher resistance to swelling and rupture of chickpea starch (Mohammed *et al*., 2012), though the lowest pasting temperature needs lower energy to activate the gelatinization process is an advantage in backing (Marchini *et al*., 2022) and the high resistance of starch to swell and rupturing leads to the high pasting temperature (Kaur & Singh, 2005).

Setback viscosity (SV) indicates a low rate of starch retrogradation and syneresis (Raihan, M. & Saini, 2017). It is influenced by starch, in which starch with low levels of amylose might have the ability to a reduced retro-gradation process than the starch with high levels of amylase and have lower setback viscosity (Awolu *et al*., 2015).

Final viscosity is the ability of starch to form a viscous paste on cooling, which depends on the gelling ability during processing (Ajatta *et al*., 2016). It depends on the amylose content of starch which influences its stability (Kumar *et al*.,2014). As Jan *et al*.,(2022) stated increase in final viscosity from 2199cp for 100%wheat flour to 423cp in wheat-soya blend due to the formation of swollen granules. Similarly, the substitution of sorghum, oat, or corn flours with wheat flour increases in final viscosity as the substitution level of composite increases due to the association between the starch molecules form a gel at low temperature (Vásquez *et al*., 2017), therefore composite flour with higher amylose content gives a higher final viscosity and more stable (Kumar *et al*., 2014).

Breakdown viscosity measures the ability of the flour to resist heating and shear stress, whereas trough viscosity measures the ability of the paste or gel formed to resist breakdown during cooling (Ohizua *et al*., 2017).Peak time is a measure of the cooking time or the time required to reach a peak in viscosity (Adegunwa et al., 2014). In a previous study, a lower peak time was recorded for a wheat-soy blend with a ratio of (65:35) blend as compared to wheat flour (Jan *et al*., 2022).

2.7. Dough Rheological Test

2. 7 .1. Farinograph

The farinograph test is one of the most widely used flour quality tests. The data are utilized as parameters in the formulation to estimate the quantity of water needed to produce dough, assess the impact of components on mixing capabilities, assess flour blending needs, and verify flour homogeneity. The data are also utilized to anticipate processing impacts such as dough development mixing needs, overmixing tolerance, and dough consistency throughout production. The results of a farinograph can also be used to predict the texture of a finished product. Under precise kneading conditions, dough development is monitored using a farinograph. Farinograph operation is based on the resistance of the dough to the kneader shaft (Abebaw Tsegaye, 2020).

Dough stability is the time needed before the dough consistency starts to decline from the 500 BU line. Dough weakening is the reduction in the dough consistency from the 500 BU line after 5 min, and water absorption is the amount of water required to center the farinograph curve on the 500 Brabender units (BU) line. Water absorption is expressed as a percentage and refers to how much water is required for flour to be optimally processed into end products whereas Peak Time denotes dough development time, beginning when water is added and ending when the dough reaches maximum consistency. This indicates the optimum mixing time under standard conditions. Peak time is expressed in minutes, and it is the time it takes to form a ball of dough (Koca & Anil, 2007).

Different studies studied on farinograph characteristics of dough, studied on inclusion of yellow split pea flour (15 and 20%) with wheat flour increases dough development time and decreases stability due to gluten–legume protein interactions (Kotsiou *et al*., 2021). The gluten weakening results in competition between legume proteins and wheat flour proteins for water or the added proteins disrupt the protein–starch complex in wheat flour (Hall & Ainsworth, 2004). Mohammed *et al.*, (2012) proposed substitution of wheat flour for chickpea flour increased dough development time from 2.1min to 6min, decreased dough stability from 6.1min to 3.6min, and increased the energy requirements for optimal dough consistency development.

2.7.2. Falling Number

The falling number is expressed in seconds and provides a measure of alpha-amylase enzyme activity in the sample. A high falling number indicates low enzyme activity, whereas a low falling number indicates high enzyme activity. In bread making the optimum FN value is needed because the enzyme affects dough properties such as gassing power and consistency and, if it is excess results in excessive liquefaction and dextrinization, resulting in bread with a wet sticky crumb (Khalil *et al*., 200).

2.8. Response Surface Methodology (RSM)

According to the definition provided by Murphy *et al*., (2005), an experiment is a sequence of tests, known as runs, in which modifications are made to the input variables to identify the causes of changes in the output response. Design of Experiments is a strong approach for investigating novel processes, learning more about new processes, and improving these processes for world-class performance (Almeida *et al*., 2008). Engineering experimenters frequently aim to determine the optimal conditions for a certain operation. Experiments are carefully planned to determine the best number of design parameters. The optimum might be a maximum or lowest in response variables influenced by several independent factors.

From the response surface approach, central composite design (CCD) is an excellent strategy to attain optimal results (Sons. inc, 2009), and Response surface methodology (RSM), a collection of mathematical and statistical approaches for modeling, analyzing, and solving problems with numerous variables and responses throughout the optimization process. The response surface technique assesses the link between controlled input variables and the resultant response surfaces. It is well known contemporary strategy for creating approximation models using physical experimentation data (Yolmeh & Jafari, 2017).

3. MATERIALS AND METHODS

3.1. Sample Collection, and Storage

Faba bean (Gebelcho), and wheat (kingbird) variety samples were collected from the Wolkite, and Debre Zeit Agricultural Research Centre, respectively. All samples were packed in a plastic bag and stored in dry condition at Wolkite University Food Engineering laboratories for further study.

3.2. Location of the Experimental Site.

The experiment and faba bean roasting and milling process were conducted in Wolkite University Food Engineering laboratories by using the baking oven, and analysis of raw material and product proximate composition, falling number, physical, functional properties, and sensory evaluations were done at Wolkite University, department of Food Process Engineering Laboratories, and farinograph and pasting properties were done in Addis Ababa University.

3.3. Sample Preparation Methods

3.3.1. Roasting of Fava Bean

Roasting was done by taking 1 Kg of the cleaned fava bean seed and washed it with distilled water to remove derts at room temperature. Then seeds were roasted at different temperatures (130 to 150 °C) and times (15 to 25 minutes) in the oven, placed on a tray, stirred with a fork, and cooled at room temperature before milling (Nzewi & Egbuonu, 2011).

3.3.2. Milling, and sieveing of Fava Bean and Wheat Flour

The whole roasted faba bean was milled by hammer mill (Model BH24 1 DY , Armfield England). The sieve opening configuration was chosen from the literature for various legume flours, and a preliminary test was done by baking wheat-roasted fava bean bread at different particle sizes and selecting the color depending on the bean bran on the crust, and crumb. Based on preliminary testing, the sieve opening configurations were set up to produce three flours of varying sieve sizes and sieve arrangements. Large (L), Medium (M), and Small (S) flours were produced by using sieves with openings of 0.6-0.4mm, 0.4-0.3mm, and 0.3-0.15mm on the bottom for further analysis, and wheat flour was milled and sieved according (Zafar et al., 2020).

3.3.3 Preparation of Composite Flour

The composite flours were produced by blending wheat flour with roasted fava bean flour in 70:30 proportions. This ratio was selected in preliminary study based on highest protein content as compared to < 30 blend and the flow diagram for flour preparation is spresented in the Figur 3.1.

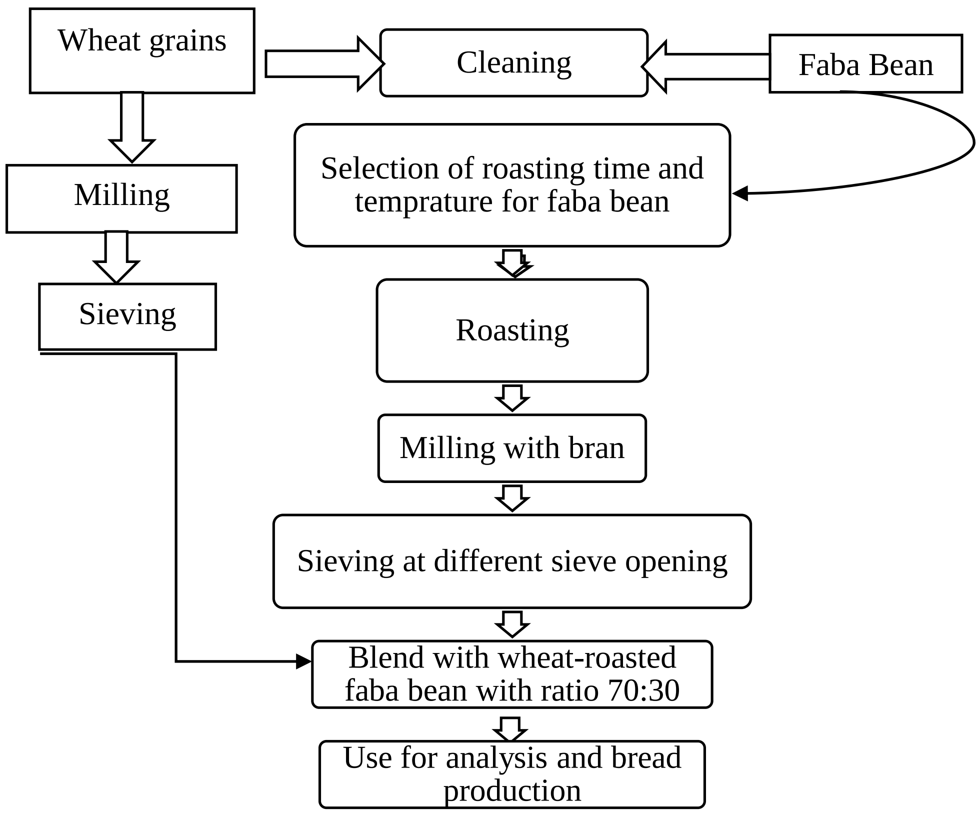

Figure 3. 1 Flwdiagram for flour preparation

3.4 Experimental Framework of the Research

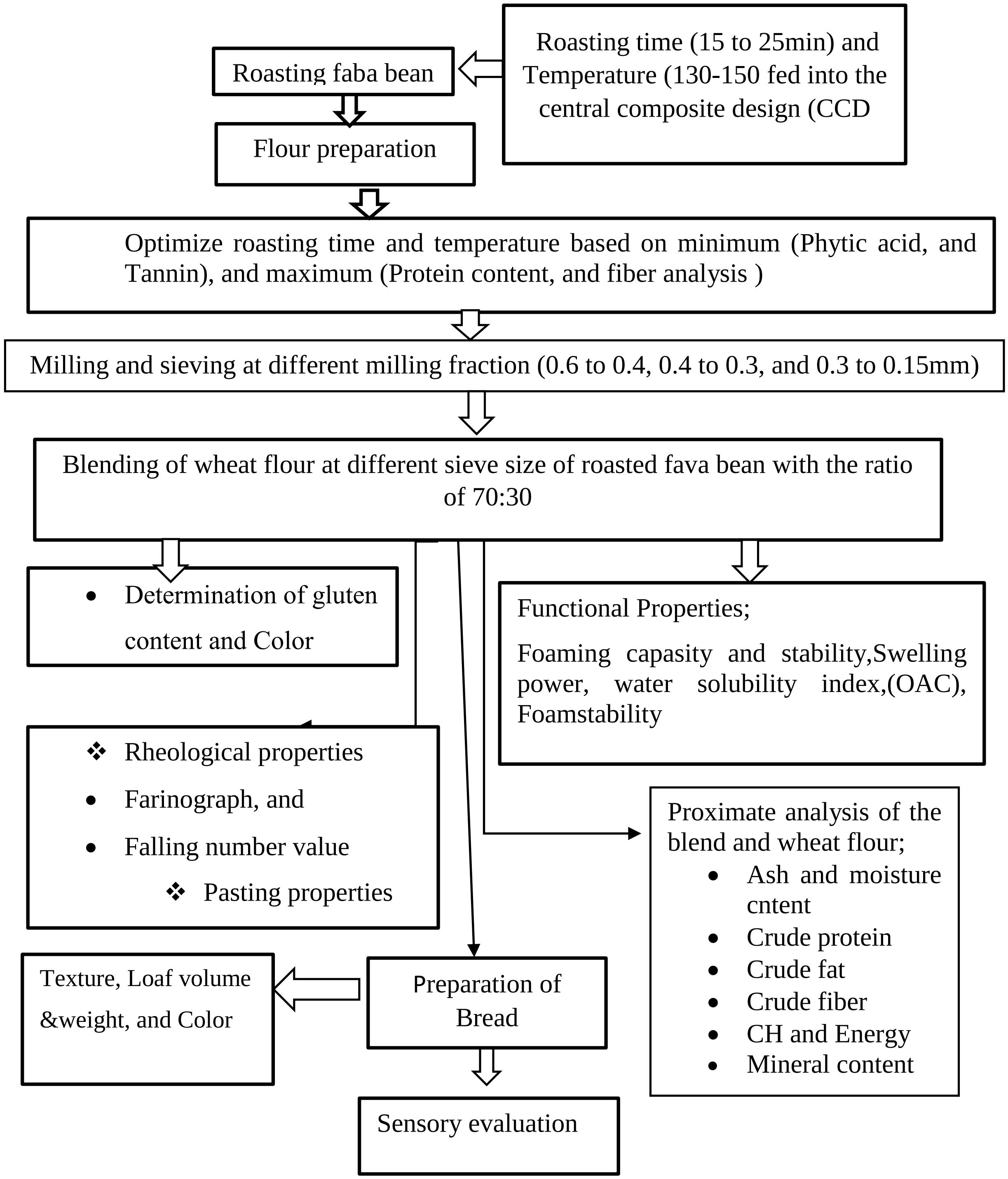

Figure 3. 2 Exprimental framework of the research

3.5 Method of Analysis

3.5.1. Anti- Nutritional Content of Roasted Fava Bean

3.5.1.1 Tannin

Tannin content bean flour was determined according to Wodajo and Emire, (2022). About 1mg of roasted and raw faba bean flour was added to the screw-capped test tube, and 10 ml of % HCl methanol and extracted through a shaker (150 rpm) for 24 hr. at room temperature and centrifuged (3000 rpm/ 5min). The supernatant was used for tannin estimation and about 1 ml clear supernatant mixed with 5ml of vanillin-HCl reagent in the test tube and About (0.0,0.2, 0.4,0.6,0.8, and 1 ml) D-Catechin were used as standard and added 1% 0f HCl methanol to make 1 ml, and 5 ml of vanillin HCl reagent was added to both standards and sample. After 20 min, the absorbance of the sample solution and the standard solution were measured at 500 nm by using a spectrophotometer. The absorbance of the blank is subtracted from the absorbance of the corresponding vanillin- contain sample. A standard curve has been constructed (Absorbance VS D-Catechin concentration) and the linear portion of the curve was extrapolated to produce the standard curve. Finally, the tannin content was calculated and a value of tannins was expressed in milligrams of D-Catechin equivalent per gram of sample.

