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College of Dry land Agriculture and Natural Resources

Department of Food Science and Postharvest Technology

Optimization of Sweet Potato Flour and Black Cumin Seed Blending Ratios with Wheat Flour to Produce Quality Bread

By;

Kidanemariam Tesfay Zenebe

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Advisors:

Mr. ZenebeTadesse (MSc. Assist. Prof. in Food Technology)

Mr. LijalemTareke (MSc. Assist. Prof. in Food Science and Technology)

Mekelle University, Ethiopia

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DECLARATION

As Thesis research advisors, we hereby certify that we have read and evaluated this Thesis prepared, under our guidance by **KidanemariamTesfayZenebe** entitled: **Optimization of Sweet Potato flour and Black Cumin Seed Blending Ratios with Wheat Flour to Produce Quality Bread** for consideration by the Department of Food Science and Post-harvest Technology. We recommend that it be accepted as fulfilling the thesis requirement

ZenebeTadesse (MSc. Assist. Prof.) ____________________ ____________________

Name of Major advisor Signature Date

LijaleTareke (MSc. Assist. Prof) ____________________ ____________________

Name of Co- advisor Signature Date

LijalemTareke (MSc. Assist. Prof.)__________________ _________________

Name of Dep't PG coordinator Signature Date

TeklebrhanGidey (MSc)_ _________________ __________________

Name of Head department Signature Date

As a member of the board of examiners of the M.Sc.thesis opens a defense examination, we certify that we have read and evaluated the thesis done by **KidanemariamTesfayZenebe** and examined the candidate. We recommended the thesis to be accepted as fulfilling the thesis requirement for the Degree of Master of Science in Food Processing Technology.

___________________________________ _____________ ________________________

Name of Internal Examiner Signature Date

___________________________________ _____________ ________________________

Name of External Examiner Signature Date

DEDICATION

This work is dedicated to all my beloved family and my friends for all their support and motivation throughout my work.

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STATEMENT OF THE AUTHOR

First, I declare that this thesis is my work and all sources and material used in this thesis have been properly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for MSc. in Food Processing Technology. I confidently declared that the thesis is not submitted to other institutions and for any award of an academic degree or diploma. Brief quotations from this thesis are allowed without any special permission provided that an accurate acknowledgment of the source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the Head of the Department of Food Science and Post-harvest technology or the Dean of the College of Dry land Agriculture and Natural Resource when the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

Name: KidanemariamTesfayZenebe

Signature: _________________

Date of submission: _________________

Department: Food Science and Post-Harvest Technology (FSPT)

Mekelle University, Ethiopia

BIOGRAPHY OF THE AUTHOR

The Author, Kidanemariam Tesfay Zenebe, was born on June 19, 1994, G.C, in WoredaLaelayAdiaboTabiahadegti. He completed his elementary school at Hadegti elementary school and he covers his secondary and preparatory school at Adidaero secondary and preparatory school. After he accomplished his preparatory school, he joined Mekelle University College of Dry land Agriculture and Natural Resources, Department of Food Science and Post-harvest Technology in 2013/2014. From 2013/2014 till 2017 he studied his BSc degree in Food Science and Post-harvest Technology. He was awarded a BSc degree in Food Science and Postharvest Technology in July 2017. Soon after graduation, he became a staff member of the Food Science and Post-Harvest Technology Department at Adigrat University. In 2020/2021, he joined the department of graduate studies at Mekelle University to follow his studies leading to a Master of Science Degree in Food Processing Technology in the regular MSc program.

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LIST OF ABBREVIATIONS

AACC	American Association Cereal Chemistry
CCD	Central Composite Design
CHO	Carbohydrate
ANOVA	Analysis of Variance
BD	Bulk Density
RSM	Response Surface Methodology
SPB	Sweet Potato Blend
SPF	Sweet Potato Flour
WAC	Water Absorption Capacity
G/M	Gram Per milliliter
OAC	Oil Absorption Capacity
Fig	Figure
NS	Nigella Sativa
FAO	Food and Agriculture Organization
WF	Wheat flour

ABSTRACT

This study aimed to optimize the proportion of black cumin and sweet potato flour and its effect on physicochemical qualities and sensory acceptability for bread development. The three level of concentration ratios of black cumin obtained from the baseline survey of data are black cumin(B1), 1.09g, black cumin (B2)= 2.29 g, and black cumin (B3) = 3.49 g). A total of 13 formulations were analyzed with sweet potato flour ranging from 8 to 22 gram and black cumin flour ranging from 0.59 to 3.89 gram. A response surface methodology (RSM) coupled with Central Composite Rotatable Design (CCRD) was employed to design and optimize the varying levels of sweet potato flour and black cumin. The responses analyzed included carbohydrate content, protein content, and sensory acceptability. The sensory attributes were significantly affected by the blend proportion of sweet potato flour and black cumin ($p < 0.05$). The experimental results showed that increasing black cumin levels improved protein content and sensory attributes up to an optimal point, while excessive amounts slightly reduced carbohydrate levels. The predicted and experimental values were compared and showed no significant differences at $p<0.05$. Hence, the developed models were found adequate and had good predicting capacity. The models' prediction values have no significant difference with the measured confirmation values (with minimal deviation). Results indicated that increasing sweet potato blend (SPB) levels generally enhanced carbohydrate content at 85.03%. In contrast, protein content was positively influenced by higher BCB levels, with the highest measured value of 8.0%. Sensory scores were highest (4.75) at a mid-range formulation of black cumin and sweet potato, suggesting a favorable over all acceptability. The optimal formulation was determined to consist of 11.8 g of sweet potato and 3.49 g of black cumin, achieving a desirable nutritional profile with 82.22% carbohydrates, 7.9% protein, and a high sensory score of 4.41 reflecting strong consumer preference. In terms of mineral content, it was notably rich in calcium, iron and zinc. These predicted blending ratios of sweet potato flour and black cumin could help to formulate bread production with acceptable energy, nutritional qualities and sensorial acceptance from wheat flour composite.

Keywords: *wheat; sweet potato; Black cumin; bread quality; proximate composition; sensory acceptability.*

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the Study

Wheat bread is one of the fermented baked products made primarily from wheat flour, water, yeast, and salt. The bread-making process typically involves kneading**,** proofing**,** shaping (molding), and baking the dough. The gluten content of the wheat flour is essential to provide the dough with elasticity and strength, enabling it to trap gas produced during fermentation and develops the desired structure and texture of bread (Gilcardoso et al., 2021).

Although wheat flour is one of the most commonly used flours for bread production worldwide due to the high demand, insufficient protein, minerals, and sensorial development of the wheat flour have led researchers to explore alternative sources such as sweet potato flour for bread making (Elizabeth et al., 2021).

Sweet potato (*Ipomoea batatas*) is an essential tuber crop produced and consumed worldwide. Presently, it is cultivated in over 115 countries (FAOSTAT, 2019) and is recognized as a secondary staple food, playing a crucial role in the diets of individuals in several developing nations (Kurabachew, 2015; Moyo et al., 2022; Sohindji et al., 2022) Orange fleshed sweet potato is a distinctive variety of sweet potato characterized by its distinct orange color and appealing sweet flavor. From a nutritional perspective, Orange fleshed sweet potato is ranked among the most nutritious crops due to its substantial vitamin A content (Sohindji et al., 2022).

Sweet potatoes are a staple crop in the tropics that can significantly benefit the economies of many African nations, reduce food insecurity, and enhance nutrition (Otekunrin et al., 2019). Sweet potato flour has been shown to be a rich source of energy, carbohydrates, beta-carotene (pro-vitamin A), vitamin C, vitamin B6, essential minerals (including calcium, zinc and iron), and dietary fiber (Alam et al., 2020) Such researchers are participated in the development and utilization of composite flours blends of various flours derived from starchy tubers, such as sweet potatoes, combined with cereals and protein-rich flours that aims to produce specific nutritional profiles and functional characteristics that can be used as alternative of wheat bread(Noorfarahzilah et al., 2014).

Black cumin *(Nigella sativa)* is used to alleviate pain and as an anthelmintic, appetizer, carminative, sudorific, digestive, diuretic, emmenagogue, guaiacol, antifebrile, galactagogue, and cathartic (Hossam et al.,2022).Its high protein and carbohydrate content, as well as its strong antioxidant content, increase the value of black seed in human nutrition. At the same time black cumins' protein concentrates appear to be potentially beneficial materials in food technology because of their foaming properties (Krawecka et al., 2022),and their high antioxidant content is utilized as a food additive to protect lipids and oils from oxidative degradation in processed meals. The combination of black seed meal and wheat flour to make nutritious bread and flat bread (Hossam et al., 2022). Although it is well known that black cumin flours are more nutritious than wheat flour, with higher protein content and more important nutrients, more thorough research is needed to precisely measure these advantages.

Black cumin is one of the spices which are commonly used in many food products traditionally. They are used for example to increase aroma, enhance the flavor of cheese, pickles, soups, sauces, and vegetables traditionally (Verma& Kumar, 2015). According to Verma& Kumar, (2015).black cumin seeds have traditionally been used to enhance the palatability and flavor profile of foods. However, the specific quantity or concentration of black cumin seeds typically used in food preparation remains unknown (Iqbal et al., 2014).

It is essential to determine the ideal ratios of sweet potato flour and black cumin seed to formulate with wheat flour. The potential effects of using sweet potato flour and black cumin as substitutes for wheat flour in bread-making have not been thoroughly investigated. Therefore, the purpose of this study was to examine how sweet potato flour and black cumin influences the bread made from wheat flour, aiming for enhancing the bread's proximate composition and sensory qualities of the bread (Krawecka et al., 2022).

1.2. Statement of the problem

Wheat grain is a staple cereal that is rich in gluten and is commonly used for bread production in the world. However, there are limitations in proteins, minerals and sensorial developments of the wheat flour composite. To address these issues, researches have been required focused on using sweet potato in combination with wheat flour as an alternative. Through this kind of research works the limitations of sensorial development and improved nutritional composition can be solved by blending sweet potato flour and black cumin.

This study aims to undertake these challenges by incorporating flours of black cumin seeds in the production of bread made from composite flours of wheat and sweet potato. Traditionally, black cumin has been utilized in our community as a flavoring agent in wheat bread to enhance its flavor, aroma, and shelf life. To the best of the author's knowledge, there is limited or no research on standardized or minimum ratios for incorporating black cumin in wheat bread production. Although black cumin is one of a spice which is traditionally used in bread production, the minimum concentration ratio is not yet scientifically known (Das et al., 2014). Therefore, addressing the current challenges in bread making is timely.

1.3. Objectives

1.3.1. General objectives

The general objective of this Research is Optimizing Sweet Potato Flour and Black Cumin Seed Blending Ratios with Wheat Flour to Produce Quality Bread

1.3.2. Specific objectives

- ✓ To assess the proportion of traditional use of black cumin seed in wheat bread making.
- ✓ To evaluate the proximate composition and functional properties of bread made from wheat flours and sweet potato blended with black cumin seed.
- ✓ To optimize the blending ratios of sweet potato flour and black cumin seed with wheat flours for bread making.
- ✓ To analyze the sensory acceptance of bread made from wheat and sweet potato flours and black cumin seed blend.

1.4. Significance of the study

The primary significance of this study could be to compare and identify the benefits of black cumin concerning the proximate composition and sensory quality of bread made from composite of wheat and sweet potato flour in Ethiopia. This research aimed to recommend optimal levels or ratios of black cumin that are suitable for composite bread. The findings of this study will serve as a foundation for enhancing the nutritional quality and sensory acceptability of bread that incorporates black cumin and sweet potato tubers into wheat flour.