$$Tannin\ content(\frac{mg}{100g}) = \frac{((A_s - A_{b)-Intersept)\times 10}}{S \times D \times W} \tag{3.1}$$

Where; A_s is sample absorbance, A_b is the absorbance of blank,

W is the weight of the sample, and D is the density of tannin

S is the slope of the absorbance equation of a standard curve

3.5.1.2. Phytic Acid

Phytic acid analysis was determined according to Wodajo, and Emire, (2022). About 0.2 g of roasted and raw faba bean flour was extracted with 10 ml of 0.2N HCl for 1h at an ambient temperature and centrifuged (3000 rpm/30min). The supernatant was used for phytates estimation. About 2 ml of Wade reagent was added to 3 ml of clear supernatant. A series standard solution was prepared containing 0, 5, 9, 18, 27, and 33 ppm of Phytic acid (analytical grade sodium phytates) and made 50 ppm by using 0.2N HCl. A 3ml of the standard was added into the test tube separately, and then homoginized both samples and standards were finally after the addition of Wade reagent let for 10 min, and red absorbance at 500 nm was read using

UV-VIS spectrophotometer. A standard curve was made from absorbance versus concentration and the slop and intercept were used for the calculation of phytic acid as follows;

$$Phytic\ acid(\frac{ug}{g}) = \frac{((A_{s-A_b}) - intercept) \times 10}{S \times W \times 3} \qquad (3.2)$$

Where; A_s is sample absorbance, and A_b is standard absorbance

S is the slop of standard cure, and W is the weight of the sample,

3 ml of standard and ample, and 10 ml of vortexed

3.6 Particle Size Distribution For Roasted Bean

The particle size distribution of flour samples obtained from roasted fava bean flour was carried out using a sieve analysis technique as described by Raza *et al.*, (2019). Different sieves with varying aperture sizes (small (S), Medium (M), and Large (L) flours were produced using sieves with openings of 0.6-0.4mm, 0.4-0.3mm, and 0.3-0.15mm on the bottom, and (100g) of flour placed inside the top sieve. The sieve was shaken for 10 min after which the quantity of flour retained on sieve was collected, weighed, and calculated.

$$\%\text{Recovered} = \frac{W_{\text{sieve}}}{W_{\text{total}}} \times 100 \qquad 3.3$$

Where: W sieve is the weight of aggregate in sieve

W total is the weight of the total aggregate.

3.7 Determination of gluten

Determination of gluten will be determined by the method of (AACC, 2000). About 20 g of wheat-roasted beans, and wheat flour of each particle size were weighed into a Petri dish of known weight and thoroughly mixed with 1 ml of water to form a dough. The dough is kneaded under running water-salt solution to remove starch and later put into a Petri dish and weighed. Then it was dried in an oven at 130-133°C for 2 hours. Cool the dried gluten in desiccators and weigh it after drying. The % gluten is calculated as follows:

$$\%\text{wet gluten} = \frac{\text{weight of gluten}}{\text{weight of original flour}} {}^{\text{x}}100 \qquad (3.4)$$

3.8 Functional Properties of Flour

3.8.1. Water Absorption Capacity

Water absorption capacity (WAC) was determined by duplication according to Kaur & Singh, (2005). The centrifuge tubes and crucibles were dried in the oven at 105℃ for 20 minutes. And allowed to cool in a desiccator, after cooling, the crucible and the centrifuge tubes were weighed. About 1g of the sample was weighed into the tube and about 10 ml of distilled water was added and stirred gently with a stirring rod for 30 minutes. The tube containing the paste was centrifuged at 4000 rpm for 15 minutes. After that, the supernatant was poured and the residue remaining in the tubes will be weighed and used to calculate water absorption capacity.

$$(\mathrm{WAC}) = \frac{\text{weight of tube after dicantation} - \text{centrifuge tube } (\mathrm{w2}) - \text{initial wright}(\mathrm{w1})}{\text{initial wright}(\mathrm{w1})} \quad (3.5)$$

3.8.2. Oil Absorption Capacity

Oil absorption capacity will be determined according to Ohizua *et al*., (2017). One gram of flour was mixed with 10 ml refined oil in a centrifuge tube and allowed to stand at room temperature (30 ± 2°C) for 1 hr. It will be centrifuged at 1600 x g for 20 min. The volume of free oil was recorded and decanted. Fat absorption capacity was expressed as ml of oil bound by 100 g dried flour.

$$\mathrm{OAC}(\%) = \frac{\text{Amount of oil added} - \text{Free oil}}{\text{Weight of sample}} \times \text{density of oil } \times 100 \qquad (3.6)$$

3.8.3. Foaming Capacity and Stability

Foaming capacity and stability were determined according to Ohizua *et al.*, (2017). About 2g of flour was weighed and added to 50 ml of distilled water in a measuring cylinder. The flour water suspension was mixed and shaken for 30 sec and the total volume was recorded.

$$(\mathrm{FC})\% = \frac{\text{Volume after shaking } (\mathrm{V2}) - \text{volume before shaking}(\mathrm{V1})}{\text{volume after shaking } (\mathrm{V2})} \times 1003.6 \qquad (3.7)$$

$$(\mathrm{FS})\% = \frac{\text{Volume after standing } (\mathrm{V2}) - \text{volume before shaking}(\mathrm{V1})}{\text{volume after shaking } (\mathrm{V2}) - \text{volume before shaking}(\mathrm{V1})} \times 1003.7 \qquad (3.8)$$

3.8.4. Swelling Capacity

Swelling capacity was determined by the modified method described by Okolo, (2019). The samples were filled up to 10ml marking a 100ml graduated cylinder and water will be added to adjust the total volume to 50 ml mark. The top of the graduated cylinder was covered tightly and mixed by insertion of the cylinder. The suspension was inverted once again after 2 minutes and allowed to stand for a further 30 minutes. The volume occupied by the sample was taken after 30 minutes.

$$SC = \frac{\text{Volume before soaking } - \text{Volume after soaking and centrifugation}}{\text{Weight of sample}} \tag{3.9}$$

3.9 Pasting Properties of Flour Blends

The pasting property was determined using the Rapid Visco Analyzer (RVA-4500 Perten Instruments Australia Pty. Ltd., Macquarie Park NSW, Australia) as described by (AOAC, 2000). The sample was turned into a slurry by mixing 3 g of the sample with 25 ml of water inside the RVA can. The can was inserted into the tower, which will then lower into the system and the slurry will heat from 50°C to 95°C and cool back to 50°C within 14 min. Finally, the parameters were estimated as peak, trough, final, breakdown, and setback viscosities, pasting temperature, and time to reach peak viscosity.

3.10 Rheological Properties of Dough

3.10.1. Farinograph Properties

Farinograph properties of wheat and composite flur was determined by Brabender Farinograph R-E, (Model 810130 USB/230V/ 50-60Hz, Duisburg,Germany). A 300g of flour each flour was prepared and placed into the corresponding farinograph mixing bowl. Water from a burette was added to the flour and mixed to form a dough. As the dough was mixed, the farinograph records a curve on a graph, and the amount of water added (absorption) affected the position of the curve on the graph paper, less water increased dough consistency and moved the curve upward, then the curve was centered on the 500-Brabender unit (BU) line ±20 BU by adding the appropriate amount of water and is run until the curve leaves the 500-BU line (Rosales-juárez *et al*., 2008).

3.10.2. Falling Number

The falling number values were determined using a falling number device (model 5100 falling number meter). The falling number method (Abebaw Tsegaye, 2020) was followed for the determination of ᾱ-amylase activity for each blend and wheat flour using the falling number apparatus. Seven grams of flour was added to 25 g water in a special glass tube and shaken to aid dispersion. The tube and its contents are heated in boiling water for 60 sec. The viscosity of the gel at the end of the heating time was assessed by allowing the special stirrer plunger to fall through the gel. The total heating time (60 sec) plus the time the plunger took to fall the set distance through the gel is termed the falling number.

3.11 Proximate Analysis flour

3.11.1. Moisture Content

The moisture content of the sample was determined according to AOAC, (2005). This was done by washing a moisture dish and drying it to a constant weight in an oven at 100 °C and cooled in a desiccator then it was weighed again. The initial weight was coded (W1). About 2 g of the sample in each experiment was placed in each weighed moisture dish and reweighed. The weight in each case was represented as (W2). The moisture dish containing the sample in each case was kept in an oven at 130 ºC for 60 min, until when dried and then weighed. It was kept back in the oven and reweighed after about 1 h to ensure a constant weight (W3). Then the moisture content was calculated as follows:

$$\%\ \text{Moisture content} = \frac{w_2 - w_1}{w_3 - w_1} * 100 \qquad (3.10)$$

Where

W1 = weight of the empty dish

W2 = weight of dish and sample before drying

W3 = weight of dish & sample after drying

3.11.2. Ash Content

The ash represents the organic component of the sample after all moisture has been removed as well as the organic material. The crucibles were cleaned and dried in a muffle furnace at 550°C for 30 min. The dried crucibles were cooled in a desiccator for 30 min and weighed (W1). About 2.5 g of fresh sample was weighed in dried and cooled crucibles (W2) and charred on a hot plate under a fume-hood at 370°C until smoking ceases. Finally, the sample was ash in the muffle furnace at 550°C for 5 hr. followed by cooling and reweighing (W3) (AOAC, 2005) official method. And calculated as

$$\%\text{Ash content} = \frac{w_3 - w_1}{w_2 - w_1} * 100 \qquad (3.11)$$

3.11.3. Crude Protein

The crude protein of the flour was determined using the Kjedahl method (AOAC, 2004). One gram of each sample was introduced into a digestion flask. The Kjedahl catalyst was then added to the sample. 20 ml of concentrated sulphuric acid was added to the sample and fixed to the digester for 8h until a clear solution was obtained. The cooled digest was transferred into a 100 ml volumetric flask and made up to mark with distilled water. The distillation apparatus was set and rinsed for 10 minutes after boiling. 20 ml of 4% boric acid was pipetted into a conical flask. Five drops of methyl red were added to the flask as an indicator and the samples were diluted with seventy-five mils distilled water. 10ml of the digest was made alkaline with 20ml of NaOH (20%) and distilled. The steam exit of the distillatory was closed and the change of color of the boric acid solution to green was turned. The mixture was distilled for 15min and the filtrate was titrated against 0.1 N hydrochloric acid, HCl. Then finally protein value was determined using 6.25 as a conversion factor, and the result was expressed as an amount of crude protein.

$$\%\ \text{Crude Protein} = \%\text{N2}\ \frac{\text{N}_{14}\text{v}_\text{f}\text{T}}{\text{w}\cdot 1000\cdot \nu_\text{a}}\cdot 6\cdot 25 \qquad (3.12)$$

Where W = weight of sample analyzed, T = titrable value blank,

Vf = Total volume of digest,

N = Concentration of H2SO4 titrant,

Va = Volume of digest distilled

3.11.4. Crude Fiber

Determination of Crud Fiber The fiber content of the sample was determined using a method of the official method of AOAC, (2005) . 2 g of sample was weighed into a fiber digester crucible as W1. The sample was digested with 1.25 % H2SO4 followed by digestion with 1.25 % of NaOH. At each digestion step with the acid and the alkaline, the sample was washed with distilled water three times. After digestion was completed the sample was dried in an oven at 130 o C for 1 hr. and the weight was recorded as W2. Then the sample was ashed on a muffle furnace at 550 o C for 4 hrs. and weighed (W3). Finally, the fiber content of the sample was calculated as;

$$\text{Crude fiber }(\%) = \frac{\text{weight of sample \& crucible} - \text{weight of ash \&cucible}}{\text{weight of sample}} \times 100 \qquad (3.13)$$

3.11.5. Crude Fat

Crude fat was determined according to AOAC, (2005) Clean and dried thimble was weighed (w_1) and 5g oven-dry flour was added and reweighted (w_2). The round bottom flask was filled with petroleum ether at 40 to 60 ºC up to ¾ of the flask. The Soxhlet extractor was fixed with a reflux condenser to adjust the heat sources and the solvent boils gently. The samples in the thimble were inserted into the Soxhlet apparatus and extraction under reflux was carried out with petroleum ether for 6 hours. After the barrel of the extractor was empty, the condenser was removed and the thimble was removed, taken into the oven at 60 ºC for 1 hour, and later cooled in the desiccator and weighed again (w_3)

$$\%\text{fat} = \frac{\text{weight loss of sample (extracted fat)}}{\text{the original weight of the sample}} \times 100 \qquad (3.14)$$

3.11.6. Carbohydrate

The total amount of carbohydrates in the sample was determined by subtracting the sum of the proximate from one hundred (Evanson Inyang & Ekop, 2015)

$$\%\text{Utilizable Carbohydrate} = 100 - \%\text{fat} + \%\text{cruid protien} + \%\text{ ash} + \%\text{cruid fiber} + \%\text{moisture}$$

3.11.7 Energy Determination

The energy content of the samples was estimated by multiplying the number of grams of carbohydrates, protein, and fat by 4 kcal, 4 kcal, and 9 kcal, respectively. Then add the results together per 100 g of flour (Evanson Inyang & Ekop, 2015).

3.11.8 Minerals Concentration

To determine the mineral content, the method outlined by AOAC, (2000) was employed, utilizing an atomic absorption spectrophotometer (AAS). Specifically, iron, magnesium, calcium, and zinc were measured at wavelengths of 248.52 λ, 285.49 λ, 422.81 λ, and 214.11 λ, respectively.

3.12 Bread Product Development

The bread was formulated as described by Codină *et al*., (2019) and contained 100 g wheat-faba bean composite flours (mixed in wheat:roasted broad bean ratios of 70:30 with different milling fraction) and, commercial compressed yeast Saccharomyces cerevisiae type (3% flour basis), sodium chloride (2% flour basis) and water for wheat flour 56.57% and 57.9%,58.1% and 54.2% for small, medium, and largest particle size roasted fabean composite flour respectively. All the ingredients were mixed at the speed of 200 rpm for 15 min in a laboratory mixer. Then, the dough samples were molded and placed into loaf pans and were placed for 60 min. Finally, the samples were baked in an oven for 30 min at 180℃ Bread samples were cooled for 2 h, and then subjected to physical and sensory analysis.