Furthermore, the results will contribute to value addition and the minimization of post-harvest losses of sweet potato tubers within our community. The initiative will also promote sweet potato production, increase farmers' incomes, create more jobs, and reduce dependence on wheat imports, thereby decreasing the foreign exchange spent on wheat. These efforts will contribute to improved food and livelihood security for the vast majority of the population. Therefore, incorporating sweet potato flour with wheat flour, particularly in bread production, presents a valuable opportunity to enhance nutritional quality. Consuming products rich in dietary fiber, protein, and minerals helps to elevate the nutritional status of the community.

1.5. Scope and Limitations of the Study

The study was focused on optimization of sweet potato and black cumin blending ratios with wheat composite flour to produce bread which made from a composite flour of wheat and sweet potato. However, further studies like shelf life, microbial load, vitamins, anti-nutritional constituents, antioxidant activity and the remained minerals such as Sodium, Potassium, Manganese and copper are left for further investigations

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Black cumin in Ethiopia

Ethiopia is renowned for its diverse and favorable agro-ecological zones**,** which provide ideal conditions for the cultivation of a wide variety of spices, vegetables, and crops. According to Dessie et al., (2019), this ecological diversity supports the growth of numerous spice species, making Ethiopia a significant player in the global spice market. The country produces over 14 different varieties of spices**,** including notable types such as black cumin, white cumin; pepper, paprika, turmeric, fenugreek, garlic, korarima, coriander, ginger and cardamom. These spices serve both local consumptionandcommercial export purposes, highlighting their economic importance (Tesfa et al., 2017).

Ethiopia's prominence in the spice industry is reflected in its global rankings. It stands as one of the leading spice producers and consumers worldwide, holding the first position in Africa and ranking seventh globally in spice production (Vijayalaxmi&Sreepada, 2014; FAOSTAT, 2019). Ethiopians utilize spices to enhance the flavor of bread, butter, meat, soups, and vegetables, as well as to create medications and fragrances, among other applications (International Trade Centre, 2010; Tesfa et al., 2017).

One essential spice, black cumin, is primarily cultivated to provide a pleasant aroma and to enhance the flavor of vegetables, pickles, soups, sauces, and cheese (Atta, 2003). According to Takruri&Dameh (1998), approximately 70% of the world's cumin is produced in India, which is also consumed in countries such as China, Indonesia, Singapore, Malaysia, Bangladesh, Nepal, and India itself (Spices Board India, 2009). There are two main varieties of cumin: white and black. India produces about 210,000 tons of the estimated 300,000 tons of cumin produced globally (Sonke&Lisanne, 2013). In 2012, global cumin production was estimated at 300,000 tons, with India contributing approximately 210,000 tons of that total (Sonke&Lisanne, 2013).

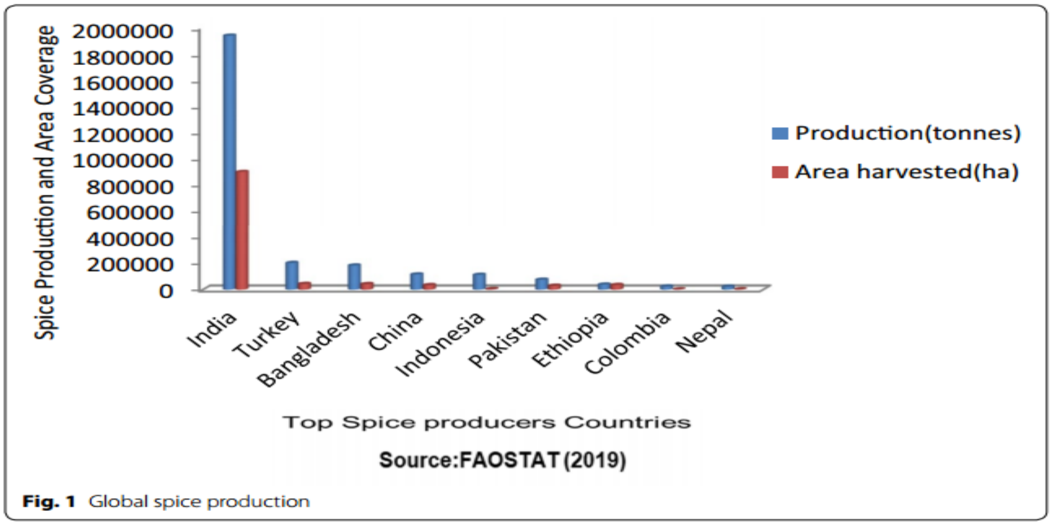

Fig1: Global spice production Trend FAOSTAT (2019).

In Ethiopia, black cumin is a highly valued spice, primarily cultivated to flavor foods, produce oil for perfumes and medicinal purposes, serve as a source of income, contribute to crop diversification, and support export activities (Teshome&Anshiso, 2019). It is also used to reduce the spiciness of pepper powder in the country. As a result, black cumin production can be increased through the adoption of modern agricultural technologies or by enhancing the efficiency of existing inputs and technologies (Edwards et al., 2003).

Fig 2: Black cumin seed (Aisa et al., 2019).

2.2. Traditional Applications of Black cumin seed in Ethiopia

Black cumin seeds are widely recognized not only for their nutritional value but also for their diverse health benefits and culinary applications. Traditionally, black cumin is used as a spice to enhance the flavor of various foods and beverages. According to Javed et al., (2010), the seeds are commonly added to tea, coffee, and toast, and serve as a flavoring agent in a variety of culinary preparations, including yogurt, pickles, sauces, and salads. These uses underscore black cumin's versatility and cultural significance in food traditions. Historically, black cumin seeds and their oil have been used extensively in traditional medicine in Ethiopia and other countries, where they are revered for their health benefits and healing properties. This longstanding usage underlines the importance of black cumin as a functional food ingredient with both nutritional and therapeutic value (Javed et al., 2010).

They have been used to treat various ailments, including asthma, bronchitis, rheumatism, and other inflammatory diseases (Padmaa&Paarakh, 2010). The seeds are believed to be effective in managing a wide range of conditions, such as cough, bronchitis, asthma, chronic headaches, migraines, dizziness, chest congestion, dysmenorrhea, obesity, diabetes, paralysis, back pain, infections, inflammation, hypertension, and gastrointestinal issues like indigestion, bloating, dysentery, and diarrhea (Tariq, 2008).

2.3. Composition and Nutritional profiles of Black cumin Seeds

The compositional and nutritional characteristics of black cumin seeds have been extensively studied to understand their potential health benefits and applications in food systems. According to Mamun&Absar(2018), proximate analysis of black cumin seeds revealed significant macronutrient content, including approximately 20.8% protein, 31.9% carbohydrates, and 38.2% lipids. These values underscore black cumin seeds as a rich source of energy and essential nutrients. In addition to macronutrients, the seeds exhibited a moisture content of 4.64%, an ash content of 4.37% indicating their mineral richness and a crude fiber content of 7.94%, which contributes to digestive health.

Beyond basic nutritional components, black cumin seeds also contain various secondary metabolites known for their functional and bioactive properties. Screening identified compounds such as alkaloids (10.1 mg/100 g)**,** flavonoids (3.7 mg/100 g)**,** saponins (7.6 mg/100 g)**,** and tannins (2.2 mg/100 g)**.** These phytochemicals are associated with antioxidant, antimicrobial, and anti-inflammatory effects, further emphasizing the seeds' potential as a functional food ingredient (Mamun&Absar, 2018).

2.3.1. Minerals

The mineral content of black cumin seeds has been extensively studied due to their nutritional and therapeutic importance. According to Kabir et al., (2019), the seeds are especially rich in essential macro minerals such as potassium, sodium, phosphorus, magnesium, and iron. These minerals play crucial roles in various physiological functions and significantly enhance the seeds' overall nutritional value.

Table 1: Mineral content of black cumin (mg/100 g)

Mineral	Mamun&Absar (2018)	Jasir (1992)	Sultan et al., (2009)	Nergiz&Otles (1993)	Kabir et al., (2019)
Sodium	100	0.75	17.6	85.3	44.8
Calcium	579.3	0.04	570	188	366.7
Phosphorus	91.5	1.8	543	_	481.5
Iron	41.8	0.15	9.7	57.5	42.6
Zinc	_	0.06	6.23	_	6.7
Manganese	_	0.02	8.53	_	3.1

2.3.2. Proteins

According to Jassir (1992), black cumin is used both as a spice and an herb in culinary applications to enhance flavor and pungency, while also offering nutritional, antibacterial, antioxidant, and medicinal benefits. The amino acid profile of black cumin seeds reveals a variety of essential and non-essential amino acids present in varying concentrations. The primary non-essential amino acids identified in black cumin seeds include glutamic acid, aspartic acid, arginine, and glycine, which together constitute approximately half of the total amino acid content. Among the essential amino acids, leucine is present in the highest concentration. It has been observed that black cumin seeds generally contain higher amounts of non-essential amino acids compared to essential amino acids (Çakir&Gülseren, 2019).

2.3.3. Fats

Black cumin seeds are known for their rich fatty acid profile, which enhances their nutritional and functional properties in food applications. According to (Kabir et al., (2019), the seeds contain a variety of fatty acids, including both saturated and unsaturated types. Among the saturated fatty acids, palmitic acid is the most abundant in black cumin seed oil. In contrast, the unsaturated fatty acids generally present in higher concentrations are primarily oleic acid (a monounsaturated fatty acid) and linoleic acid (a polyunsaturated fatty acid).Furthermore, the essential oil extracted from black cumin seeds has demonstrated therapeutic benefits due to its key volatile components. Additionally, saponins found in black cumin seeds exhibit significant anticancer properties (Adamska et al., 2019).

Table 2: Proximate composition of black cumin seed

Groups	Percentage (%)
Fixed oil	32-40
Volatile oil	0.4-0.45
Protein	16-19.9
Minerals	1.79-3.74
Carbohydrates	33.9
Fiber	5.5
Water	6

Sources :(Randhawa&Ghamdi, 2011).

2.4. Nutritional Composition of Sweet Potato

According to the Food and Drug Administration, foods are nutritionally classified based on their contribution to the Daily Value of essential nutrients. A food is considered a low source of a nutrient if it provides less than 5% of the Daily Value, an excellent source if it contributes 10% to 19%, and a rich source if it supplies more than 20% of the Daily Value. Within this framework, sweet potatoes are widely recognized as a rich source of β-carotene, a precursor to vitamin A, and are valued for their significant contribution to micronutrient intake. As noted by (Alam et al., 2020) & Wang et al., 2016), sweet potatoes also contain high levels of essential minerals such as calcium, potassium, magnesium, iron, copper, and manganese. Additionally, they provide several important vitamins, including B1, B6, C, and E, as well as dietary fiber.

Additionally, sweet potato leaves are an excellent source of lutein, surpassing traditional vegetables such as kale, spinach, broccoli, lettuce, and green peas in lutein content (Ishiguro, 2019). Both the leaves and roots of the sweet potato contain significantly higher amounts of protein. The protein found in the leaves is of good quality, particularly in terms of amino acid composition; lysine has been reported as the only or second limiting amino acid, highlighting the potential of sweet potato leaves as a valuable protein source (Suarez et al., 2020; Tang et al., 2021). Furthermore, sweet potato leaves are considered comparable to, or even superior to, spinach and other major and wild vegetables of Asian and African origin in terms of vitamins, minerals, and other nutrients (Afolayan&Jimoh, 2009)

Table 3: Nutritional value of sweet potato

Constituent	Mean	Variation %
Dry matter	29.87	14.99-41.98
Protein	4.22	1.34-11.08
Sugar	15.26	8.78-27.14
Starch	66.08	44.59-78.02
Crude fiber	3.99	2.70-7.60

Source: (Tson et al., 2001).

2.5. Bread Making Process

The bread-making process consists of three stages: mixing and developing the dough, aerating the dough, and baking it in the oven. As a fundamental component of daily human nutrition, bread has inspired various efforts to create diverse types for the global market. Numerous techniques for bread production have been developed, all aimed at transforming raw flour into a leavened food product, primarily through fermentation (Cauvain& Young, 2007).

2.5.1. Dough Mixing

Bread is primarily composed of wheat flour, water, yeast, and salt. The mixing process plays a crucial role in integrating these ingredients into uniform dough. According to Cauvain& Young (2007), mixing is essential not only for evenly distributing the components but also for promoting gluten development, which directly affects the dough's physical and rheological properties, such as elasticity, extensibility, viscosity, stickiness, and resistance to deformation.

Excessive mixing beyond this point can cause the breakdown of the relatively stable molecular interactions between gluten-forming proteins within large gluten aggregates, leading to the disruption of the dough network (Hamer et al., 2009; Bhatia, 2018). Other effects of mixing include the production of carbon dioxide gas through the action of yeast enzymes on sugars, as well as the incorporation of air. This air is essential for providing the oxygen necessary for oxidation and yeast activity. Additionally, it creates nuclei for gas bubbles formed from the carbon dioxide released during yeast fermentation, while the gluten network helps trap the carbon dioxide gas during baking, preventing its escape (Cauvain& Young, 2007).

2.5.2. Dough Fermentation

The fermentation process is influenced by various factors, with the duration typically ranging from 2 to 6 hours or longer, depending on variables such as yeast concentration, baking method, and type of flour used (El Sheikha, 2015). Temperature and relative humidity are critical for optimal yeast activity; temperatures between 30 and 35°C and relative humidity levels of 85% or higher promote effective yeast function. However, yeast activity decreases at temperatures above 40°C. The optimal pH range for yeast activity is between 4 and 6, with yeast performance declining below pH 4 and becoming inactive below pH 3 (Bhatia, 2018). Additionally, the presence of nutrients, such as vitamins and essential minerals, can significantly impact yeast performance (Broach, 2012).

2.5.3. Dividing

The dough must be divided either by hand or with machinery into appropriately sized portions for the desired finished bread. Depending on the target weight, the bulk dough is separated into pieces of equal size and weight. To compensate for weight loss during baking, an additional 12% of the dough's weight is typically added. To ensure consistent weight and prevent variations in dough density caused by CO2 production which can lead to weight discrepancies the division process should be completed promptly. If there is a delay, corrective measures such as degassing should be applied. When the dough contains evenly distributed, uniform bubbles, its density remains stable, making the division process more accurate (Rao, 2017).

2.5.4. Proofing

In bread production, the intermediate proofing stage is a crucial step that takes place between dough dividing and final shaping. This stage involves a brief resting period, typically lasting between 2 and 20 minutes, allowing the dough to regain its structural properties before being shaped into its final form. According to Bhatia (2018), this resting phase plays a vital role in restoring the dough’s extensibility and elasticity, which may have been compromised during the mechanical processes of dividing and rounding.

The optimal conditions for intermediate proofing involve controlled temperatures ranging from 26.7°C to 29.4°C and a relative humidity of 75%**,** which facilitate gentle fermentation and effective relaxation of the dough. These conditions promote consistent gas retention and support the dough's structural integrity, contributing to improved handling properties and better final product quality**.** As emphasized by (Bhatia, 2018), incorporating an appropriate intermediate proofing stage is fundamental for achieving uniformity and consistency in bread making

If the temperature is too high, it diminishes the dough's gas-holding capacity, resulting in a sticky texture. Conversely, temperatures below the recommended range can slow fermentation, hindering proper gas expansion. Low relative humidity can cause the dough pieces to harden, leading to tough curls and streaks in the bread crumb. Conversely, excessive humidity can result in moisture condensing on the surface of the dough (sumnu et al., 2008).

2.5.5. Baking of Dough

The dough is considered fully proofed when it reaches its maximum expansion. Before baking, the dough can undergo several pre-treatments, including glazing and scoring. Glazing is a technique applied to the surface of the bread crust to enhance its color and sheen (Jahromi et al., 2012). Typically made from whole eggs, skim milk, shortening, and occasionally sugars, gums, and starches, glazes are applied prior to baking (Chin et al., 2011; Jahromi et al., 2012).

Regarding the baking process, the oven temperature typically ranges from 220 to 250°C, although this can vary depending on the type of oven and the specific product being baked. When the dough exits the final proofer, its internal temperature is similar to that of the proofing chamber, approximately 35°C. As the dough enters the oven, the surface temperature begins to rise, and heat gradually penetrates toward the center of the dough. During baking, the center of the dough reaches a temperature of approximately 92–96°C to ensure that the structure of the bread is fully set (Cauvain, 2012).

2.5.6. Bread Cooling

The cooling process is a critical step in bread production, especially before slicing and packaging. Once loaves are removed from the oven, they must be cooled promptly to ensure product quality and shelf stability. Cooling serves several purposes: it facilitates easier slicing, prevents condensation inside the packaging, and contributes to the overall texture and structure of the bread. According to Bhatia (2018),&Rao, (2017), the ideal internal temperature for slicing is approximately 30°C, at which point the crumb is firm enough to be cut cleanly without tearing.

Typically, cooling is carried out under controlled environmental conditions, with air circulation and ambient air exposure set around 24°C and 85% relative humidity, which promote efficient heat loss while minimizing excessive drying. Bread is considered ready for packaging when its moisture content drops to within the legal limit of 38% to 42%**,** ensuring product safety, freshness, and compliance with food standards (Bhatia, 2018; Rao, 2017).

2.6. Factors Affecting Composite Bread Quality

2.6.1. Flour

Flour is the primary ingredient used to make bread, and the best type for baking high-quality bread is refined flour. Flour with high protein content (over 12.5%) is ideal for bread-making. Glutenin and gliadin make up approximately 85% of the proteins in flour, while the remaining proteins include albumin, protease, and globulin. Gluten is a cohesive, elastic substance formed when flour is mixed with water. This gluten is essential to the dough's structure, as it traps the carbon dioxide gas produced by yeast during fermentation (Zarh, 2010).

2.6.2. Water

Water plays a fundamental role in the formation and development of dough structure during bread making. When flour and water are mixed, water initiates the hydration of gluten-forming proteinsgliadin and glutenininteract to form the gluten network, a key structural component that imparts elasticity and strength to bread (Shewry et al., 1992).

2.6.3. Leavening agent

Leaven is used in bread making to generate carbon dioxide and ethyl alcohol through the fermentation of sugars. The leaven used in bread making is typically yeast, specifically *Saccharomyces cerevisiae*. There are two main types of yeast: wet yeast, which contains 60-70% water, and dry yeast, which has 7-8% water content (Zarh, 2010).

2.6.4. Salt

Salt is essential in bread making because it enhances flavor, regulates fermentation rate, strengthens gluten, and improves the dough's extensibility and gas retention. Without sufficient salt, the dough becomes too soft, ferments too quickly, produces bland bread, and results in a coarse texture (Kent & Evers, 1994).

2.6.5. Sugar

Bread can be made using a variety of sugars, each with a distinct level of sweetness, including sucrose, dextrose, fructose, and maltose. During fermentation, sugar serves as nourishment for the yeast. The residual sugar remaining after fermentation contributes to the bread's sweetness, aids in caramelization during baking, and imparts a brown color (Pederson, 1971).

2.6.6. Fat

Fat plays a crucial role in bread formulation, significantly contributing to both the processing characteristics and the quality of the final product. During dough preparation, fat acts as a lubricant for gluten, reducing friction between gluten strands. This lubrication enhances dough handling and elasticity, allowing it to stretch and expand more easily, which in turn promotes better volume development during fermentation and baking. This adaptability is especially important in large-scale baking operations where consistent dough handling is essential (Zarh, 2010).

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Survey and laboratory works

The survey was carried out in Woreda Thatay Koraro, North Western zone of Tigray, Ethiopia. The laboratory works were conducted at the Departments of Food Science and Post-harvest Technology (FSPT) and Geology laboratories of Mekelle University.

3.2. Materials used in the study

The materials used in this research included Orange fleshed sweet potatoes, sourced from Shire - Maytsebri Agricultural Research Center. All other ingredients such as black cumin seeds, wheat (refined flour), yeast, salt, and water for bread formulation were purchased from local commercial markets.

A hammer mill was used to grind dried sweet potato samples into fine particles suitable for analysis. Hydrochloric acid (HCl) served to dissolve ash and metal salts and was also used in the preparation of standard solutions. Deionized or distilled water was employed throughout the procedures for sample dilution and cleaning. Zinc oxide (ZnO) and either calcium wire or calcium carbonate ($CaCO_3$) were used to prepare standard solutions for zinc and calcium, respectively. An analytical balance ensured precise weighing of samples and reagents, while filter paper and funnels facilitated the filtration of digested or ashed samples.

For sample ashing, a Bunsen burner was first used to carbonize the organic matter, followed by complete ashing in a muffle furnace. Crucibles were used to contain samples during ashing, and desiccators allowed the crucibles to cool before weighing. A steam bath or hot plate was employed to evaporate solutions to dryness. The mineral content specifically iron (Fe) at 248.3 nm, zinc (Zn) at 213.8 nm, and calcium (Ca) at 422.7 nm was determined using an Atomic Absorption Spectrophotometer (AAS).Standard and sample solutions were prepared using volumetric flasks, with beakers and conical flasks used for general handling. Pipettes and micropipettes enabled the accurate measurement of small liquid volumes required for sample preparation. Appropriate safety equipment, including gloves, lab coats, and safety goggles, was used throughout to ensure laboratory safety

3.3. Data Collection Method

Primary data for the survey was carried out through direct interviews with randomly selected respondents. The questions were prepared in English and interpreted into the local language (Tigrigna). The baseline survey was conducted in the North western zone, Woreda Tahatay Koraro.Voluntary Mothers were asked about the types of spices they used for bread making, the reasons for using them, and the quantities of spice typically used in traditional bread production.

3.4. Experimental Design

The blending ratios of sweet potato flour and black cumin to wheat composite flours for the bread making employed RSM coupled with CCD (Central composite design),and the RSM coupled with CCD of the independent variables was designed as the -α = 8 g, -1 = 10 g, 0= 15, 1 = 20, and α = 22 for sweet potato flour blend and -α = 0.59 g, -1 = 1.09 g, 0= 2.29 g, 1 = 3.49 g, and α = 3.89 g for black cumin blend as can be seen in Table 4. Response variables (carbohydrate content, protein content and sensory quality) of the produced bread were predicted using the following polynomial equation (Equation 1-3). If the experimental data was suitable to linear Equation 1, for second-order model Equation 2, or for quadratic terms Equation 3 was tested according to (Zenebe et al., (2024).

$$\boldsymbol{y = \beta_0 \sum_{i=1}^{k} \beta_i x_i + \varepsilon} \qquad \textbf{(1)}$$

Where k represents the number of variables, β_0 is the constant term, β_i represents the coefficients of the linear parameters, x_i represents the variables, and ε refers to the residual associated with the experiments.

$$\boldsymbol{y = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \sum_{1 \le i \le j}^{k} \beta_{ij} x_i x_j + \varepsilon} \qquad \textbf{(2)}$$

$$\boldsymbol{y = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \sum_{i=1}^{k} \beta_{ii} x_i^2 + \sum_{1 \le i \le j}^{k} \beta_{ij} x_i x_j + \varepsilon} \qquad \textbf{(3)}$$

Where: β_{ij} and β_{ii} refer to the regression coefficients of interactive parameters and quadratic parameters, respectively. SPB = sweet potato blend, BCB = black cumin blend, CBH = carbohydrate. Other proximate composition and functional properties of the bread were analyzed for the bread produced at the optimum points.