3.13. Bread Quality Analysis

3.13.1. Loaf Volume and Weight

The loaf volume of bread was measured using rapeseed replacement (Koksel, Sivri, Ozboy, Basman, & Karacan, 2000). After 15 min from the oven, the loaf was put in a metallic container with known volume (VC). The container was topped up with rapeseed, the loaf was removed and the volume of the rapeseed was noted (VR). Loaf volume (VL) could then be calculated and recorded according to

$$\mathrm{VL(ml)} = \mathrm{VC} - \mathrm{VR} \qquad (3.15)$$

After cooling for 1 h, the same loaves used for measuring volume, were weighed on digital scales W (g), The Specific volume (VS) of bread was calculated as

$$\mathrm{Vs}\left(\frac{\mathrm{ml}}{\mathrm{mg}}\right) = \frac{\mathrm{VL}}{\mathrm{W}} \qquad (3.16)$$

3.13.2. Color

The Color of composite flour and bread was determined by using Minolta colorimeter (3NH technology Co;LTD china). and each color from three coordinates in the color space observed.: L* (luminosity), a* (red-green), and b* (yellow-blue) (Aranibar *et al*., 2018)

3.13.3. Texture Of Crumb

The texture of the crumb was evaluated according to AACC, (2000), after ninety minutes of coming out of the oven, crumb texture was analyzed with a texture analyzer. A return distance of 30 mm, 5 g trigger force, and a 36 mm diameter cylindered aluminum probe(p/36) were used. Three 2.5 cm thick slices measure from one loaf out of each batch. and a mean value was calculated for each loaf.

3.13.4. Sensory Evaluation Of Bread

Sensory evaluation was conducted for the freshly baked breads by 15 semi-trained panelists consisting of male and female students and workers, from the Food Process Engineering at Wolkite University. The bread made frome composie flour were presented randomly in identical containers, and coded with WRFL,WRFM, and WRFS, for bread made from a mixture of large, medium, and small sieve sizes of roasted fava bean wheat flour respectively and wheat flour was used as control. The sensory test was conducted, and the overall acceptability, appearance, color, flavor, and texture of the samples were evaluated on a nine-point hedonic scale, scoring from 1=extremely dislike, 2= dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like, 8-=like very much, 9=extremely like

3.14. Experiential Design And Data Analysis

The purpose of this study was to determine an acceptable milling fraction and roasting temperature for fava beans to increase the nutritious content of wheat flour. Thirteen treatments were created using response surface methodology (RSM) and Central Composite Design (CCD), with temperatures ranging from 130 to 150°C and times ranging from 15 to 25 minutes. The protein, phytic acid, and tannin content of fava beans were examined to determine the optimal time and temperature. The model equations in terms of coded factors (A and B) for time and temperature respectively can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels are coded as -1, and the data was statistically analyzed, and three-dimensional graphics were created using RSM. Model adequacy was evaluated by model analysis, the lack-of-fit test, R-squared, Adj-R-squared, coefficient variation (CV%), standard deviation, Precision R-squared, Adj-precision, and F-test (coefficient of determination) analysis. RSM described the behavior of the response variable as a function of the regression variables that were explained by utilizing the equation (3.16) and equation (3.17), which express the desired experimental output nature of the response surface was demonstrated using CCD in RSM to explain the amount of optimization for the two independent variables with second order quadratic model by connecting the answer (Y) to the two independent components (Saeed *et al.*, 2015).

$$Y = \beta_{1X_1} + \beta_{2X_2} + \beta_3 X_3 + \beta_4 X_4 + \beta_{12} X_1 X_2 + \beta_{13} X_1 X_3 \qquad 3.17$$

Where y = the predicted variable, x1,2,3,4 = the time and temperture combination, β′s = the coefficient of the linear and quadratic terms of the model

$$Y = \beta_0 + \sum_{i=1}^{n} b_i X_i + \sum_{i=1}^{n} b_{ii} X_{i^2} + \sum_{i=1}^{n-1} \quad \sum_{j=i+1}^{n} b_{ij} X_i X_j \qquad 3.18$$

where Y is the predicted response function, β0 represents the constant term (offset), βi and βii express the coefficient of the linear and quadratic result, respectively, X_i and X_j represent the coded value of variable i, j, and β_{ij} expresses the interaction coefficient effect parameters related to the experiments.

After determining the optimal parameter, wheat flour was blended with fava bean milling fraction and tested. The interval of the milling fraction was chosen from the literature, and a experimental investigation was done using wheat-roasted fava bean bread. Mini-tab Statistical Software (version 20) was used to analyze the impact of roasted fava bean milling size (0.6-0.4mm, 0.4-0.3mm, and 0.3-0.15) on wheat flour's pasting, rheological, proximate, and functional properties. Results were expressed as mean values ± standard deviations. Statistical significance was determined at $\alpha = 0.005$. When one way ANOVA revealed significant differences, Tukey's comparison was used to determine where sample differences existed in the correlations between flour and dough variables and bread quality

4. RESULTS AND DISCUSSION

4.1. Nutritional and Anti-Nutritional Components of Roasted Fava Bean

In this study, the oven-roasting method was used to investigate the effect of roasting temperature and time on the protein, fiber, tannin, and Phytic acid content of fava beans. The experimental design used for variance determination was response surface methodology (RSM) with central composite design (CCD). The best model was chosen based on its low standard deviation, low predicted sum of squares, and high R-squared. and 4.2 indicates The Cook's distance, Leverage , and difference in fits (DFFITS) for protein, fiber, presented in Figure 4.1 and for tannin, and phytic acids in Figure 4.2, and there is no out lines or unexpected error in all response.

4.2 Fitting for the Best Model

4.2.1 Effects of Variables on Protein, And Fiber

The results of protein and fiber content of roasted bean flour at various temperatures and times were summarized in Table 4.1. Several researchers explained the protein and fiber content of roasted legumes depend on roasting time and temperatures (Olanipekun *et al*., 2015).

A quadratic model for protein and crude fiber was proposed by the design program for this response to test for their adequacy and to describe their variation with independent variables. All statistical analyses including the ANOVA test, post ANOVA statistics, Lack of Fit test, Normal plot of residuals, etc. were done similarly. All the tests indicated that the model was statistically acceptable. The Model F-value for protein, and crude fiber 14.74, and 57.63 respectively implies the model is significant. There is only protein (0.13%), and fiber (0.01%) content chance for an F-value. This could occur due to noise, and also P-values less than 0.05 indicate model terms are significant. In this case, AB, A^2, and B^2 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant.

Lack of Fit is not significant relative to the pure error. There is a 67.50% chance for protein and a 14.7% chance for fiber that a Lack of Fit, F-value this large could occur due to noise hence non-significant lack of fit is a good (Awolu, 2017). The coefficients of the model and other statistics are given in the appendix. The R^2 and Adjusted R^2 values of the model were 0.68 and 0.85 for protein and 0.98, and 0.95 for fiber respectively. The adequate precision value of protein and fiber 10.795 and 19.19 respectively indicated that the model could be used to navigate the design space as it was greater than 4.0 (Montgomery, 2001), and a multiple regression model of both protein and fiber vs time and temperature yielded the following fitted model equations.

$$\text{Protein} = 27.13 - 0.183 * \text{A} + 0.0383 * \text{B} - 0.6125 * \text{AB} - 0.4622\text{A}^2 - 0.722 * \text{B}^2 .. (4.1)$$

$$\text{Fiber} = 9.4 + 0.0983 * \text{A} - \text{o}.7183 * \text{B} - 0.05 * \text{A} * \text{B} + 0.2891 * \text{A}^2 + 1.34\text{B}^2 \ldots\ldots\ldots (4.2)$$

Where A: Time (minute), B: Temperature (°C), AB: Time * Temperature

The increase in roasting time increased sicnificantly protein content, whereas the roasting temperature did not show a significant difference on protein content, and both time and temperature signifficntly affect the fiper content of bean flor. From equation (4.1)the coefficients of A^2, and B^2 were negative therefore they will show a negative quadratic effect on protein, in other hands in equation (4.2), A^2 and B^2 were positive, so it will show positive quadratic effect.

The highest protein value was in flour from beans roasted at 140°C for 20 minutes (27.34%). Variations in roasting temperature and time significantly ($p < 0.05$) affected the protein content of the roasted flour. The protein content of fava bean increased by 0.16% to 7.08% for temperature (130,140°C) and time (15, 20,25min). Similarly, a significant increasing at ($P \leq 0.05$) in protein content was reported during roasting tigernut from raw (4.275) to roasted (7.57%) tigernut flour, and kidney bean 20.92% to 25.24%, the increase in protein content for roasted sample may due to increase the activity of the proteolytic enzyme, which hydrolyze the protein content of the sample into amino acid and peptides (Olanipekun *et al*., 2015).

The level of protein was decreased at (150 °C) roasting temperature, and time (25min). A similar decreasing for Bambara Groundnuts (Ndidi *et al*., 2014), black soya beans at 180°C for 10 sec (Chauhan *et al*., 2022), and also (Y. Kumar & Sharanagat, 2021) found a decrease in the protein content of black Chickpea, roasted by micro wave at 600 W for 10 min may due to denaturation of some protein and loss of nitrogenous volatile compounds due to high heat treatment. According to Farinde *et al*., (2018) the protein digestibility increased with a decrease in protein content which was studied on the roasting and cooking of lima beans.

Table 4. 1 The response value for protein, fiber, tannin, and phytic acid

run no	A: time (min)	B:temperature° C	Protein (%)	Fiber (%)	Tannin (mg/100g)	Phytic acid mg/100g
1	20	150	26.51	9.84	6.449	663.8
2	25	130	26.47	11.85	6.84	788.94
3	20	140	27.29	9.56	6.77	658.48
4	20	140	27.27	9.48	6.99	648.65
5	20	140	27.26	9.32	6.75	658.54
6	15	140	26.59	9.75	7.73	729.74
7	20	130	26.15	11.63	9.52	763.67
8	15	130	25.57	11.48	9.99	799.75
9	20	140	27.34	9.22	9.87	648.93
10	25	150	25.18	10.58	6.29	640.82
11	25	140	26.59	9.62	6.75	667.71
12	15	150	26.73	10.23	6.99	749.84
13	20	140	26.66	9.45	7.15	657.86
Control			25.53	8.86	11.64	810.01

The control values for all response were raw faba bean flour

Fiber is important for a human diet to contribute to gastrointestinal tract health and prevent colon cancer (Olanipekun *et al.*, 2015). The influence of roasting time and temperature on dietary fiber is illustrated in Table 4.1. The total dietary fiber content of roasted beans varied from 9.22% to 11.89 in roasting temperature and time 140°C,20m, and 130°C, 25min respectively. An increase in roasting time significantly ($p<0.05$) increased dietary fibers. These observations are comparable with black chickpea (Y. Kumar, and Sharanagat, 2021), and Marble vine (Ajatta *et al.*, 2021). Cooking, boiling and microwave heating legumes leads to increases in the soluble fiber fraction and decreases in the insoluble fraction due to the partial substitution of hemicellulose and insoluble pectin substances is reported by Tosh, and Yada, (2010).

High fiber content in the diet might assist enhance food digestion, and regulate serum lipids and glycemic index, consequently lowering the risk associated with high cholesterol and chronic heart disease (Chen *et al.*, 2020). Beans' high protein and low sugar content contribute to the formation of resistant starch from amylose-lipid complexes and Millard-reaction products during cooking contributed to increasing insoluble dietary fibers (Byarugaba *et al.*,2023).

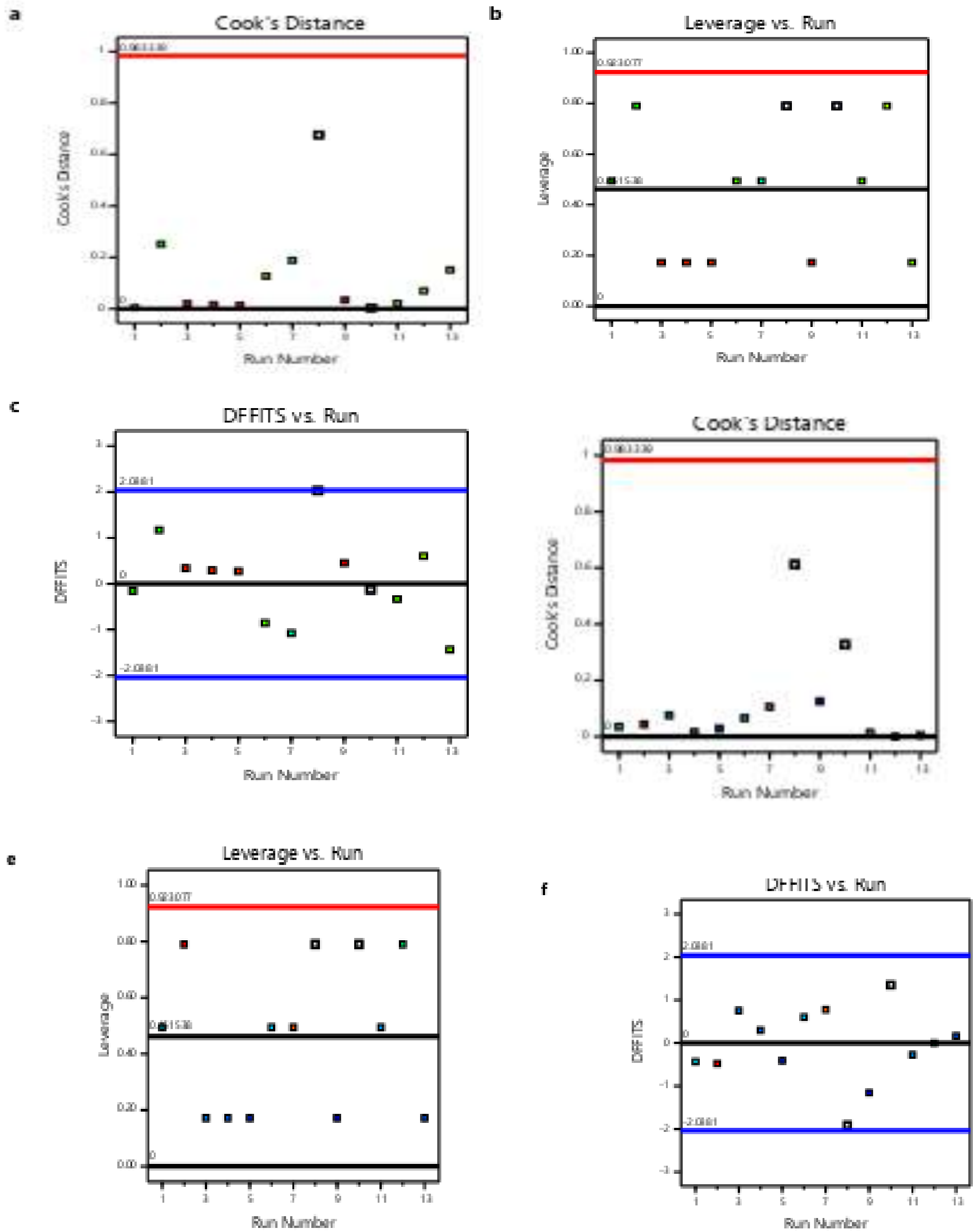

Figure 4. 1 Cook's distance, Leverages, and difference in fits (DFFITS) for proatien (abc), Fiber (def) model

4.2.2. Effects of Variable on Tannin, and Phytic acid

According to (Khattab & Arntfield, 2009), the roasting process improves the nutritional value of legumes by lowering the initial Phytic acid and tannin levels, which is significant for protein and mineral absorption. The Model F-value of tannin and Phytic acid content of roasted bean flour 5.58 and 252.34 respectively indicates that the models were significant ($P < 0.05$). R^2 0.5273), and (0.9945) and also Adjusted R^2 (0.4328), and (0.9905) for tannin and Phytic acid respectively were in reasonable agreement. In addition, the adequate precision (7.9322) for tannin and (41.1286) are greater than 4, indicating a good fit of experimental data and the acceptability of the model for prediction purposes. The model coefficients and other statistics were provided in Table 4.2. Using these criteria, the following response models were chosen to reflect the change in tannin and Phytic acid concentration in roasted bean flours with independent variables of temperature and time.

$$\text{Tannin content} = +26.21431 - 0.161000 * \text{A} - 0.110350 * \text{B} \ldots\ldots\ldots..(4.3)$$

$$\text{Phytic acid} = 656.30 - 30.31 * \text{A} - 49.65 * \text{B} - 24.55 * \text{AB} + 37.89 * \text{A2} + 52.91 * \text{B2} \ldots (4.4)$$

The coefficients of A and B were negative. Therefore, an increase in roasting temperature and time may decrease the tannin, and Phytic acid content of bean flour (equation 4.3, and 4.4,). The tannin content indicates a leaner model but the Phytic acid content shows a quadratic model, the coefficients of A^2, and B^2 were positive, therefore it shows a positive quadratic effect. The various roasting temperatures and times affect the tannin content of the bean (Table 4.1). The coefficients for A and B were negative. Thus, increasing the roasting temperature and time may reduce the tannin and Phytic acid concentration of bean flour (equations 4.3 and 4.4) respectively. The tannin content implies a leaner model, but the Phytic acid content indicates a quadratic model; the coefficients of A2 and B2 were positive, implying a positive quadratic effect.