3.5. Steps for Preparation of Sweet potato Flour

The sweet potato tubers were thoroughly sorted to remove foreign materials from the lot. The sorted tubers were washed to remove adhering soil, dirt and extraneous materials. The tubers were peeled and sliced to facilitate fast rate of drying and ease milling operations. The sliced tubers were blanched in order to inactivate enzymes to avoid any browning reaction and then cooled and drained followed by sun drying for several days (3–5 days) .The tubers were milled, sieved into fine flour and packaged for further use (Adeleke&Odedeji, 2010).The flour making process was done as follows.

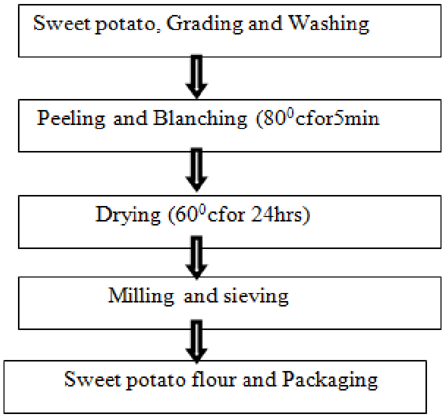

Fig 3: Sweet potato flour preparation process (Adeleke & Odedeji, 2010).

3.6. Preparation of Black cumin seed

Black cumin seeds were bought from the Adihaki market in Mekelle city. The seeds were manually cleaned to remove any impurities, followed by a thorough wash with tap water to eliminate soil and dust. Afterward, they were sun-dried for an hour, according to the baseline survey information. The seeds were then stored in a clean container, packed in a clean and sealed plastic bag and kept in a cool dry room.

Fig 4: Back cumin seed

3.7. Bread Making Process

The breads were prepared using the straight dough method, which involves a series of steps including mixing, kneading, bulk fermentation, molding, rounding, intermediate proofing, final proofing, baking, cooling, and packaging. The Breads were prepared and baked based on the straight dough method used by Anton (2008) with slight modifications as the mixtures were mixed and kneaded with water in a flat wooden material manually instead of using electric mixer. And flour (500%), salt (5%), yeast (10%) and water 65-70% were used in each blend during the preparation of the dough. These ingredients in bread formulation were determined based on knowledge from traditional experienced bakers and literatures (Mepba *et al.,* 2007; Mardiana, 2008; Jolaosho, 2010; Ukpabi, 2010). The dry ingredients were weighed using a digital analytical balance (Model: ME204, Mettler Toledo, China).

Based on the experimental design shown in Table 4, the sweet potato blending ratios(SPB) (8, 10, 15, 20, and 22 g) and black cumin seed blending ratios (BCB) (0.59, 1.09, 2.29, 3.49 and 3.89 g) were prepared. Next, the dry ingredients were mixed with 10 g of yeast, 65-70%water and 5g of salt, which had been dissolved in water at 30ºC-35^{0}C the optimal temperature for activating the yeast cells.

The mixture was then blended for 5 minutes using the same mixer set at low, medium, and high speeds. During the mixing process, additional water was added gradually until cohesive dough was formed. After kneading, the dough was covered with a moistened cloth and placed in a proofing cabinet set at 30ºC with 85% relative humidity. The total fermentation time at room temperature was 300 minutes. After the first 90 minutes, the dough was punched to release carbon dioxide, allowing fresh air to enter, and then returned to the proofing cabinet. More gas bubbles filled the dough during the final rise, also referred to as proofing. The second punch occurred 30 minutes later (Cappelli & Bettaccini, 2020).

The dough from each blending ratio was divided into three equal portions, each weighing 100 g, and shaped. The shaped dough pieces were placed in metal baking pans and returned to the proofing cabinet for 30 minutes at room temperature to complete the proofing process, which is the final stage of fermentation. After proofing, the dough was prepared for baking. The rolls were baked in a preheated standard electric oven (Model MS2535GISW, France) at 220°C for 20 minutes, and then allowed to cool at room temperature for 1.5 hours. Once cooled, the loaves were removed from the metal pans and left to cool further at room temperature before evaluation. The cooled loaves were then dried at 60°C for 9 hours and ground into a fine powder using an electric grinder (High-Speed Sampling Machine Model FW100) for laboratory analysis, as shown in Fig.5

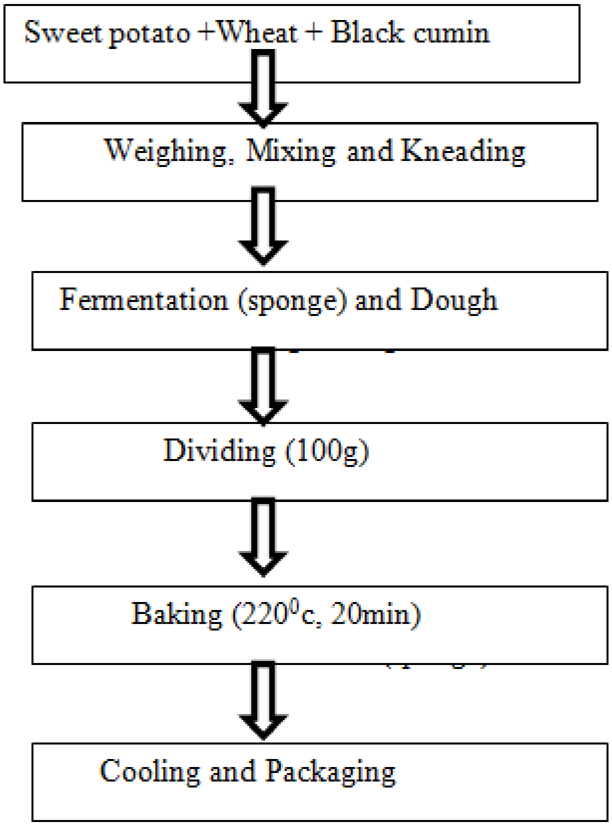

Fig 5: Flow diagram for preparation of blended bread (Cappelli&Bettaccini, 2020)

3.8. Lab Analysis for Proximate Composition of composite bread

3.8.1. Moisture content

The moisture content of the sample was determined following the method outlined by AACC (2000). A clean, dry dish was first prepared and weighed (W1). A 5 g representative sample was then weighed along with the dish (W2). The sample was dried at above 100°C for 6 hours, and then cooled in desiccators. After cooling, the weight was recorded as W3. The moisture content was calculated using the formula below.

Equation 4: MC % Determination $\text{Moisture content (\%)} = \frac{W2 - W3}{W2 - W1} \times 100$

Where, W1 = weight of the dish (g), W2 = initial weight of the sample and dish before drying (g) and W3 = weight of sample and dish after drying (g).

3.8.2. Crude Protein

The protein content of all flour samples was determined using the Kjeldahl method, as outlined by AACC (2000). A 1 g sample was placed into a Kjeldahl digestion flask. A catalyst mixture consisting of 1 g of $Na_2SO_4$and anhydrous $CuSO_4$ in a 10:1 ratio was added. Subsequently, 5 mL of concentrated H_2SO_4 was introduced, and the flask was placed in a digester. The temperature was raised to 350°C, and digestion was allowed to proceed for over 2 hours until completion.

The flask was removed from the digester and allowed to cool. Once cooled, the contents of the flask were diluted with 30 mL of distilled water, followed by the addition of 25 mL of 40% NaOH to neutralize the acid and create a slightly alkaline solution. The contents were then distilled immediately by inserting the digestion tube into a receiver flask containing 25 mL of 4% boric acid solution, from which approximately 150 mL of distillate was collected. Finally, the distillate was titrated with a standard 0.1 N HCl solution.

Equation 5: Nitrogen Determination$N(\%) = \frac{(VHCl \times NHCl \times 14)}{M\times 1000} \times 100$

Protein Determination

% Protein = F × %N Where: V HCl = Volume of HCl in litter consumed to the endpoint of the titration, N HCl =Normality of HCl (used often is 0.1 N), m = the sample weight on a dry matter basis, 14= Molecular Weight of Nitrogen, N=is Nitrogen (%), F=Conversion factor 6.25, and P=is protein (%)

3.8.3. Crude Fat

Crude fat content was determined using the Soxhlet extraction method, as outlined by AACC (2000). A 3 g ground sample was placed into a thimble and positioned in a 50 mL beaker, which was dried in an oven at 100ºC for 2 hours. The beaker (150-200 mL) was then weighed and rinsed multiple times with petroleum ether. The sample in the thimble underwent Soxhlet extraction with petroleum ether for 6 to 8 hours. Once the extraction was complete, the fat was evaporated in a fume hood using a steam bath until no solvent odor remained. The beaker and its contents were then dried in an oven for 30 minutes at 100ºC. After cooling the beaker in a desiccator, it was weighed (mf). The fat content in the flour was subsequently calculated using the appropriate formula.

Equation6: Fat Determination Fat (%) $= \frac{(\mathrm{Mf} - \mathrm{Mi}}{\mathrm{M}}) \times 100$

Where, mf= dried mass of fat with beaker (g), mi = mass of beaker (g), and, m =sample mass (g).

3.8.4. Crude Fiber

The crude fiber content was determined according to the AACC (2000) method. A 3 g ground sample (m1) was placed in a 500 mL beaker and subjected to digestion with 1.25% sulfuric acid, followed by washing with water. The sample was then further digested with 1.25% sodium hydroxide and filtered using a coarse porous crucible (75 µm) under a vacuum of approximately 25 mmHg. The remaining residue was washed again with 1.25% sulfuric acid at near-boiling temperature. Subsequently, the residue was dried at 110ºC overnight, cooled in a desiccator, and weighed (m2). After drying, the sample was ashed at 550ºC until the ashing process was complete, cooled in a desiccator, and weighed again (m3). The total crude fiber content in the flour was calculated as a percentage using the appropriate formula.

Equation 7: Crude Fiber Determination% F $= \frac{(\mathrm{M2} - \mathrm{M3}}{\mathrm{M1}}) \times 100$

Where, F=is the total crude fiber (%), m1 = mass of sample (g, db), m2 = mass of the sample before ashing (g), m3= mass of the sample after ashing (g)

3.8.5. Total Ash

According to the method of the AACC (2000), the total ash content of the flour was determined by the gravimetric method. The crucible was cleaned dried and ignited at 550 ºC for 1 hrandweighed (m1). The ground sample (3g) was weighed (m2). The sample was dried at 120 ºC for 1 hour, then the dried sample was carbonized over a blue flame and ignited in a muffle furnace at 550 ºC until ashing was complete (over 12 hr). After being ignited, the sample was cooled to ambient temperature and weighed (m3). Finally, the total ash content was calculated as follows. **Equation 8:** Ash Determination $\text{Ash}\ (\%) = \frac{(\text{M3} - \text{M1})}{\text{M2} - \text{M1}} \times 100$

Where: m1 = mass of empty crucible (g) m2 = mass of crucible + sample after ashing (g) m3= mass of the final sample with crucible (g)

3.8.6. Carbohydrate

The content of carbohydrates was determined by the difference method. This method requires subtracting the sum of the percentages of moisture, crude protein, crude fat, and ash content from 100.Carbohydrate Determination

Percent of carbohydrate =100-(% Moisture content+% crude protein+% fiber+%crude fat+% ash).

3.9. Determination of Functional Property of bread

3.9.1. Water Absorption Capacity

The water absorption capacity of bread flour samples was measured using the method outlined by (Chandra et al., (2015), with slight modifications. For this, 0.83g of the sample was mixed with 10mL of distilled water and placed in centrifuge tubes. The mixture was stirred periodically and allowed to stand for 30 minutes before being centrifuged (model EBA 8S Hettich, Germany) for 25 minutes at 2310g. The water absorption capacity was then expressed as the grams of water absorbed per gram of the sample on a dry weight basis. The water absorption capacity was calculated as follows:

Equation9: WAC Determination

$$\text{WAC}\left(\frac{\text{g}}{\text{g}}\right) = \frac{(\text{weight of centrifuge tube after drying} - \text{weight of centrifuge tube}) - \text{weight of sample}}{weightofsample}$$

3.9.2. Oil Absorption Capacity

The oil absorption capacity of the bread flour samples was determined following the method described by (Chandra et al., 2015) with slight modification. For the determination of oil absorption capacity, the sample (0.5 g) was assorted with 6 mL of olive oil and centrifuged at 2310 g for 25 min. Separated oil was removed from the tubes and kept inverted for 25 min to drain the oil before reweighing. The oil absorption capacities were expressed as a gram of oil-bound per gram of the sample on a dry basis. Oil absorption capacity was calculated using

Equation 10: OAC Determination

$$OAC\left(\frac{g}{g}\right) = \frac{(\mathrm{weightofcentrifugetubeafterdrawingoil} - (\mathrm{centrifugetubeweight})\ +\ \mathrm{weightofsample}}{\mathrm{weightofsample}}$$

3.9.3. Bulk Density

The bulk density was determined using the method outlined by Oladele&Aina (2007). A 50g sample of pulp flour was placed into a 100ml measuring cylinder. The cylinder was then tapped repeatedly on a laboratory table until a consistent volume was achieved. The bulk density (g/cm³) was calculated by dividing the weight of the flour (g) by the volume of the flour (cm³).

Equation 11: BD Determination

$$\mathrm{BD}\ (\mathrm{g/ml}) = \frac{(weightofsample)}{(volumeofsample)}$$

3.10. Mineral Determination of composite bread

3.10.1. Iron

The iron content was determined using an Atomic Absorption Spectrophotometer, following the method described by AACC (2000). A 2.0 g sample was placed into a pre-weighed crucible and ashed in a muffle furnace at 550°C until a white ash was obtained. The ash was dissolved in 10 mL of a 1:1 (v/v) mixture of concentrated HCl and distilled water, filtered, and diluted to 50 mL with deionized water. For iron standard preparation, a 1000 ppm Fe stock solution was prepared by dissolving 1.000 g of pure iron wire in 30 mL of 6 M HCl, gently heating to complete dissolution, and diluting to 1 liter with deionized water. Working standards of 0.0, 0.5, 1.0, and 2.0 mg/kg were prepared by serial dilution from the stock solution. A 5.0 mL aliquot of the prepared sample solution was aspirated into the AAS. Absorbance was measured at 248.3 nm using an air-acetylene flame. Iron content was calculated by the following formula.

Equation 12: Iron determination $\text{Fe}\ (\text{mg}/100\text{g}) = \frac{(\mu\text{g}/\text{ml}) \times 100}{\text{Sample mass (g)(db)}}$

Where, µg/ml is the reading concentrations determined from absorbance versus concentration of standards calibration curve.

3.10.2. Zinc

Zinc content was determined using Atomic Absorption Spectrophotometry (AAS), following the method described by AACC (2000). A 2.0 g sample was ashed in a muffle furnace at 550°C, and the resulting ash was dissolved in 20 mL of a 1:1 (v/v) mixture of hydrochloric acid (HCl) and distilled water. The solution was then filtered and diluted to a known volume. A 5.0 mL aliquot of this solution was used for zinc determination by AAS at a wavelength of 213.8 nm, employing an air-acetylene flame. A 1000 ppm zinc stock solution was prepared by dissolving 1.380 g of zinc oxide (ZnO) in 10 mL of 6 M HCl, then diluting to 1 liter with deionized water. From this stock solution, working standards of 0.0, 0.5, 1.0, and 2.0 mg/kg were prepared by serial dilution to construct the calibration curve. Zinc content was calculated by the following formula.

Equation 13: Zinc determination $\text{Zn}\ (\text{mg}/100\text{g}) = \frac{(\mu\text{g}/\text{ml}) \times 100}{\text{Sample mass (g) (db)}}$

Where, µg/ml is the absorbance reading concentration.

3.10.3. Calcium

Calcium content was determined using an Atomic Absorption Spectrophotometer (AAS), following the AACC (2000) method. A 2.0 g sample was weighed into a pre-ignited crucible, carbonized over a Bunsen burner, and ashed at 550°C in a muffle furnace. The resulting ash was dissolved in 10 mL of 3 M HCl, boiled, and evaporated nearly to dryness on a steam bath. The residue was then re-dissolved in 20 mL of 2 M HCl, filtered into a 100 mL volumetric flask, and diluted to volume with distilled water. A 5.0 mL aliquot of this solution was mixed with 1% lanthanum chloride solution and diluted to 25 mL before aspiration into the AAS. Absorbance was measured at 422.7 nm using an air-acetylene flame. A 1000 ppm calcium stock solution was prepared by dissolving 1.249 g of calcium wire in 30 mL of HCl, adding 50 mL of distilled water, and diluting to 1 liter. Working standards of 0.0, 0.5, 1.0, and 2.0 mg/kg were prepared by serial dilution from the stock solution each containing 1% lanthanum chloride (i.e., 5 mL of lanthanum solution per liter).Calcium content was calculated with the following formula:

Equation 14: Calcium determinationCa $(\mathrm{mg}/100\mathrm{g}) = \frac{\mathrm{C}\times 100}{\mathrm{Sample\ mass\ (g)(db)}}$

Where, C= the concentration of the sample from the plot of absorption in (µg/ml); S= Sample mass (g)

3.11. Sensory Acceptability of composite bread

Sensory acceptability of the produced bread was evaluated using five-point hedonic scale scorecard as described by (Zebib et al., (2020).Based on the experimental design 13 bread samples were assessed by 20 sensory panelists (men and women with ages ranges between 24 and 32) selected from the staff and undergraduate class of the food science and post-harvest technology department of Mekelle University who have experience in bread eating and already taken sensory analysis courses. Just before the test, they were informed in group discussions on how the sensory evaluation and scoring would be conducted. The bread samples were evaluated on a scale of 1 to 5 (1 = very poor, 2 = poor, 3 = neither poor nor good, 4 = good, 5 = very good) of a given sensory attribute.

Individual panelists were asked to taste a piece of bread sample with a score of the sensory attributes of taste, aroma, appearance, texture and overall acceptability. Natural spring water was provided to each panelist for rinsing his/her mouth before and after tasting each sample. Conversations or any other form of exchange of ideas were not allowed between panelists during tasting. The sensory bread samples were arranged in random order and presented in a prepared pan on a tray in front of the panelists.

3.12. Data Analysis

The collected survey data were analyzed using descriptive statics such as means, standard deviation using both one way and two ways ANOVA. Performance of the RSM models were characterized based on the determination coefficient (R^2), root mean square error (RMSE) and predicted values and other diagrams of predicted versus actual values as described by Zenebe et al. (2024). Design Expert software version 10.1 and Excel was employed for statistical analysis of the data.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1. Baseline Survey

A baseline survey was conducted to gather information on the use of black cumin seed in the traditional production of wheat bread. The survey involved 29 mothers, and based on the data collected, the mean, minimum, and maximum amounts of black cumin seed used in relation to 500 grams of wheat flour were determined. The results showed the following values: a minimum of 1.09 g (± 1.2SD), a mean of 2.29 g (± 1.2SD), and a maximum of 3.49 g (± 1.2SD) of black cumin seed. These mean values were then used to standardize the concentration levels of black cumin seed for the practical laboratory work, based on a 500g portion of wheat flour.

4.2. Over all Experimental Design and Analyzed results

Based on the experimental design of the independent variables (ratios of sweet potato flour and black cumin) the measured results and predicted outputs for all responses (carbohydrate, protein, and overall acceptability) are presented in Table 4. It can be observed that the difference among the measured results and predicted outputs of the individual responses is insignificant. This shows the developed predicting models are accurate to predict the carbohydrate, protein, and overall acceptability of the bread made by blending sweet potato flour and black cumin into wheat flour.

Table 4: Experimental design, measured results, and expected outputs

Std	Factors		Responses					
	A:SPB	B:BCB	**Carbohydrate (%)**		**Protein (%)**		**Sensory value**	
	Unit g	Unit g	Predicted	Measured	Predicted	Measured	Predicted	Measured
1	10	1.09	78.57	78.5	7.13	7.17	4.31	4.31
2	20	1.09	83.69	83.76	5.91	5.94	3.82	3.83
3	10	3.49	82.99	82.55	7.97	8	4.23	4.23
4	20	3.49	83.71	83.46	6.82	6.83	3.61	3.62
5	8	2.29	80.53	80.64	7.57	7.6	4.14	4.15
6	22	2.29	85.02	85.03	5.92	5.92	3.38	3.38
7	15	0.59	79.93	79.98	6.57	6.56	4.35	4.35
8	15	3.89	82.94	82.46	7.76	7.8	4.2	4.21
9	15	2.29	81.54	81.31	7.11	7.13	4.7	4.74

10	15	2.29	81.54	81.32	7.11	7.13	4.73	4.75
11	15	2.29	81.54	81.31	7.11	7.13	4.73	4.73
12	15	2.29	81.54	81.31	7.11	7.13	4.73	4.73
13	15	2.29	81.54	81.31	7.11	7.13	4.73	4.74

4.3. Fitting the response surface models and model fit summary of Responses

It is expected to select the highest order polynomial where the additional terms are significant and the model is not aliased. As can be seen in Table 5, the suggested models for all responses are quadratic. The suggested models for protein, carbohydrate and sensory value (as overall acceptability) show lack of fit p-values <0.001.Moreover, the difference between Adjusted R² and Predicted R² values for suggested models of carbohydrate, protein and sensory value are less than 1which is acceptable. Lack of Fit p-value Tests if there is unexplained structure in the residuals. P < 0.05 = significant Lack of Fit which is Bad and this to be > 0.05, which would mean no significant lack of fit.

Unfortunately, even the Quadratic model has significant Lack of Fit for CBH (p = 0.0007and for sensory value p= 0.9735) which suggests some curvature or variation is still unexplained, or the pure error is very low (making small differences look statistically significant).Generally Lack of Fit p-value shows when > 0.05 no significant lack of fit and the Model fits adequate well more over ≤ 0.05 Significant lack of fit which is Model doesn't fit well may be missing important terms.