The tannin content of raw bean (11.64mg/g) is almost comparable with the previous report of raw fava bean in the range of 12.2–16.2 mg/100g (Rahate *et al*., 2021).In this investigation, the reduction in tannin content of the bean was recorded between (14.18%-44.6%) which agrees with tiger nut, (Oladele *et al*., 2009), and Bambara groundnut (Ndidi *et al*., 2014). (Luo & Xie, 2013) reported, due to higher temperatures the degradation or formation of insoluble complexes may decrease in tannin content of both green (59.2%) and white fava bean seeds

(67.3%,) by dehullnig, and soaking following cooking methods by (56.9–65.7%), and (24.0–28.5%) respectively, which was similar decreasing for red kidney bean by soaked or boiled may due to tannin leaching out of the seed into the treatment (Godrich *et al*., 2022).

Table 4. 2 ANOVA illustrating linear, quadratic, and lack of fit of the response variables, and Predicted and experimental value

Column1	Protein	Fiber	Tannin	Phytic acid
Model (P value)	<0.0001	0.001	0.024	<0.0001
Model(F value)	14.74	57.63	5.58	252.34
R2	0.98	0.9	0.53	0.99
Adjusted R2	0.96	0.85	0.44	0.99
Predicted R2	0.82	0.68	0.27	0.97
C.V	1.81	0.68	1.35	0.97
Lack of fit (P value)	0.66	0.15	0.92	0.35
Lack of fit(F value)	0.5	3.17	0.28	1.48
Standard deviation	0.19	0.25	7.55	5.78
A (P value)	0.33	0.24	0.08	<0.0001
A (F value)	1.09	1.64	3.87	168.28
B (P value)	0.72	<0.0001	0.02	<0.0001
B (F value)	0.13	87.7	7.28	451.51
AB (P value)	0.002	0.96	-	<0.0001
AB (F value)	23.15	0.003	-	73.61

Predicted and experimental value

Response	predicted value	Experimental value
Protein (%)	26.34	25.85+-0.05
Fiber (%)	10.04	11.65+-0.01
Tannin (mg/g)	6.33	6.85+-0.01
Phytic acid (mg/g)	652.7	651.68+-0.002

P<0.05 is significant, P > 0.05 is not significant; C.V, coefficient of variation, A;time, B temperature

In this study, the phytic acid content of raw fava beans were (810mg /100g), which is lower than previous studies for chickpeas (943–990 mg/100), and for raw kidney bean (1158–1188 mg/100 g) (Godrich *et al*., 2022), and higher than lentils (675 mg/100 g)), Green pea 543 mg/100 and yellow-pea flour 574 mg/100 g (Kim A Millar & Gallagher, 2019). Roasting time and temperature of fava beans failed to cause significant changes in phytic acid levels which reduced phytic acid in fava beans by (1.27-20.9%), which was similar to findings previously reported in the roasting and popping of chickpeas, and red kidney beans, these reductions is may due to heat sensitive nature of Phytic acid and the formation of insoluble complexes between phytates and other components (Olanipekun *et al*., 2015). Oladele *et al*., (2009) reported toasted tigurnut reduced by up to 40% because more moisture was lost when the toasting time was increased. The higher phytic acid binds all the essential minerals such as calcium, magnesium, iron, and zinc, which imparts the availability of all these nutrients in the digestive tract Rahate *et al*., (2021), and it is important to slow down the rate of digestion of carbohydrates which lowers blood glucose, and the lower PA protects cancer and cardiovascular diseases (Farinde *et al.*, 2018).

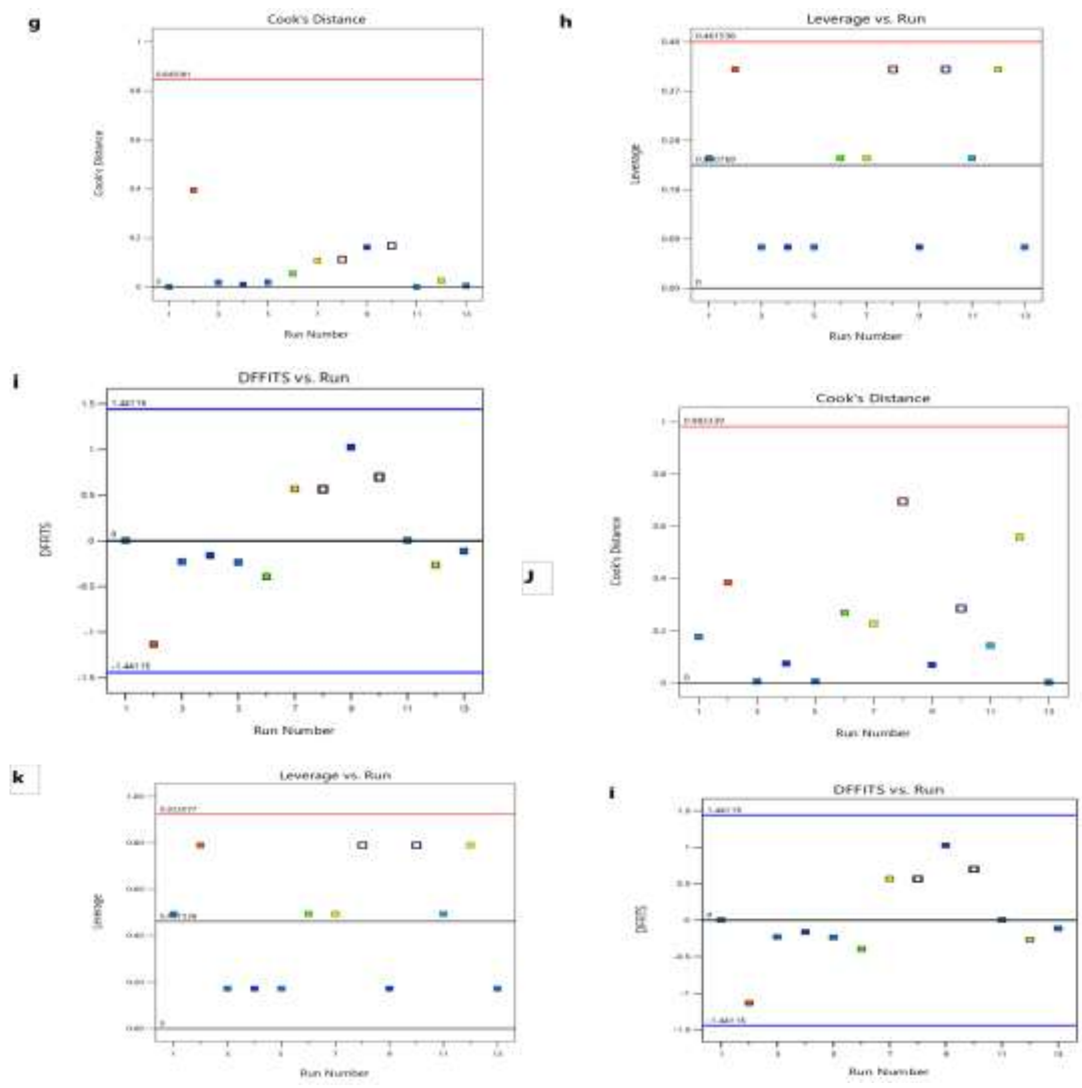

Figure 4. 2 Cook’s distance, Leverages, and difference in fits (DFFITS) for Tannin (ghi), and phytic acid (jkl) model

4.2.3. Optimized Level of Nutritional, and Anti-Nutritional Value

The numerical optimization of roasting parameters were carried out using Design-Expert statistical software based on the initial experimental results. Our target was to obtain the highest yield of protein and fiber, and also lowest yield of tannin and Phytic acid content of roasted fava bean. The numerical response analysis found the opbtimum values were 26. 32%, 10.04%, 6.33mg/100g, and 652.702mg/100g with a desirability of 0.626 (Fig.4.3) for protein, fiber, tannin, and phytic acid respectively. The experiment was conducted according to the predicted and optimal conditions of 20.691 min, and 150.0 °C temperature. The adequacy of the model in predicting the response efficiently was verified by comparing the observed and predicted values of the responses (Table 4.2), and both the predicted value and exprimental value were almost comparable.

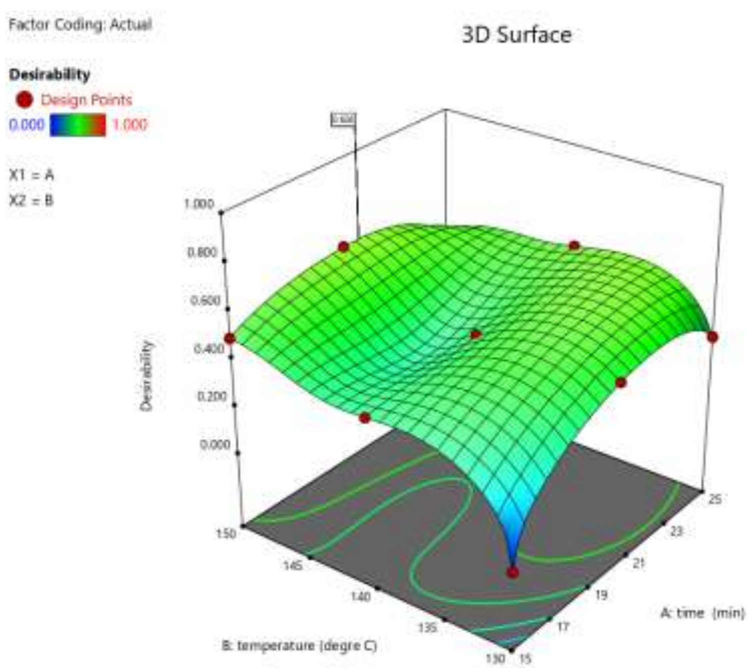

Figure 4. 3 Optimized 3D plot of desirability function

4.3. Particle Size Distribution of Roasted Fava Bean

Changes in particle size distribution impact the flour properties like functional and physicochemical properties (Kim A Millar & Barry-Ryan, 2019), and rheological and pasting properties of various flour (Ahmed *et al.*, 2016), and particle size distribution of flour. It is important for the application of bakery products (Science *et al*., 2015). Hence it is important to consider the particle size of flour for the development of fortified bread.

The mean value of particle size distributions of roasted fava bean flour obtained in this study were 9.09%, 42.6%, and 48. 473 % for L, M, and S (0.6-0.4, 0.4-0.3,0.3-0.15mm) sieve sizes respectively as shown in Table 4.7. The data indicated that as the mesh size decreased the percentage of flour retained increased and about 90% and 10% of particle size distribution were between 0.4 and 0.15mm, and 0.6-0.4 mm respectively. Flour with larger particles flows better than with smaller particles, and the large particles having less surface energy to attract with one another tend to adhere together and have less resistance to flow (Raza *et al*., 2019). Therefore, flour with large particle size distributions is important for storage (have a long shelf life).

4.4. Composite Flour Properties

4.4.1. Color

The color values of wheat-roasted bean flour varied with particle size Table 4.3. The brightness (L* value) decreases from wheat flour (95.36±0.067) to the biggest particles (74.62±0.63). There was no significant difference between the highest L* and lowest a* values for small and medium particle sizes, but there was a significant difference for large particles. The reduction in particle size increases surface area and light reflection (Ahmed *et al*., 2015). A positive *a** values characterizes the extent of the reddish component, while a negative value epitomize the greenish component. A positive *b** value indicates a yellowish component, whereas a negative value indicates a bluish component (Wodajo and Emire, 2022) . The yellowness (b*) of the mix decreased as particle size was lowered, The fineness of flour is related to decreases in the pericarp fraction, where most of the flavonoids are normally contained, and therefore decreasing flavonoid content may decrease the yellowness of flour (Shafi *et al.*, 2017).

4.4.2 Gluten Content

Gluten forms when two wheat proteins, glutenin, and gliadin, interact with water while mixing and kneading, and bind together to form a network, providing dough structure, even though legume proteins do not include gluten (Abdelrahim *et al*., 2016). When beans are mixed with wheat flour, they dilute the gluten concentration and influence gluten production quality. The total gluten level in the combination may be reduced, potentially resulting in changes in dough, texture, and baking properties (Boj *et al*., 2021).

In this investigation, the wet gluten concentration of wheat flour was found to be in the previous study's range of 17.35 to 29.65% on the bread (Bieliková & Kraic, 2011). The wet gluten content of the blend ranged from (20.05 to 21.07%), indicating that the milling fraction bean had a significant impact on the gluten content of wheat flour (23.87%), and the mean did not show a significant difference between small and medium particle size, but there was a significant difference with the largest particle size, as shown in Table 4.3. Similarly, the decrease in gluten concentration with increasing the degree of legume brane was investigated using chemical composition. Therefore, a decrease in gluten content in large particle size may be due to increases in its brane (Abdelrahim *et al*., 2016).