Table 5: Model fit summary for all Responses

Type of response	Source	Sequential p-value	Lack of Fit p-value	Adjusted R²	Predicted R²	
CBH	Linear	0.0011	< 0.0001	0.6917	0.4613	
	2FI	0.0111	< 0.0001	0.8389	0.7307	
	Quadratic	**< 0.0001**	**0.0007**	**0.9998**	**0.9992**	**Suggested**
	Cubic	0.0007				**Aliased**
Protein	Linear	< 0.0001		0.932	0.8853	
	2FI	0.8639		0.9247	0.8767	

	Quadratic	**< 0.0001**		**0.9995**	**0.9981**	**Suggested**
	Cubic			1		**Aliased**
Sensory value	Linear	0.2411	< 0.0001	0.0971	-0.2509	
	2FI	0.8903	< 0.0001	-0.0009	-0.7168	
	Quadratic	**< 0.0001**	**0.9735**	**0.9998**	**0.9998**	**Suggested**
	Cubic	0.9735		0.9996		**Aliased**

4.4. ANOVA for Quadratic Models of the Responses

The effects of independent variables (ratios of sweet potato flour and black cumin) on protein, carbohydrate, and overall acceptability were quantitatively evaluated using response surface method (RSM). By applying quadratic model, the effect of the individual coefficients was analyzed as shown in Table 6. Linear terms of the independent variables (ratios of sweet potato flour and black cumin) for predicting the protein, carbohydrate and sensory value qualities have shown significant effect (all $p < 0.001$). The interaction effect of independent variables (ratios of sweet potato flour and black cumin) has shown significant $p < 0.001$) effect for the carbohydrate and over all acceptability whereas for protein has shown less significant ($p < 0.1$).

Table 6: ANOVA of Quadratic models for all responses

Source	**Sum of Squares**			**Mean Square**			**F-value**			**p-value**		
	Sensory value	**Protein**	**CBH**	**Sensory value**	**Protein**	**CBH**	**Sensory value**	**Protein**	**CBH**	**Sensory value**	**Protein**	**CBH**
Model	2.52	4.61	34.75	0.5034	0.9215	6.95	10469.16	5209.78	11506.9	< 0.0001*	< 0.0001*	< 0.0001*
A-SPB	0.5935	2.85	19.15	0.5935	2.85	19.15	12343.38	16118.9	31712.4	< 0.0001	< 0.0001	< 0.0001
B-BCB	0.04	1.51	6.55	0.04	1.51	6.55	832.66	8556.22	10851.6	< 0.0001	< 0.0001	< 0.0001
AB	0.0042	0.0009	4.73	0.0042	0.0009	4.73	87.88	5.09	7833.11	0.0001-	0.0587	< 0.0001
A^2	1.66	0.2365	4.11	1.66	0.2365	4.11	34596.84	1337.29	6804.64	0.0001	< 0.0001	< 0.0001
B^2	0.3785	0.0091	0.0042	0.3785	0.0091	0.0042	7872.24	51.48	6.93	0.0001	0.0002	0.0338
Residual	0.0003	0.0012	0.0042	0	0.0002	0.0006						
Lack of Fit	0	0.0012	0.0041	5.52E-06	0.0004	0.0014	0.069		69.12	0.9735**	**	0.0007*
Pure Error	0.0003	0	0.0001	0.0001		0						

* Significant at 0.5% **Not significant at 0.5%

The Model F-value for all response implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.P-values less than 0.05 indicate model terms are significant. In this case A, B, A^2, B^2 are significant model terms to predict the effects of ratios of sweet potato flour and black cumin blend on protein, but A, B, AB, A^2, B^2 for carbohydrate and sensory value are significant model terms. Values greater than 0.1indicate the model terms are not significant. The interaction between sweet potato flour and black cumin ratio significantly influences the carbohydrate content and the overall acceptability. But in protein there is minimal or weaker interactions, with a p-value less than 0.05. DF specifies the number of independent components in the sum of squares. And, Mean Square is the ratio of the sum of squares to DF. Cor Total indicates that amount of variation around the mean of the observations

4.5. Summary of Analysis of Variance (ANOVA) and Validation of Developed Quality Predictive Models

Table 7 shows standard deviation, mean value, coefficient of variation (CV), adj-R^2, pre-R^2, adequacy of precision, and PRESS of all developed response models. As can be observed from Table 7 the response variables for carbohydrate, protein and sensory (overall acceptability) shown R^2 higher than 0.99, the developed models are accurate enough to predict for the carbohydrate, protein and sensory (overall acceptability) properties of the produced bread.

Table 7: Fit Statistics of model for all responses.

Statistical parameter	**Statistical value**		
	CBH	**Protein**	**Sensory value**
Std. Dev.	0.0246	0.0133	0.0069
Mean	81.76	7.04	4.29
C.V. %	0.0301	0.189	0.1617
R^2	0.9999	0.9997	0.9999
Adjusted R^2	0.9998	0.9995	0.9998
Predicted R^2	0.9992	0.9981	0.9998
Adeq Precision	390.05	230.62	287.54

The Predicted R^2 of 0.9981 is in reasonable agreement with the Adjusted R^2 of 0.9995; i.e. the difference is less than 0.2 for the carbohydrate, protein and sensory (overall acceptability) responses. Moreover, Adeq Precision measures the signal to noise ratio in which a ratio greater than 4 is desirable. The ratios for the carbohydrate, protein and sensory (overall acceptability) responses indicate an adequate signal. These models can be used to navigate the design space.

The digenesis of developed models using residual versus predicted values shown in Figure 7 indicates the predicted and actual values of the data from the developed model shown significant difference.

Final equation of responses in terms of actual factors

Model equations were tested to linear and polynomial equations to select best fit. The selected model should have insignificant lack-of-fit and not from the aliased suggestion. Accordingly, significant model terms were selected having p-values < 0.05. A backward auto selection using the Design Expert software package was employed. All the linear, interaction, and quadratic terms in both responses for carbohydrate, over all sensory acceptability and protein are significant and included in the models.

However, except the quadratic term and a linear term for sweet potato blend (SPB), the linear, interaction, and quadratic terms for the black cumin blend (BCB) are not significant. Since the suggested model is quadratic, and the quadratic term for this variable is included considering at p-value < 0.05 the model equation was developed including these terms. The equations were developed in terms of actual factors used to make predictions about the response for given levels of each factor.

Equation 15: $Protein(\%) = 6.6 + 0.099SPB + 0.2BCB + 0.002SPB * BCB - 0.007SPB^2 + 0.0263BCB^2$

Equation 16: $CBH(\%) = +75.5 - 0.2SPB + 3.57BCB - 0.18SPB * BCB + 0.03SPB^2 - 0.012BCB^2$

Equation17: $Sensoryvalue = 0.16 + 0.55SPB + 0.8BCB - 0005SPB * BCB - 0.012SPB^2 - 0.17BCB^2$

Where: CBH refers to carbohydrate, BCB to black cumin blend, SPB to sweet potato blend.

Diagnosis of developed models using actual versus predicted values

Visualizing the actual versus predicted values using a scatter plots is a crucial step in diagnosing the performance of a developed model. Such discrimination helps to assess how the model's predictions perfectly align with the observed data. This shows potential issues like bias, poor fit, or the need for model refinement. Visualization tools, such as scatter plots of actual vs. predicted values and residual vs. predicted plots help to diagnose the developed model's fit (Onu et al., 2021). Residual vs. predicted plots are powerful illustrative diagnostic techniques employed to criticize the assumptions and performance of statistical models.

In particular, the regression analysis helps to show how the degree of difference and similarity between the predicted and residual values. By criticizing the relationship between the residuals (the difference between observed and predicted values) and the predicted values, one can identify significance of properties for the model fit and put suggestions on decisions about model improvement (Cho et al., 2022).The residual vs. predicted plots for the developed models are shown in Figure 6. It is observed that none of the measured values are scattered away from the strait line. The measured values versus the predicted values were obtained from the models' development.

The points are aligned very closely to the standard 45-degree straight line. We can confirm that there is an excellent correlation among the experimental and predicted values of the responses. Since the plot of the residuals have shown dominantly the data points were centered between −1.0 and +1.0 points (Onu et al., 2021). Therefore, response transformations were not required and the quadratic regression models were found adequate in modeling the blending of the ingredients to produce bread with enhanced carbohydrate, protein and acceptable sensory values.

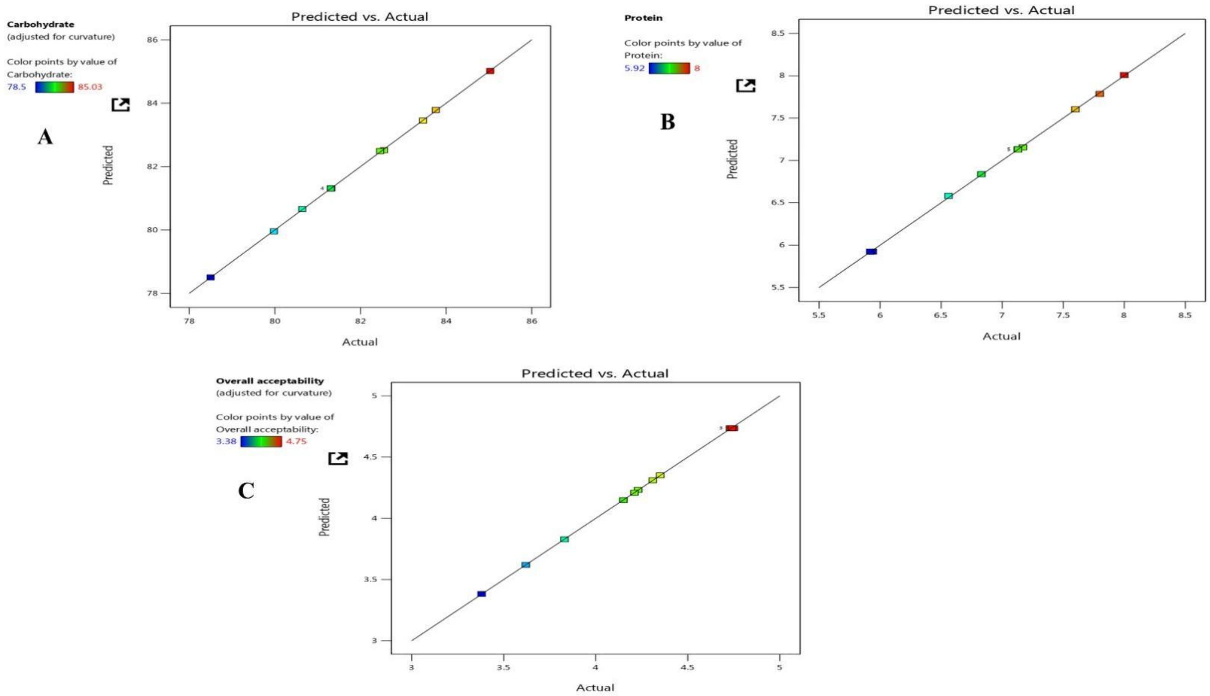

Fig 6: Actual versus Predicted Plots of (Protein, carbohydrate and Sensory) in terms of overall acceptability).

4.6. Effects of the independent variables (ratios of sweet potato flour and black cumin) on the responses (protein, carbohydrate and sensory properties)

Linear, quadratic effects as well as mutual interactions among the tested variables of the independent variables (ratios of sweet potato flour and black cumin) on the responses (carbohydrate, protein and sensory value) of the produced bread samples were checked by the significance of every coefficient at p-values as depicted in Table 6.The 3D Response surface and contour plots shown in Figures 9, 12 and 15, which are generated using Design Expert software visualize the combined effects of two factors on any response. Moreover, the combined interaction effects of each independent variable are demonstrated in Figures 7, 10 and 13.

4.6.1. Interaction effect of Sweet Potato Flour and Black Cumin Seed Blend on the Protein Content of Bread

The interaction effect of proteins Parallel curves (no strong interaction) since the two curves (black and red) are almost parallel. This indicates that there is *not* a strong interaction between SPB and BCB the shape of the response is similar at both BCB levels. Even though the regression equation includes an interaction term (+0.002 SPB × BCB), it's very small, and the plot visually confirms that the interaction effect is minimal.
The results for the effect of independent variables (sweet potato flour and black cumin blend) on the final bread quality are shown in the ANOVA (Table 6). From the optimization model the linear and quadratic terms ratios of the sweet potato flour and black cumin blend have shown significant effect ($p < 0.05$) on protein quality of the produced bread. However, interactive effect of these independent variables has shown less significant effect ($p < 0.1$).