Table 4. 3 particle size distribution of roasted fava bean , and Color, and Gluten content of composite flour

	particle size distribution of roasted fava bean		
Sieve size	**L**	**M**	**S**
Value%	9.09 ±0.01	42.6±0.44	48.47±0.05

	Color and Gluten content of composite flour			
Sample code	**Gluten content(%)**	**L^***	**a***	**b^***
WF	23.87±0.23[a]	95.36±0.067[a]	-95.07±6.7[c]	16.38±0.15[d]
WRFL	20.05±0.18[c]	74.627±0.63[c]	-8.113±0.67[a]	55.65±2.92[a]
WRFM	20.99±0.01[b]	89.49±3.28[b]	-54.41±4.05[b]	41.89±4.7[c]
WRFS	21.07±0.07[b]	85.83±0.59[b]	-52.8±3.52[b]	51.72±1.92[b]

All values are mean of triplicates ±standard deviations L, (0.6-0.4mm); M, (0.4-0.3mm); S, (0.3-0.15mm), WF: wheat flour as acontrol; WRFL:wheat-roasted bean blend with (0.6-0.4mm); WRFM: wheat-roasted bean (0.4-0.3mm) blend; WRFS: wheat-roasted bean (0.3-0.15mm) blend; L*brightness, a*redness, and b*yellowness

4.4.3. Functional Properties

The functional properties of wheat flour and roasted fava bean flour at different milling fraction is illustrated in Table 4.4. Wheat flour showed the highest foaming capacity and lowest foaming stability, and a small particle size blend showed a high water solubility index (38.6±2.29) and foaming stability (10.5±0.69%). The foaming capacities and foam stabilities depend on protein concentration and interaction of several proteins with starch and the dissolution of fats (Kaur & Kaushal, 2013).

The increase in water solubility index in wheat-raw faba bean was reported by Aprodu *et al*., (2019). The lower amount of soluble protein and polar and non-polar lipids in composite flour are responsible for low foaming capacity (Bamigbola *et al*., 2016). The highest (11.71±0.07), and smallest (9.12±0.09) swelling power was recorded in medium , and largest particle sizes respectively, and the smallest and medium particle sizes did not show a significant difference (α=0.005). The swelling capacity of millet-wheat flour increases as the millet flour level increases, which indicates the extent of associative forces within the composite flour granules (Adegunwa *et al*., 2014). (Jan *et al*., 2022) suggested that the higher swelling power in flour indicated good organoleptic characteristics in terms of mouthfeel.

Table 4. 4 Functinal Properties of wheat flour, and its blend

sample code	**Foaming capacity (%)**	**Foam stability (%)**	**Sp (g/g)**	**WSI (%)**	**OAC%**
WRFL	5.94±0.07[b]	10.5±0.69[a]	10.55±0.00[a]	38.6±2.29[a]	29.46±0.58[b]
WRFM	6.77±0.0[b]	9.075±0.02[ab]	11.71±0.07[a]	35.37±0.07[a]	32.37±0.07[b]
WRFL	9.1±0.01[a]	7.18±0.67[bc]	9.12±0.09[b]	29.46±0.58[b]	38.6±2.69[a]
WF	9.59±0.7[a]	5.59±0.12[c]	7.55±0.00[c]	32.16±0.4[c]	32.16±0.41[b]

Data presented as means ± standard. Means that do not share a letter are significantly different (α=0.005), WF: wheat flour; WRFS: wheat-roasted bean blend with (0.6-0.4mm); WRFM: wheat-roasted bean (0.4-0.3mm) blend; WRFL: wheat-roasted bean (0.3-0.15mm), FC; foaming capacity, FC; foaming stability, Sp; swelling power, WSI; water solubility index

The highest, and lowest oil absorption was recorded in the largest (38.6±2.69%), and small (29.46±0.58%) particle sizes of composite flour respectively. Different properties of fiber like surface properties, overall charge density, thickness, and hydrophobicity, might increase the oil absorption capacity of the flour (Chareonthaikij *et al.*, 2016). Higher oil absorption capacity (OAC) may represent more hydrophobic groups on the surface of the protein (Ohizua *et al*.,2017). Comparatively flour with higher OAC is favorable in food formulations where an improvement in oil absorption capacity is required (Awolu *et al*., 2015).

4.4.4. Pasting Properties

Table 4.5 shows the pasting characteristics of wheat and wheat-roasted faba bean in various milling fraction blends. Blending wheat flour with different bean milling fractions had a significant (α =0.05) effect on the pasting qualities of wheat flour. The pasting properties of the flour may be influenced by the starch gelatinization and protein combination, which affect mainly the crumb and loaf volume of the final bread product (Kim A Millar & Barry Ryan, 2019).

The mean values of PV, BD, FV, SB, Ptime, and PT for wheat flour in this investigation were nearly identical to those reported in a previous study (Adebayo et al., 2023). PT increases significantly with bean particle size increases. The lowest and maximum PT was measured for WRFM (89.65°C) and WRFL (90.52°C), respectively. Conversly, Shafi *et al*., (2017) showed a decrease in PT when increase the particle size of water chestnut in wheat-waterchestnut blend. In the previous study, the increase in pasting temperature of wheat-chickpea blends may be due to the higher resistance to swelling and rupture of chickpea starch (Mohammed *et al*., 2012), though the lowest pasting temperature requires lower energy to activate the gelatinization process, which is an advantage in backing (Marchini *et al*., 2022), and the high resistance of starch to swell and rupturing leads to the high pasting temperature (Ocheme *et al*., 2018).

The trough viscosity was recorded (673,691, 453, and 524Cp) for WF, WRFS, WRFM, and WRFL respectively, and the highest and the smallest TV values were shown in smallest and middle particle size respectively. Toasting can cause protein denaturation in flours, leading to a high peak and trough viscosity in wheat-pea flour (Kim A Millar & Barry-Ryan, 2019). The coarse particle size of legume flour might act as a physical barriers in the dough matrix, preventing the creation of a cohesive gluten network, and can break gluten strands, resulting in a weaker dough structure and greater viscosity (Shafi *et al*., 2017).

The particle size significantly affects the P_{time}, FV, and SB of the blend at (α=0.005) and the value obtained in this study for SB, P_{time}, and FV increases from (433 to 576Cp), (5.93 to 6.08 minute), and (957 to 1267Cp) with decreasing in particle size of bean in wheat flour blend respectively. Similarly, Shafi *et al*., (2017) reported that increased these parameters with decreasing particle size for wheat-water chestnut flour may be due to the finer flour decrease in fiber, more retrograded than the coarse particle size, (Kim A Millar & Barry-Ryan, 2019) showed the higher proportion of damaged starch, and the shortest peak time may due to increase in gel strength after roasting. A similar decrease was reported by Adegunwa *et al.*, (2014) for a millet-wheat blend which decreases from 6.16 minutes for 100% wheat flour to a different variation of 5.53-6.16 minutes as the level of millet flour increases. Similarly, the incorporation of wheat flour with walnut flour decreases the peak time with an increased level of walnut (Offia-Olua, 2014).

The mixing of wheat flour with roasted faba beans at different milling fractions affects the PV, and BV. Both parameters increase with increased fines of roasted bean, which is similar to (Ahmed *et al.*, 2016). The lowest value of PV, and BD was demonstrated in wheat flour (2023Cp), and (1350Cp) respectively, although the PV value was recorded (2080,2168, and 2718Cp) in the combination of roasted bean with wheat flour in decreasing particle size, and the BD were recorded in WRFM and WRFS (2027Cp) and WRFL (1715Cp). The highest PV value in the finest flour may lead to an increase in the surface area of protein, and starch with a minimum amount of fiber in the flour leads to a different amount of water absorption and a different rate of swelling of starch granules (Ahmed *et al.*, 2015), whereas the highest BD value in smaller particle size may lead to less shear resistance and stability of the flour (Lu *et al.*, 2022), and flour with the highest particles having the lowest values of BD was more resistant to breakdown than a fine particle, and also less BD and SV of flour with coarse particle size makes it suitable for use in products requiring good paste stability (Coțovanu, Stoenescu, *et al.*, 2020).

Table 4. 5 Pasting Poperties of wheat flour , and its blend

sample code	**P_{time}**	**PV**	**TV**	**BD**	**FV**	**SB**	**P_T**
WF	6.13 ± 0.01^{a}	2023 ± 1.5^{d}	673 ± 1.00^{b}	1350 ± 0.1^{d}	1382 ± 1^{a}	709 ± 1^{a}	89.75 ± 0.01^{b}
WRFS	6.0833 ± 0.02^{b}	2718 ± 1.00^{a}	691 ± 1.00^{a}	2027 ± 0.1^{a}	1267 ± 1^{b}	576 ± 1^{b}	88.75 ± 0.01^{d}
WRFM	6.08 ± 0.02^{b}	2168 ± 1.00^{b}	453 ± 0.57^{d}	2027 ± 0.1^{a}	994 ± 1^{c}	541 ± 1^{c}	89.65 ± 0.01^{c}
WRFL	5.93 ± 0.006^{c}	2080 ± 1.00^{c}	524 ± 1.00^{c}	1715 ± 0.1^{b}	957 ± 1^{d}	433 ± 1^{d}	90.55 ± 0.06^{a}

Data presented as means ± standard. Means that do not share a letter are significantly different (α=0.005), WF: wheat flour; WRFL: wheat-roasted bean blend with (0.6-0.4mm); WRFM: wheat-roasted bean (0.4-0.3mm) blend; WRFS: wheat-roasted bean (0.3-0.15mm) blend; PV peak viscosity; TV trough viscosity; BD breakdown; FV final viscosity; SB setback; P time peak time (min); PT pasting temperature (°C), and Viscosity results expressed by in centipoise (cP)

4.4.5 Rheological Properties

4.4.5.1 Farino Graph Property

Rheological properties of flour are used to identify the effect of flour composition on dough qualities essential for generating a good loaf of bread (Zafar *et al.*, 2020), and the inclusion of legumes in wheat flour may dilute the gluten protein and disrupt both gluten formation and interrupted the starch-gluten matrix, resulting in the weaker and less elastic dough for pea flour is related to particle reduction (Millar *et al*., 2019). Farinograph properties of wheat flour and wheat-roasted bean flour at different milling fractions are presented in Table 4.6. Water absorption is essential for hydration and the formation of the gluten network, and it can have an important effect on bread quality (Ocheme *et al*., 2018) substituting bean flour for wheat flour results in a weaker protein network due to reduced gluten content leads to decrease in WA of wheat flour (Atudorei & Gabriela, 2021).

The water absorption capasity of wheat flour was strongly impacted by the milling fraction of beans, with results of (54.2, 57.91, and 58.1) for big, small, and medium particle sizes, respectively. These findings are similar to Wheat-Quinoa Seed blends at various milling fractions reported by Coțovanu *et al*., (2020), due to a variety of parameters such as particle size composition and damaged starch. The interaction of starch and non-starch components including proteins and cell wall matrices may contribute to the increase in flour WA (Rao *et al*., 2015). Dietary fibers, particularly insoluble polysaccharides, and cellulose can reduce WA in coarse particle size (Ahmed *et al.*, 2019). Furthermore, the tiny particle size of non-gluten flour improves water absorption (Ahmed *et al.*, 2015).

Large particle sizes may change bread quality due to poor hydration and integration in the gluten viscoelastic structure (Ahmed *et al.*, 2015). Lower particle sizes, on the other hand, indicated improved water-retention capacity as surface area increased. The role of water in final product quality as a plasticizer has a significant influence on rheological behavior (Sakhare *et al.*, 2013).

The farinograph shows that as particle size reduces, dough stability, and FQN decreases while softening rises. The competition for water between soluble proteins and gluten, along with the likelihood of proteolytic activity, may cause partial disintegration of the protein network, resulting in a loss in stability and DDT. The greatest DDT concentration was discovered in

WRFM (4.4±0.3), the lowest in WRFS (1.1±0.14), and the course particle had the highest stability (4.4033±) followed by midiume particle (3.8±0.2)when compared to finer flour.

DDT represents a measure of dough strength, the higher it is the stronger the dough (Coțovanu, Batariuc, *et al*., 2020). High particle size dough stability indicates a stronger gluten network might be due to amaranth albumin's interaction with gluten proteins (Coțovanu & Mironeasa, 2021). The highest DDT in mediume flour particles physically more interact with gluten than the finely powdered legume flour blend. This may be due to slowing down gluten development, which can result in extended dough development periods, since the gluten network takes longer to form, on the other hand finely powdered flour particles, can improve dough development by increasing water absorption and stimulating gluten production, potentially decreases the dough development time.

The increase in softness in wheat-legume mixes may be related to the incompatibility of legume protein with wheat gluten (Giménez *et al.*, 2012; Gadallah & Elsheshetawy, 2017) Similarly, the higher the WA content of the finely ground amaranth-wheat flour blend, the softer it becomes softness (Coțovanu & Mironeasa, 2021). Hence the inclusion of finely ground legume flour can improve the softness of the finished product because its larger surface area can absorb more water during dough development; on the other hand, coarsely ground bean flour particles can disrupt the gluten network, resulting in poorer dough structure and softness.

Table 4. 6 Farinograph properties of wheat flpour, and its blends

Sample code	**WAC%**	**DDT (min)**	**Stability (min)**	**Degree of softness**	**FQN**	**FN**
WF	56.57±0.15^{b}	1.5±0.14^{c}	4.03±0.06^{b}	111±1.00^{c}	16±0.01^{c}	396.5±0.1^{a}
WRFS	57.9±0.15^{a}	1.1 ±0.14^{c}	1.2±0.00^{c}	252±0.01^{a}	11±0.87^{d}	340.45±0.3^{b}
WRFM	58.1±0.1^{a}	4.4±0.3^{a}	3.8±0.2^{b}	158±0.02^{b}	49±0.09^{a}	280.5±0.07^{c}
WRFL	54.2±0.1^{c}	2.9±0.007^{b}	4.41±0.02^{a}	85.03±0.38^{d}	29±0.1^{b}	265.75±1.06^{d}

Data presented as means ± standard deviation from triplicate analysis. Means that do not share a letter are significantly different (α=0.005) WF: wheat flour; WRFL: wheat-roasted bean blend with (0.6-0.4mm); WRFM: wheat-roasted bean (0.4-0.3mm) blend; WRFS: wheat-roasted bean (0.3-0.15mm) blend; WA: water absorption; DDT: dough development time; FQN: Farinograph Quality number

The farinograph quality number is a piece of data based on the farinograph test that evaluates dough quality during mixing (IVAN *et al.*, 2018). The incorporation of bean flour with various particle sizes has a considerable effect on the farinograph quality number. The farinograph quality number (FQN) was investigated by using the shape and progression of the farinograph curve, as shown in Figures 4.4, 4.5, 4.6, and 4.7 for WF, WRFS, WRFM, and WRFL respectively. The increased stability and low dough softening value lead to a higher FQN, indicating better dough characteristics and end product quality. (Coțovanu & Mironeasa, 2021) reported the development of gluten, and resistance to softening during mixing are commonly related to desirable baking properties such as excellent gas retention, correct volume, and texture in baked products.