The reason for the linear effects of the sweet potato flour and black cumin blend with wheat flour could be the direct involvement (composition) of protein in both sweet potato flour and black cumin. However, unless their compositions are affected during the bread processing their interactive effect could be less.

According to Awulachew, (2025) studies on the blending ratios of fava bean and black cumin flours demonstrated an improvement in the nutritional content of wheat-based bread. He reported that increasing the proportion of black cumin flours enhanced the proximate composition, including ash, fiber, fat, and crude protein. This finding aligned with the experimental evidence from our study, which shows a positive linear effect of black cumin flour blends on wheat-based bread. Moreover, the protein content in black cumin flour may significantly improve the overall protein quality of the bread. Black cumin flour is rich in protein, and its addition enhances the protein quality of bread (Tanko et al., 2023).

The highest protein content was observed in the sample containing 10 g of sweet potato flour and 3.49 g of black cumin, while the lowest protein content was recorded in the sample with 22 g of sweet potato flour and 2.29 g of black cumin. The protein content decreased as the percentage of sweet potato flour increased. This decline may be attributed to the low protein content of the sweet potato flour, which reduced the overall protein level of the mixed flour as its proportion increased. The mean protein content of breads was significantly decreased ($p<0.05$) as substitution levels of sweet potato flour increased. The present finding was consistent with reports of (Aniedu&Agugo, 2010; EI- Zainy*et al.*, 2010).The response surface graph for the combined effect of levels of sweet potato flour and black cumin on protein content is given in (Figure8).

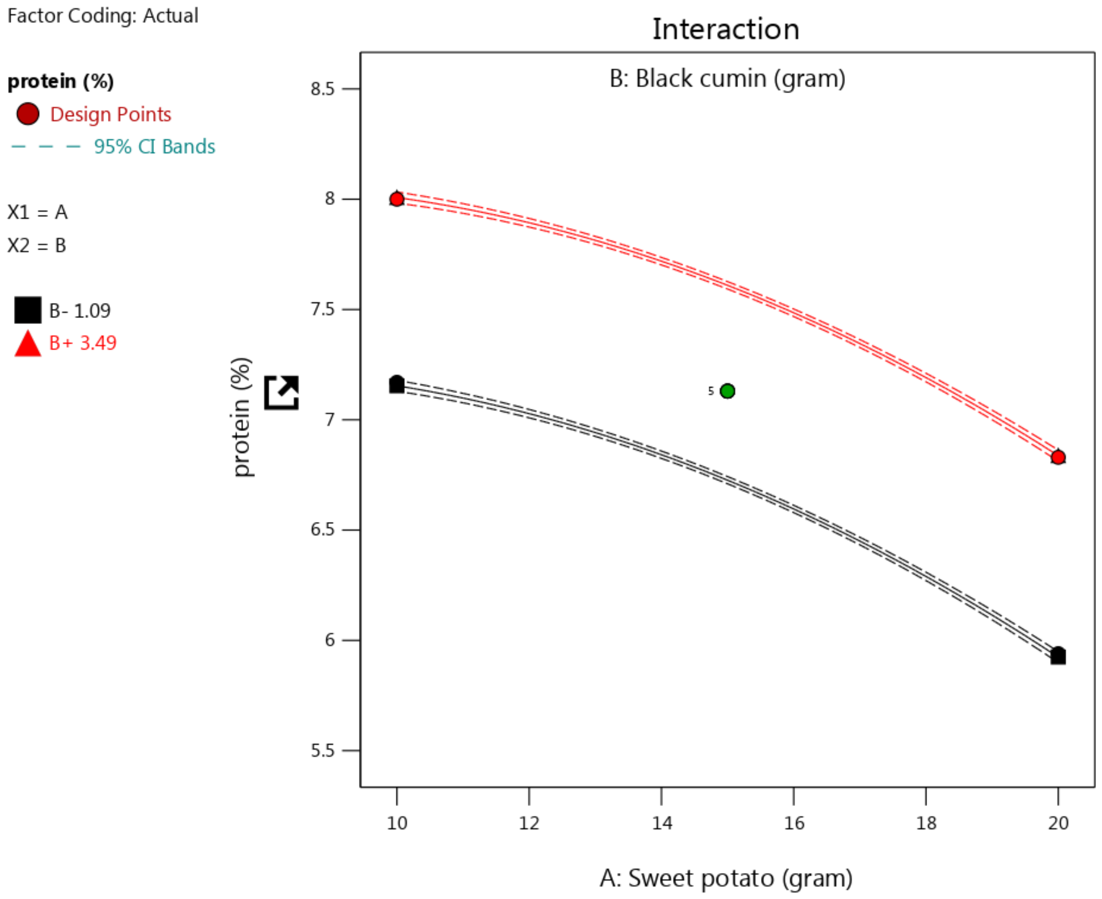

Fig 7: Interaction effect of sweet potato flour and black cumin on protein

4.7. Contour effect of black cumin and sweet potato on protein

The bread showed significant ($p < 0.05$) decrease in protein content with the increased proportion of sweet potato and black cumin ranging from 5.92- 8%. However, bread with high sweet potato flour and black cumin blending ratios created lower protein content (Ojo&Akande, 2013)

The optimization results showed that the protein had high R^2 (0.9997) and adjusted R (0.9995) values. The quadratic and linear model terms (A, B, A^2, B^2) were significant ($p \leq 0.05$) with a non-significant lack of fit. These R^2 and adjusted R^2 values together with the significant model terms for protein contents indicated that the composite flour prepared in this study had reasonable and acceptable protein contents. High R^2 and adjusted R^2 values (close to one) indicates statistical models are perfect fit (Awolu et al., 2015). These results showed that the composite flours making the bread significantly ($p \leq 0.05$) affect the protein content. The areas shaded red in the contour plot is the areas with highest protein content. It could be seen that the areas with high protein content were as a result of the black cumin incorporation. The contour plot representing the effect of the black cumin and sweet potato flour on the protein content is shown in (Figure 8).

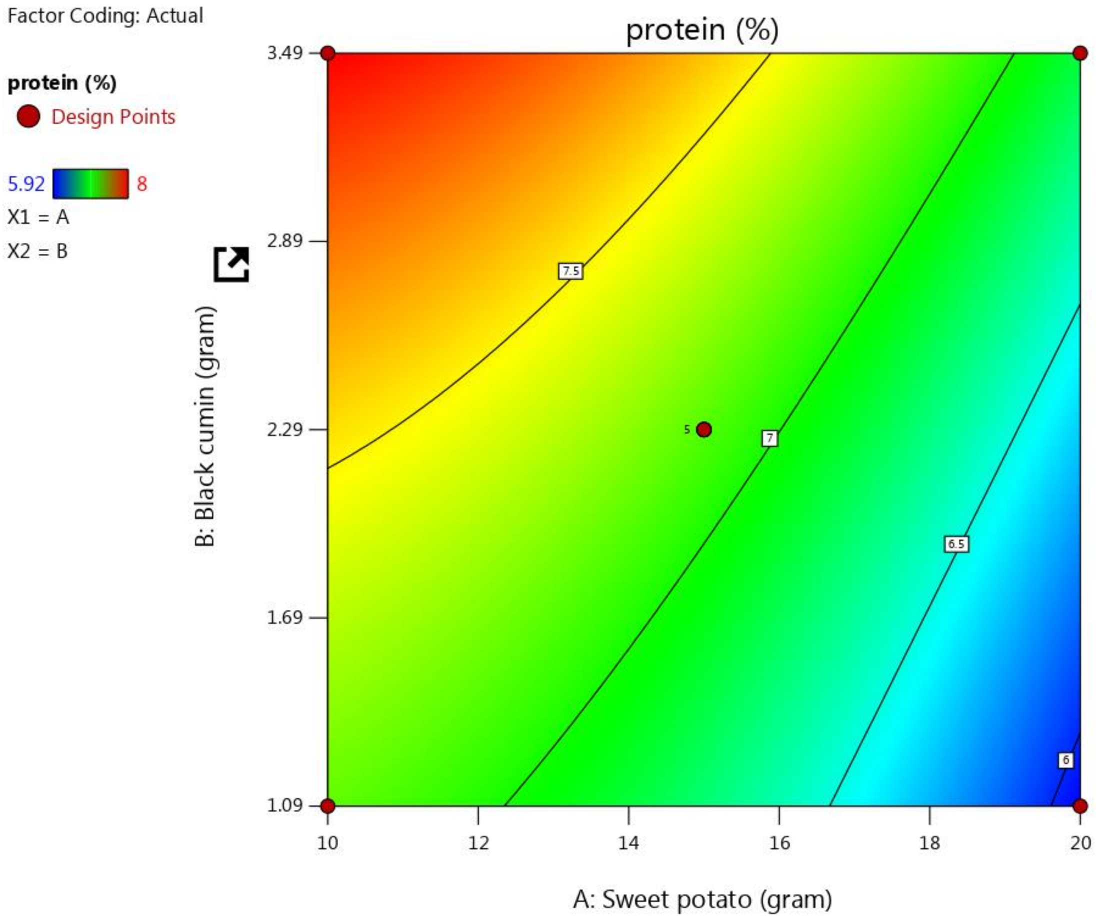

Fig 8: Contour plot effect of sweet potato and black cumin on protein

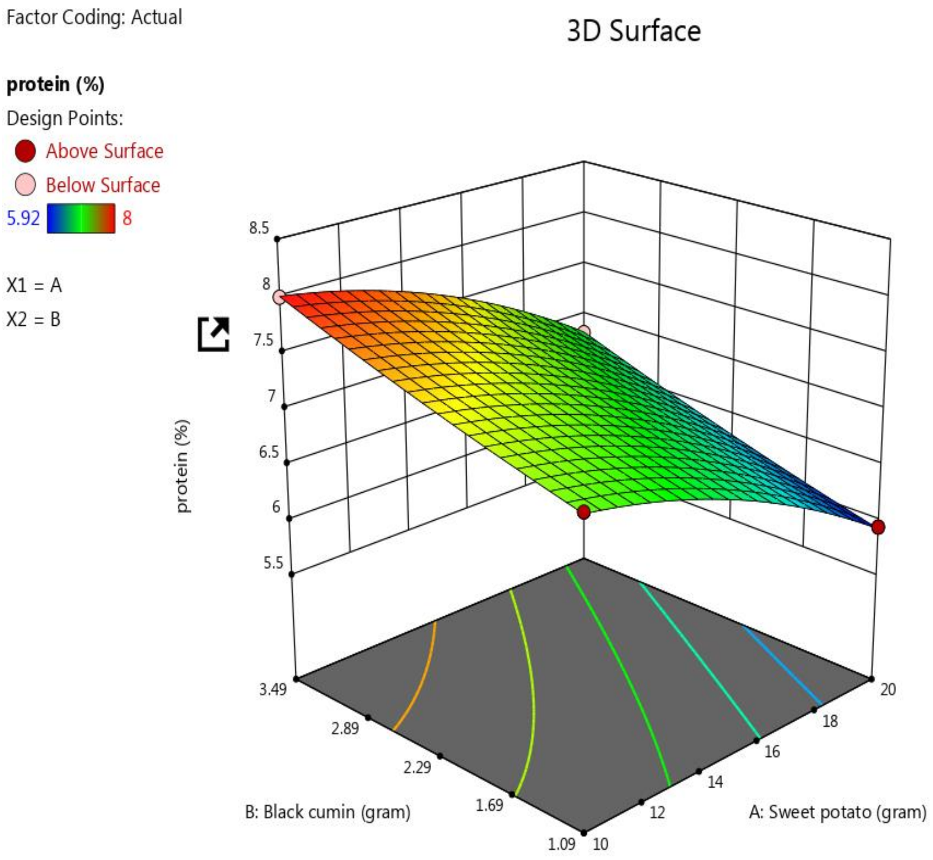

Fig9:3D plot effect of sweet potato flour and black cumin on protein

4.8. Interaction effects of sweet potato flour and black cumin blend on Carbohydrate content of the bread

The interaction effect of carbohydrate is Non-parallel Curves in these Interaction Exists **.**The two curves are not parallel, and they cross at the high end (near 20 g SPB). This indicates a clear interaction between SPB and BCB. The effect of SPB on carbohydrate depends on how much BCB is present. At low BCB, SPB increases carbohydrate significantly. At high BCB, SPB's effect is more muted and nonlinear

The ANOVA results (Table 6) indicate that both the linear and quadratic effects of sweet potato flour and black cumin blend significantly influenced the carbohydrate quality of the bread ($p < 0.05$). This stronger effect from the individual components may be attributed to the inherent carbohydrate content present in both sweet potato flour and black cumin. In contrast, the relatively lower impact of their interaction suggests that unless their chemical compositions are altered during the bread-making process, their combined effect remains limited.