In conclusion, the particle size of the roasted faba bean flour had a significant impact on the pasting properties of the wheat-bean flour blends, the finer bean particles generally leading to higher pasting temperatures, viscosities, and stability. These findings had implications for the use of these flour blends in various food applications, and the rheological properties of wheat-legume flour blends are strongly influenced by the legume flour particle size, which impacts water absorption, gluten network formation, and overall dough quality characteristics necessary for producing high-quality bread.

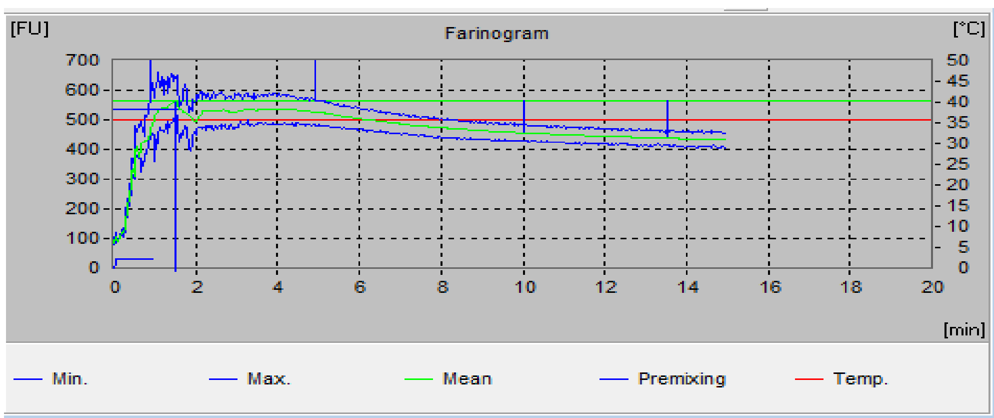

Figure 4. 4 Farinograph results for WF

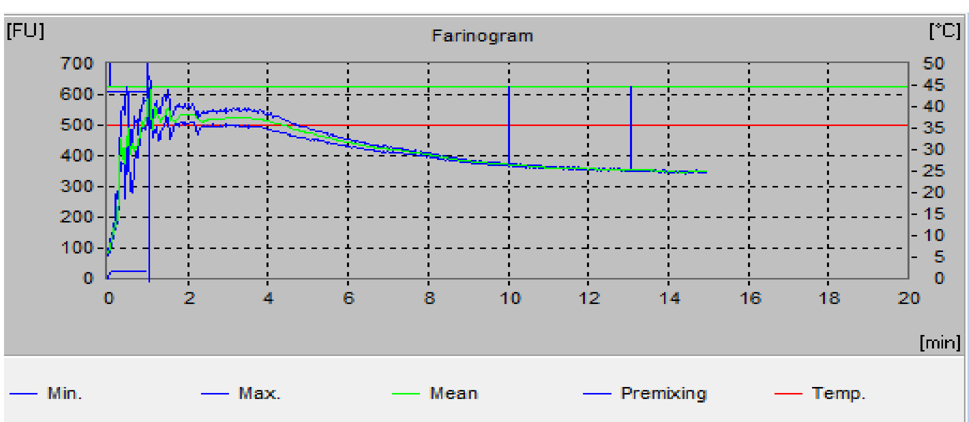

Figure 4. 5 Farinograph results for WRFS

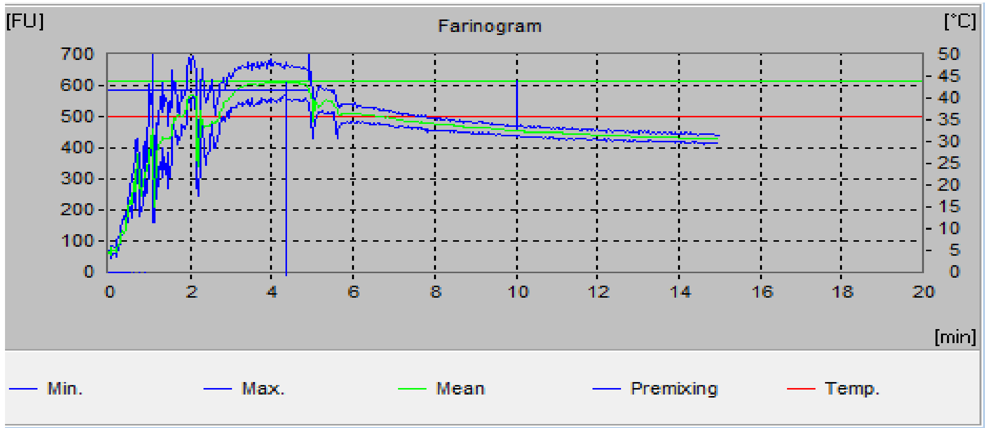

Figure 4. 6 Farinograph results fr WRFM

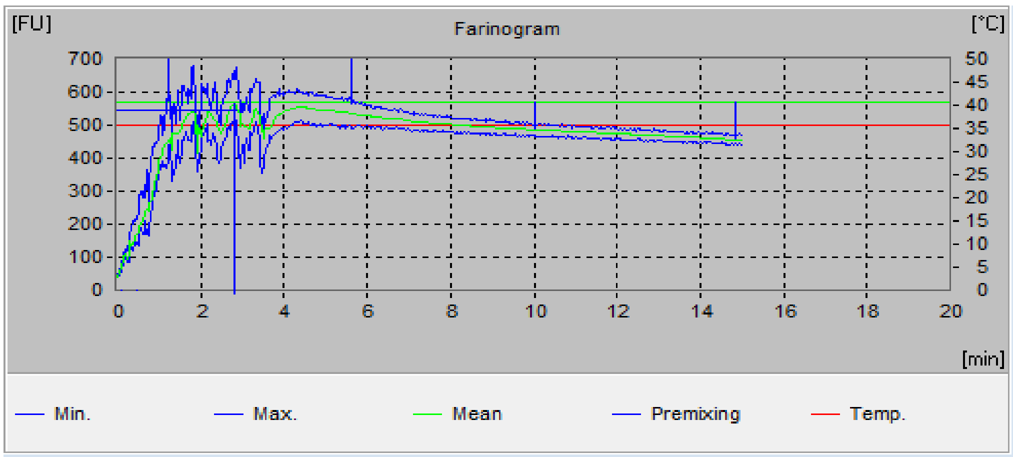

Figure 4. 7 Farinograph results for WRFL

4.4.5.2 Falling Number Value (FN)

Faba bean particle size significantly affected wheat flour FN at (α=0.005) and WRFL, WRFM, and WRFS values (265.75, 280.5, and 340.45, respectively) as illustrated in the (Table 4.6). According to these findings, the FN index increases with decreasing particle size. The FN of smallest, and medium particle size recorded in blow 180s, which was almost comparable with wheat-germinated bean reported by Benayad *et al*., (2021). Similarly Cot & Mironeasa, (2021) reported changing the structure of phenolic chemicals and interacting with α-amylase in the lowest fractions of buckwheat might enhance the FN index of buckwheat-wheat flour. Higher α-amylase activity enhance the fermentation process, leading to increased volume and superior crumb quality (Gadallah & Elsheshetawy, 2017). Therefore the FN value results in this study suggest that finely ground bean flour particles have a higher surface area, resulting in enhanced enzymatic activity, wheile the larger legume flour particles may not contribute significantly to enzymatic activity in the flour may due to lower water absorptio.

4.4.6 Proximate Composition

The chemical composition of applied flour is presented in Table 4.7. The moisture content for all blends was between 8.05 to 8.59 %, and the lowest value was obtained in coarse fraction. The addition of roasted bean flour at different milling fractions showed a significant difference at (α=0.005) with wheat flour, and its blends at different milling fractions but had no significant difference between WRFS with WRFM, and WRFL with WRFM. The lowest moisture content in this study suggested the highest shelf life than the higher moisture content. Moisture content up to 12% is higher storage stability than flour with higher moisture (Cot & Mironeasa, 2021)**.**

The protein content of wheat flour is almost comparable with the previous study reported by Man *et al*., (2015), and the protein content of composite flour decreases as the milling fraction of bean flour decreases, which ranges from 13.66% to 17.87%, and there was no difference at (α=0.005) between fraction WRFM and the other two particles. The protein level of WRFS differed significantly (α=0.005) from that of WRFL but not from wheat flour. On the other hand, the protein content of wheat flour increases with decreasing particle size has been reported for quinoa-wheat flour Coțovanu *et al*., (2020), and buckwheat-wheat flour (Ahmed *et al*., 2019), and the variation in the protein content with particle size is different for different crops, due to variation in the structure and morphology of endosperm (Bala *et al*., 2020). This may be due to the presence of different embryo parts in the milling fractions (Coțovanu & Mironeasa, 2021).

The fat content varies between 1.745 and 2.27%. The middle fraction had a considerably greater fat content (2.27), while the other flours used showed no significant difference from wheat flour. The highest fat content in the fine flour may be due to the suitability of its surface area for fat extraction (Bala *et al*., 2020), whereas the ash percentage of bean flour reduced significantly (α=0.005) from 3.705 to 3.245% with particle size reduction. The smaller and medium fractions did not show a significant difference, similar to previous reports for wheat-water chestnut flour. This indicates that a decrease in ash cantante with fines may be due to a greater association with minerals and crude fiber to starch granules in larger roasted bean fractions than in finer flour fractions which is in agreement with the previous report by Shafi *et al.*, (2017).

The data showed that the fiber, carbohydrate, and energy values of composite flour varied significantly at (α=0.005) with the milling fraction of roasted bean. The amount of CH in wheat flour was comparable with the previous reported Marchini *et al.*, (2021). Flour with large particle size distribution showed lowest carbohydrate content (63.97%), and energy (343.6 kcal/100g), while lowes fiber (6.9%) and highest carbohydrate (68.86%) recorded in finest flour. The hiegest enrgy (349.086 kcal/100g) and fiber (7.91%) values were in medium particle sizes. The reduction in fiber content with decreasing particle size might be owing to more fiber sticking to starch granules in bigger particle sizes, whereas the lowest carbohydrate amount could be related to an increase in protein and ash content (Coțovanu, Stoenescu, *et al.*, 2020). Ni *et al*., (2020) reported the introduction of legume bran in wheat flour lowered total carbons, which may reduce its accessible carbon content. Therefore both finely and course ground bean flour particles increase the fiber content of wheat flour, but the greater size may result in a less equal distribution of fiber in the flour mixtute.

Table 4. 7 Proximate analysis of applied flour

Sample code	**Moisture (%)**	**Ash (%)**	**Protein (%)**	**Fat (%)**	**Fiber (%)**	**CH (%)**	**EN (kcal/100g)**
WRFL	8.05±0.06[c]	3.71±0.8a	17.87±1.5[a]	1.81±0.04[b]	7.6±0.0[a]	63.97±0.01[d]	343.51±0.01[d]
WRSM	8.32±0.02[bc]	3.27±0.09[b]	16.49±0.7[ab]	2.27±0.1[a]	7.91±0.07[c]	65.68±0.01[c]	349.08±0.06[b]
WRFS	8.6±0.08[b]	3.25±0.03[b]	13.66±0.74[bc]	1.75±0.11[b]	6.99±0.01[b]	68.8±0.001[b]	345.75±0.01[c]
WF	10.12±0.2[a]	2.39±0.05[c]	10.29±0.3c	1.61±0.05[b]	1.55±0.01[d]	74.55±0.01[a]	35.81±0.01[a]

Data presented as means ± standard deviation from triplicate analysis. Means that do not share a letter are significantly different (α=0.005), WF: wheat flour; WRFL: wheat-roasted bean blend with (0.6-0.4mm); WRFM: wheat-roasted bean (0.4-0.3mm) blend; WRFS: wheat-roasted bean (0.3-0.15mm) blend; CH: carbohydrate; EN: energy

4.4.7. Mineral Content

The results of zinc, iron, magnesium, calcium, and potassium are presented in the 4.8. The milling fraction significantly affected the mineral content of wheat flour. The Fe content of composite flour was significant (α=0.005), which ranges from 3.92 for the control sample to 6.9mg/100 medium milling fraction, which was higher than the former report for wheat-fava bean composite flour (Benayad *et al.*, 2021), this may due to the elimination of seed cot excluded significant amount of fiber. Zn content of the blend did not show a significant difference, and the result of wheat flour (1.96) was almost comparable with the previous study (Oghbaei & Prakash, 2016), and increased to 3.027mg/100g. The value of K, Mg, and Ca ranged from 178.76 to 588.96, 27.16 to 48.71, and 150.12 to 512.12 respectively which did not show a significant difference except for small and control samples, and this mineral content was higher than the former report (S. Kumar & Pandey, 2020), in which increases the mineral contents may due to the presence of mineral utilization in the flour (Demir & Demir, 2016).

Table 4. 8 Mineral content of wheat flour, and its blend

Sample code	**Fe (mg/100g)**	**Zn (mg/100g)**	**K (mg/100g)**	**Mg (mg/100g)**	**Ca (mg/100g)**
WRFM	6.9 ± 0.07^{a}	2.96 ± 0.00^{a}	588.96 ± 69.7^{a}	48.71 ± 34.9^{a}	495.32 ± 104.6^{a}
WRFS	6.4 ± 1.7^{b}	2.89 ± 0.0^{a}	522.5 ± 75.6^{b}	39.75 ± 0.0^{b}	451.91 ± 68.3^{b}
WRFL	5.33 ± 0.01^{c}	3.027 ± 1.7^{a}	552.26 ± 134.2^{b}	52.015 ± 0.07^{a}	512.11 ± 17.1^{a}
WF	3.92 ± 0.004^{d}	1.96 ± 0.007^{b}	178.76 ± 13.87^{c}	27.16 ± 0.07^{c}	150.12 ± 67.6^{c}

Data presented as means ± standard deviation from triplicate analysis. Means that do not share a letter are significantly different (α=0.005), WF: wheat flour; WRFL: wheat-roasted bean blend with (0.6-0.4mm); WRFM: wheat-roasted bean (0.4-0.3mm) blend; WRFS: wheat-roasted bean (0.3-0.15mm) blend

The processing methods and milling influence the mineral content of cereal and legume four (Moisa *et al*., 2024). Hence the mineral content of wheat flour may be increased due to roasting bean flour typically contains higher concentrations of these minerals compared to wheat flour alone, and also the milling fraction particles may enhance mineral transfer from roasted bean flour to wheat flour. Inyang *et al.*, (2018) reported magnesium promotes bone health, serves as a catalyst for many processes, and enhances nerve and muscle conductivity, and also magnesium, potassium, and calcium lower blood pressure in humans, and iron intake is crucial to reduce the prevalence of iron deficiency anemia, the most prevalent nutritional condition globally (Atudorei *et al.*, 2021)

4.4.8. Bread Quality Evaluation

4.4.8.1. Crust, and Crumb Color

The bread color expressed as L*(lightness,0=black,100=white),a*(+a=rediness,-a=greeness), and b*(+b=yellowness, -b=blueneess). Chromaticity expressed the richness of color and similar trend to that observed for b* value, while hue angle indicate how an varage person will recognize that color (Wodajo and Emire, 2022).

Table 4. 9 Crust, Crumb Color, and Textural Profile

	Crust					Crumb				
sample code	**L***	**a***	**b***	**C**	**h**	**L***	**a***	**b***	**c**	**h**
WF	76.3±0.83ᵃ	8.83±0.07ᶜ	23.5±0.06ᵈ	25.1±0.514ᶜ	70.64±0.4ᵃ	73.61±0.3ᵇ	3.99±0.12ᶜ	18.3±0.04ᵇ	18.87±0.1ᵇ	77.66±1.2ᵃ
WRFM	63.66±0.02ᵇ	14.04±0.07ᵇ	26.05±0.01ᶜ	29.59±0.03ᵇ	62.19±0.7ᵇ	74.6±0.16ᵃ	3.7±0.01ᶜ	17.9±0.76ᵇ	18.28±0.3ᵇ	77.8±018ᵃ
WRFS	63.65±0.02ᵇ	14.1±0.07ᵇ	27.02±0.08ᵇ	30.49±0.01ᵃ	61.88±1.2ᵇ	72.39±0.2ᶜ	4.67±0.01ᵇ	18.48±0.3ᵇ	19.07±0.1ᵇ	76.2±0.5ᵃᵇ
WRFL	58.43±0.04ᶜ	15.4±0.03ᵃ	27.78±0.15ᵃ	31.76±0.01ᵃ	56.35±0.5ᶜ	71.19±0.1ᵈ	5.35±0.27ᵃ	21.69±0.6ᵃ	22.33±0.3ᵃ	75.69±0.1ᵇ

Textural profile

Sample code	**Firmness (N)**	**Chewiness(J)**	**Gumminess(N)**	**Cohesiveness**	**Resilience**
WRFL	10.9±0.07ᵃ	6.4±0.13ᶜ	6.92±0.08ᵇ	0.51±0.01ᵈ	1.15±0.21ᵇ
WF	9.47±0.26ᵇ	8.35±0.2ᵇ	8.16±0.2ᵃ	0.92±0.04ᵃ	2.5±0.07ᵃ
WRFS	8.32±0.48ᵇᶜ	9.83±0.08ᵃ	5.05±0.05ᶜ	0.66±0.00ᶜ	1.99±0.00ᵃ
WRFM	8.34±0.29ᶜ	9.26±0.26ᵃ	5.51±0.18ᶜ	0.75±0.01ᵇ	2.4±0.28ᵃ

Data presented as means ± standard deviation from triplicat means that do not share a letter are significantly different (α=0.005) WF: wheat flour; WRFL: wheat-roasted bean blend with (0.6-0.4mm); WRFM: wheat-roasted bean (0.4-0.3mm) blend; WRFS: wheat-roasted bean (0.3-0.15mm) blend; L*: brightness,: a*: redness; b*:yellowness; c: chroma index; h: hue angle

Table.4.9 shows that crust L* (brightness) and hue angle decrease with particle size increases with values ranging from 76.3±0.83 to 58.53±0.04 and 70.64±0.43 to 56.35±0.5, respectively. The brightness of the crumb in this study did show a significant difference at (α=0.005) with the milling fraction, and h, c, b* values of small, for medium, and medium with wheat flour particles did not show a significant difference in redness value.The a*, b*, and c values decreased from 8.83±0.07 to 15.41±0.03, 23.5 ±0.06 to 27.78±0.15, and 25.1±0.5 to 31.76±0.01 from control to coarse composite.

The mean value of the milling fraction has a significant difference for L* and b* values, although fine and medium particles have no significant difference with the value of h and a* values. The reduction in L* value for wheat-toasted pea bread crust was researched by Millar *et al.,* (2019) who recommended that the increase in protein improves its milliard response as well as increasing fiber content reduces the L* value and decrease in b*, and a* (Benayad *et al*., 2021; Bekele & Admassu Emire, 2023). Increase darkness of the wheat and bean bran blend studied by Ni *et al*., (2020).

4.4.8.2. Texture

The texture profile of bread made from wheat flour and blend is presented in Table.9. The characteristics of bread made from wheat flour were significantly affected (α = 0.005) by the milling fraction of roasted bean flour. Firmness refers to the initial compression force (Coțovanu & Mironeasa, 2021). The firmness of medium and the small particle size did not show a significant difference with wheat flour, and the firmness of control bread was recorded at 9.47±0.26, which was a decrease for the small (8.32±0.48) and medium (8.34±0.29) samples, while it increased for the large particle size (10.9±0.07). Similarly lower firmness was reported in medium particle size bread made from wheat-amaranth (Coțovanu & Mironeasa, 2021). Pulse flours polysaccharides, and protein content leads to higher higher retrogradation, and harder texture (K.A. Millar *et al.*, 2019). This may be due to legume flour with smaller particle sizes reducing wheat flour's hardness by enhancing interaction and blending, leading to a more uniform texture and lower hardness in the final product, and improving hydration and gluten formation.

Cohesiveness is described as the strength of the internal linkages responsible for the bread's structure, whereas gumminess is the energy required to chew food before swallowing (Coțovanu & Mironeasa, 2021). Gumminess increases with particle size, while cohesiveness decreases (compared to wheat flour). The highest gumminess (6.92±0.08) and lowest (5.05±0.05) gumminess values were recorded in coarse and small particle sizes, respectively. The largest and medium composite bread had cohesiveness values of 0.51±0.01 and 0.75±0.01, respectively. A similar trend was reported by Sopiwnyk *et al*., (2019) for bread made with wheat-roasted pea flour, and proposed that the reduction in water absorption by dough can lead to increased crumb hardness, and cohesiveness.

The resilience characteristics of the medium, and smallest particle size did not show a significant difference with significant change for the largest particle size as compared to the control one. Resilience characterizes the force and speed involved in the recovery of food when a deforming force is removed (Atudorei *et al*., 2021). The bread chewiness increased from the control sample (8.35±0.2) to the medium (9.26±0.26) and smallest (9.83±0.08) particle size, while decreasing for the biggest particle size (6.4±0.13). The lower chewiness value might be attributed to a weakening of the starch-gluten network (Atudorei *et al*., 2021).

4.4.8.3. Specific Volume and Volume

The Specific Volume and Volume wheat and wheat roasted faba bean bread illustrated in Table 4.10. The specific volume of wheat flour in this study was nearly identical to the previous study, indicating that adding legume flour reduced the specific volume of bread made from wheat (Sopiwnyk *et al*.,2019), and the specific volume of wheat flour in this study was recorded 5.83±0.09cm^3/g for the control sample and 4.31±0.08 cm^3/g for the coarse particle size, which was higher than the previous report for wheat germinated composite bread (Atudorei *et al*., 2021) and for bread made by substituting wheat flour with up to 10 % African yam bean flour which ranged from 1.89 to 2.31cm3/g (Ernest *et al*., 2022).

Table 4. 10 Volume and Specific Volume

sample	Loaf Volume cm^3	Specific volume g/cm3
WF	468.58±2.13^a	5.83±0.09^a
WRFM	465.42±0.63^b	4.9±0.16^b
WRFS	460.27±2.74^b	4.94±0.07^b
WRFL	435.79±0.79^c	4.31±0.08^c

Datapresented as means ± standard deviation from triplicate analysis. Means that do not share a letter are significantly different (α=0.005), WF: wheat flour; WRFL: wheat-roasted bean blend with (0.6-0.4mm); WRFM: wheat-roasted bean (0.4-0.3mm) blend; WRFS: wheat-roasted bean (0.3-0.15mm) blend

The volume of this study was 468.58±2.13 cm^3/g for wheat and 465.42±0.63 cm^3/g for medium particle size. There was no significant difference between small and medium particle sizes, but there was a significant difference between wheat and coarse flour (α=0.005). Atudorei *et al.*, (2021) reported the loaves, and specific loaf volume are responsible for dough's capacity to hold gas cells formed. Therefore the increase in volume in medium and small particle size is caused by an increase in water absorption, which leads to better dough structure due to enhanced interaction with gluten proteins, leading to improved gas retention and an increase in specific volume.

4.4.8.4. Sensory Attribute

The sensory analysis was conducted within 2 hours after baking, as shown in the Table.11. The addition of roasted beans with medium (0.4-0.3) and small (0.3-0.5) milling fractions resulted in a superior assessment by the panelists than the sample without any addition of roasted fava bean.

Appearance and Color

The mean score of appearance and colour of wheat and smallest particle sizes bread increased from (7.5±0.07) to 8.72±0.02 and 8.05±0.07 to 8.85±0.07 respectively, but the smallest particle sizes did not show asignificant different at α=0.005 with medium particle sizes wheare as had asignificant different with laregest particle sizes.

Taste and aroma

In his study the highest and lowest mean score of taste and aroma were faunded in smallest and largest particle sizes. Both parameters of the finale brduct increase with the deacreasing in particle sizes from 6.27±0.33 to 8.45±0.07 and 7.4±0.1 to 8.75±0.007 espectively. Similar findings were achieved for bread samples in which roasted pea flour used in bread improves the flavor of wheat flour (Kotsiou *et al.*, 2021).

Flavor

The flavor wheat-roasted faba bean at different milling fraction of bread increased significantly from 7.5±0.00 to 8.7±0.00 , and the higest and lowest mean score were recorded in medium and largest particle sizes respectively. The flavors improvmen in the sensorial attributes in wheat-legume breade clearly consider a benefit for the increament of legume utilization with wheat flour (Bojnanská *et al*., 2021).

Overall Acceptability

In this study the overat acceplability of small and medium particle sizes did not show a significant difference at α=0.005 the highest and the least overall acceptability (8.35±0.07 and 5.15±0.07) were recorded in small and largest particle sizes respeactively.

Table 4. 11 Sensory Attribut

sample code	Appearance	Color	Taste	Aroma	Flavor	Overall acceptability
WRFL	5.45±0.07^{c}	6.15±0.007^{c}	6.27±0.33^{b}	7.4±0.14^{b}	7.5±0.00^{c}	5.15±0.07^{c}
WRFM	8.26±0.32^{a}	8.7±0.14^{a}	8.45±0.35^{a}	8.7±0.00$_{a}$	8.7±0.00^{a}	8.00±0.014^{b}
WRFS	8.72±0.02^{a}	8.85±0.07^{a}	8.45±0.07^{a}	8.75±0.07^{a}	8.45±0.07^{b}	8.35±0.07^{ab}
WF	7.55±0.07^{b}	8.05±0.07^{b}	7.85±0.07^{a}	7.01±0.00^{c}	7.08±0.0^{d}	8.6±0.14^{a}

Data presented as means ± standard deviation from triplic, Means that do not share a letter are significantly different (α=0.005) WF: wheat flour; WRFL: wheat-roasted bean blend with (0.6-0.4mm); WRFM: wheat-roasted bean (0.4-0.3mm) blend; WRFS: wheat-roasted bean (0.3-0.15mm) blends

Ingeneral milling fava beans significantly improved the sensory properties of wheat bread (α = 0.005). Panelists provided better ratings for roasted beans with medium (0.4-0.3) and small (0.3-0.5) milling fractions than the control sample. Furthermore, it is feasible to conclude that roasted fava beans can be used effectively to improve the nutritional and taste profile of wheat bread. Similarly, roasting improves the sensory profile of a bread sample including pea flour, probably due to the milliared reaction during roasting, as detailed by K.A.Millar *et al.*, (2019). It may be inferred that in this study, consumers' sensory perceptions of bread with a roasted fava bean addition with a milling fraction of (0.4-0.3) and (0.3-0.15) with a 30% level in wheat flour. Furthermore, it can be inferred that roasted fava beans may be successfully employed to increase wheat bread's nutritional value and flavor.

5. CONLUSION AND RECOMMENDATIONS

5.1. Conclusion

Legumes, rich in protein and fiber are increasingly used in dietary applications. Wheat flour is a staple in bread and can be enriched with legumes to reduce malnutrition and create a sustainable food supply chain. Legumes, particularly faba beans have a greater protein content and can help prevent protein energy malnutrition in underdeveloped nations. Roasting improves the bioavailability of legumes by reducing antinutritive components. The higest protein, fiber, and minimum anti-nutritional content of roasted faba bean flour was founded in optimum roasting temperature (150.0 °C) and time (20.69 minute). However, the temperature and time at which bean flour is roasted , and its milling fraction was influence the bread quality. The particle size of roasted bean flour revealed changes in proximate, rheological, and functional qualities, as well as the textural and sensory aspects of wheat flour. The biggest particle sizes had the highest protein, ash, Zn, Mg, and Ca content followed by medium and fine particle sizes where as the medium particle sizes were hiegest in fiber, energy, Fe, and Mg value .

From rehelogical properties of dough the large particle sizes had higher stability and lowest degree of softnes, FN value, and the pasting parameters were recorded in the lowest case, except its pasting temperature as compared to the lowest and medium particle size. The highest foaming and oil absorbation capacity were founded in large particle sizes while the highest water solubility index and foaming stability were recorded in small particle sizes. The medium and smallest particle sizes revealed high loaf and specific volume respectively. The highest crust and crumb brightnes, textural and sensory scores were observed for small and medium flour. From the textural and sensory point of view both medium, and smaller particle size were almast comparabele each other, from this we conclude that the milling fraction, roasting time and temperature infulene all the wheat flour property, and its final prducts, and also both the smalest and medium particle sizes gave better final product quality.

5.2. Recommendations

The combination of wheat flour with legume flour consumption of fava bean products is important to improve its nutritional content. Faba bean is one of the best protein and other nutrient sources. Therefore, it is recommended to incorporate with wheat flour by eliminating its anti-nutritional factor to increase its bioavailability and acceptability, and based on the findings of this research work and the general understandings taken on specific fava bean and wheat flour, the following recommendations are forwarded.

- ✓ Study the shelf life of wheat-fava bean based bakery produceds.
- ✓ It is recommended to conducted on microbial load, Extensograph properties, and starch damage at different milling fraction.
- ✓ The product may need further analysis on the amino acid profile

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7. APPENDIX

1 Analysis of variance (ANOVA) for a quadratic model for protein content

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	4.78	5	0.9554	14.74	0.0013	Significant
A-time	0.0704	1	0.0704	1.09	0.3319	
B-temperature	0.0088	1	0.0088	0.1360	0.7232	
AB	1.50	1	1.50	23.15	0.0019	
A^2	0.5901	1	0.5901	9.10	0.0195	
B^2	1.44	1	1.44	22.23	0.0022	
Residual	0.4537	7	0.0648			
Lack of Fit	0.1324	3	0.0441	0.5493	0.6750	not significant
Pure Error	0.3213	4	0.0803			
Cor Total	5.23	12				

2. Analysis of variance (ANOVA) for a quadratic model of the crude fiber content

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	10.17	5	2.03	57.63	< 0.0001	Significant
A-time	0.0580	1	0.0580	1.64	0.2407	
B-temperature	3.10	1	3.10	87.71	< 0.0001	
AB	0.0001	1	0.0001	0.0028	0.9590	
A^2	0.2309	1	0.2309	6.54	0.0377	
B^2	4.95	1	4.95	140.31	< 0.0001	
Residual	0.2471	7	0.0353			
Lack of Fit	0.1740	3	0.0580	3.17	0.1470	not significant
Pure Error	0.0731	4	0.0183			
Cor Total	10.42	12				

3. Analysis of variance (ANOVA) for linear model for tannin content

Source	Sum of Squares	Df	Mean Square	F-value	p-value	
Model	11.19	2	5.60	5.58	0.0236	Significant
A-time	3.89	1	3.89	3.87	0.0773	
B-temperature	7.31	1	7.31	7.28	0.0224	
Residual	10.03	10	1.00			
Lack of Fit	2.94	6	0.4899	0.2762	0.9215	not significant
Pure Error	7.09	4	1.77			
Cor Total	21.23	12				

4. Analysis of variance (ANOVA) for a quadratic model for the Phytic acid content

Source	Sum of Squares	Df	Mean Square	F-value	p-value	
Model	41330.98	5	8266.20	252.34	< 0.0001	Significant
A-time	5512.42	1	5512.42	168.28	< 0.0001	
B-temperature	14790.74	1	14790.74	451.51	< 0.0001	
AB	2411.30	1	2411.30	73.61	< 0.0001	
A^2	3965.78	1	3965.78	121.06	< 0.0001	
B^2	7730.43	1	7730.43	235.99	< 0.0001	
Residual	229.31	7	32.76			
Lack of Fit	120.61	3	40.20	1.48	0.3473	not significant
Pure Error	108.70	4	27.17			
Cor Total	41560.28	12				

5. Different alternative of optimization solutions for Proatein, fiber,tannin, and phytic acid cntent of roasted bean.

1	20.691	150	26.34	10.042	6.331	652.702	0.626	Selected
2	20.605	150	26.354	10.039	6.344	653.478	0.626	
3	20.82	150	26.317	10.047	6.31	651.579	0.626	
4	20.857	150	26.311	10.048	6.304	651.265	0.626	
5	24.209	135.281	26.778	10.33	7.388	702.6	0.605	

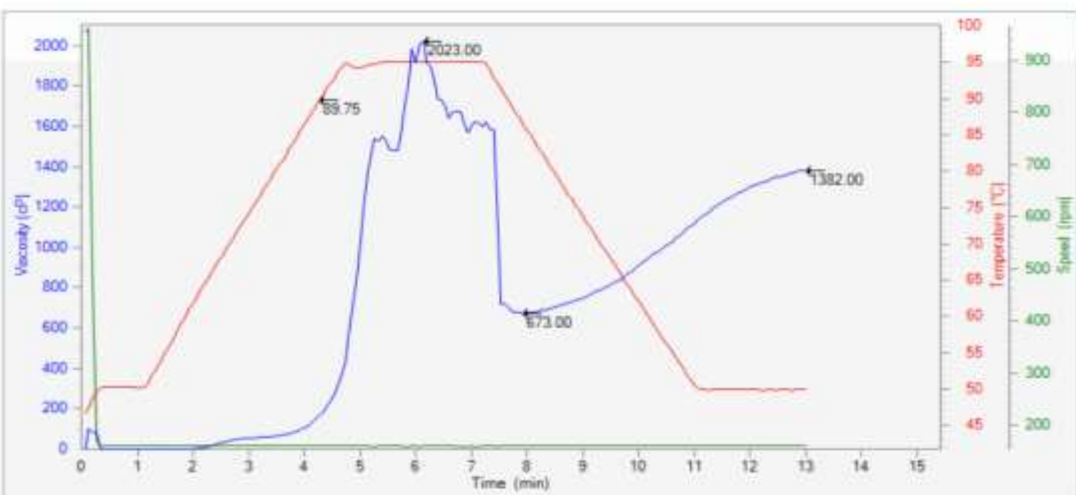

Figure 1 Pasting Properties of WF

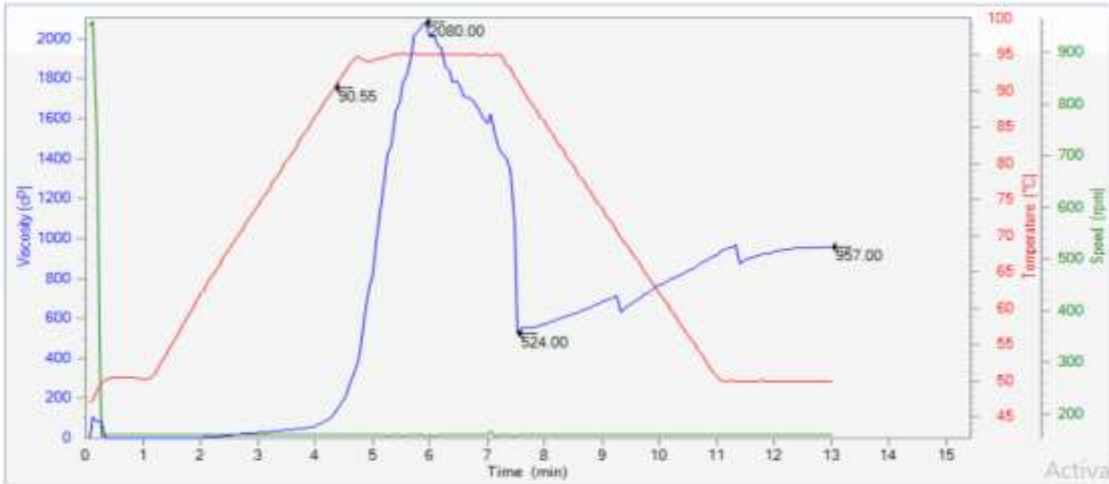

Figure 2 Pasting Properties of WRFL

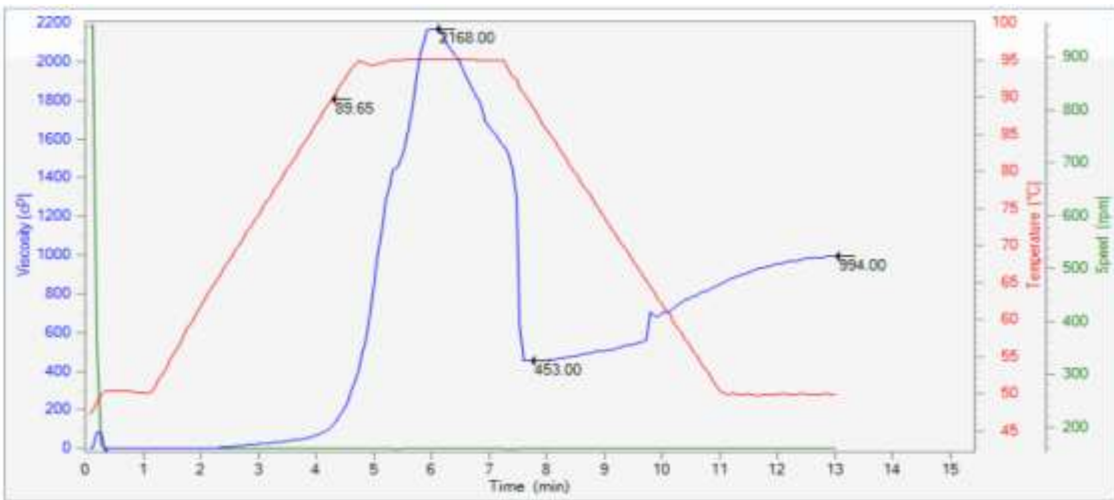

Figure 3 Pasting Properties of WRFM

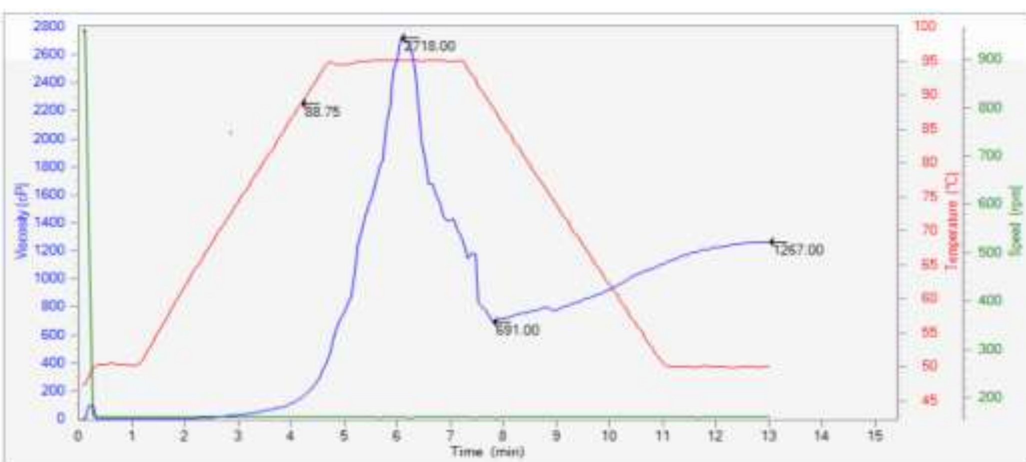

Figure 4 Pasting Properties of WRFS

Figure 5 Laboratory activity pictures

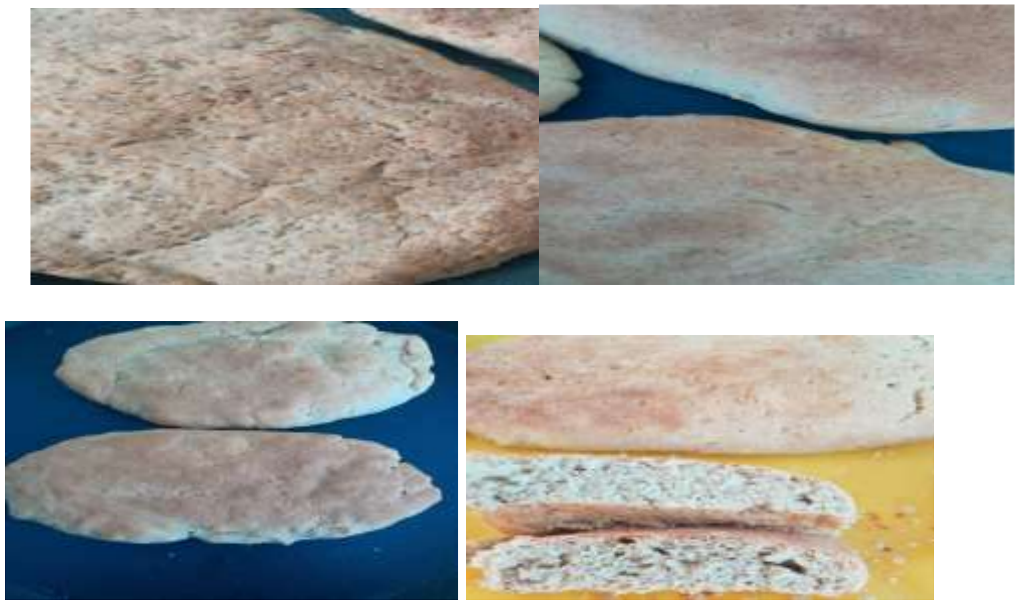

Figure 6 Some baked product image during preliminary study

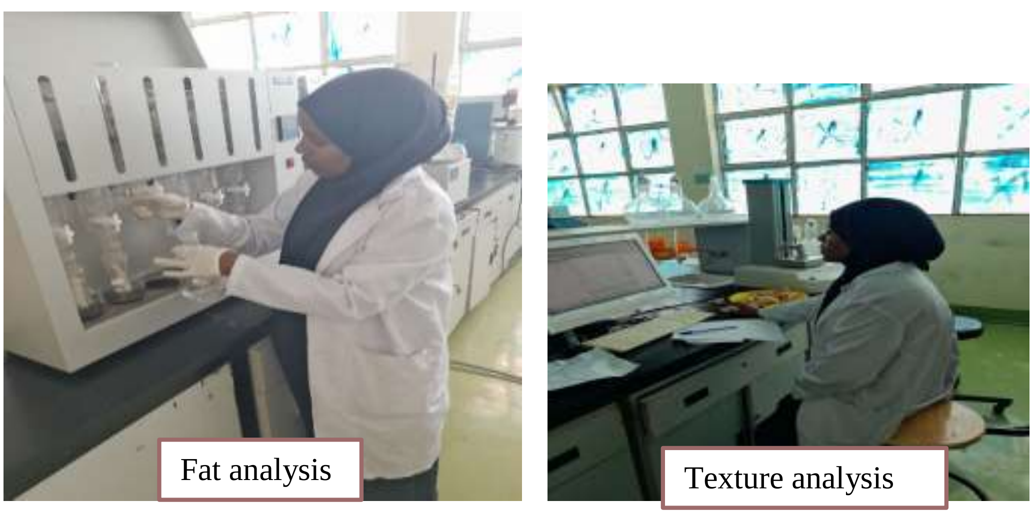

Figure 7 Analysis Pictures

Sensory Attributes Evaluation Form

You are provided with 8 samples here under coded and you are expected to evaluate the sensory qualities of the samples based on the hedonic scale presented here.

Rate as:

1=extremely dislike — 6 = like slightly

2= dislike very much — 7 = like,

3 = dislike moderately — 8 =like very much,

4 = dislike slightly — 9=extremely like

5 = neither like nor dislike

Sample Code		Quality Attributes					
	Appearance	Color	Flavor	Taste	Aroma	Texture	OverAll Acceptance
XZW							
XZL							
XZM							
XZS							