Bread made with different ratios of sweet potato, and black cumin showed variations in carbohydrate levels. The bread containing 22 g of sweet potato, and 2.29 g of black cumin had the highest carbohydrate content. This is attributed to the higher starch concentration in wheat flour and sweet potato flour and the lower starch content in black cumin. In comparison the bread containing 10 grams of sweet potato flour and 1.09 g of black cumin had the lowest carbohydrate content. These results align with previous research (Qianqian et al., 2020) which showed that breads formulated with faba bean, and black cumin flour also exhibited reduced carbohydrate levels. This decrease is likely due to the lower starch content in black cumin.

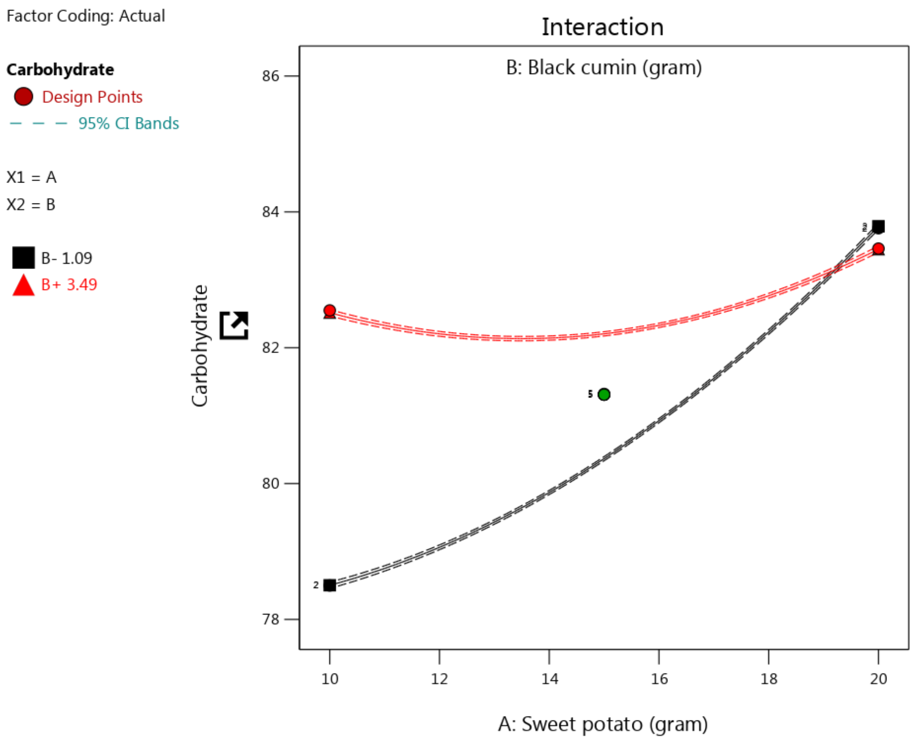

Fig 10: Interaction effect of sweet potato flour and black cumin on carbohydrate

4.9. Contour effect of black cumin and sweet potato on carbohydrate

The carbohydrate content showed significant ($p < 0.05$) increase as proportion of sweet potato increase and decrease as proportion of black cumin increase ranging from 78.5- 85.03%. The optimization results showed that carbohydrate content had high R^2 (0.9999) and adjusted R^2 (0.9998) values. The quadratic and linear model terms (A, B, AB, A^2, B^2) terms were significant ($p \leq 0.05$) with a non-significant lack of fit.

The contour plot representing the effect of the black cumin and sweet potato flour on the carbohydrate content is shown in Figure 11. These results showed that the composite flours making the bread significantly ($p \leq 0.05$) affect the carbohydrate content.

The areas shaded yellow in the contour plot is the areas with highest carbohydrate content. It could be seen that the areas with high carbohydrate content were as a result of the sweet potato incorporation.

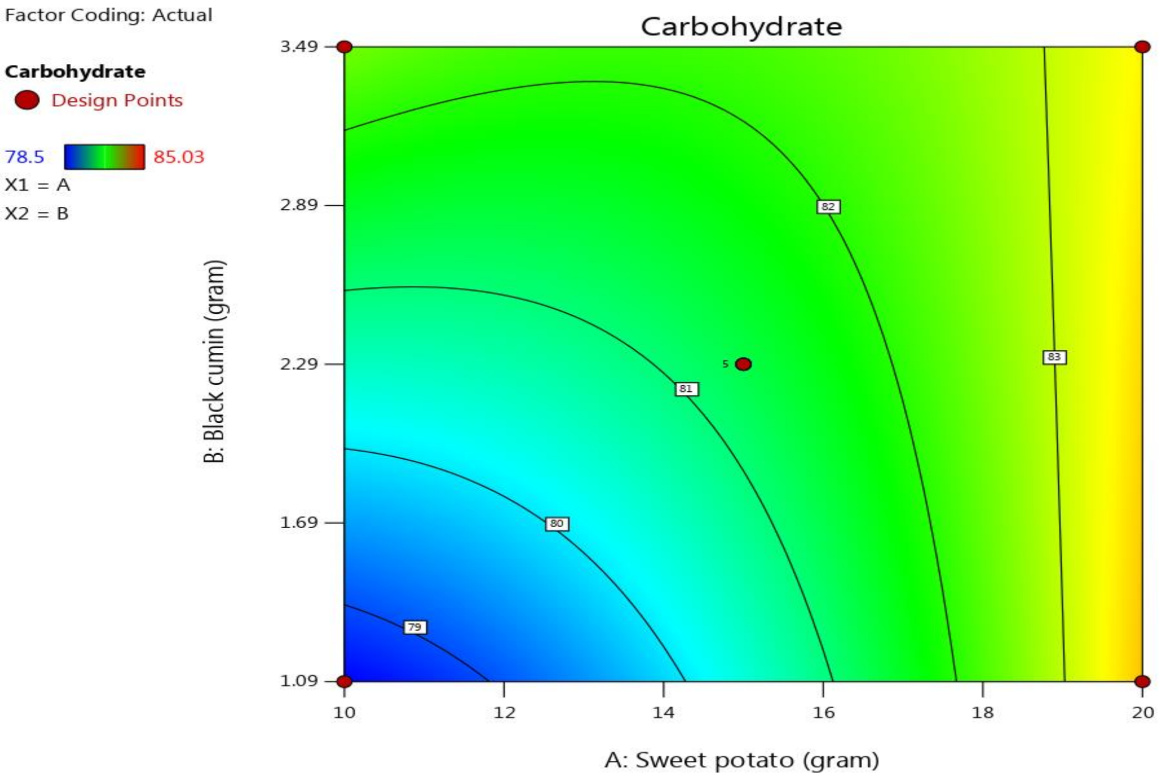

Fig 11: Contour plot effect of sweet potato and black cumin on carbohydrate

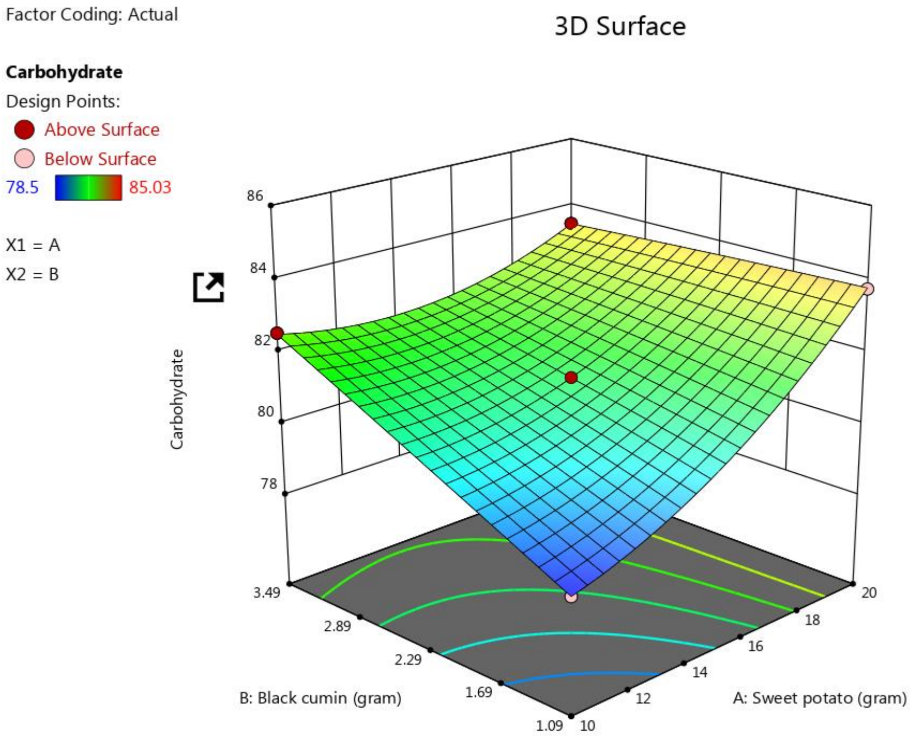

Fig 12:3D plot effect of sweet potato flour and black cumin on carbohydrate

4.10. Interaction effects of sweet potato flour and black cumin blend on overall sensory value of the produced bread

The interactions effect of overall acceptability is Parallel Curves in this (No Strong Interaction) The two curves have similar shapes and appear roughly parallel. This suggests: There is no significant interaction between SPB and BCB. The effect of sweet potato on acceptability does not depend strongly on the level of black cumin.

Although the interaction between sweet potato and black cumin levels was found to be statistically significant ($p < 0.0001$), the corresponding response surface plot suggests that the interaction effect is relatively weak in practical terms. The surface appears mostly additive, with limited curvature, indicating that while a statistical interaction exists, its influence on overall acceptability is not visually prominent. This may be due to the model's high sensitivity and low experimental error, allowing even small interactions to reach significance. Significant does not always mean strong effect**.** A statistically significant interaction means that the effect of one factor depends on the level of the other, even if the change is small.

The effect of Sensory acceptability was highest in formulations with balanced levels of SPF and BCB. Sample 10 (15 g SPF, 2.29 g BCB) recorded the highest sensory score (4.75), followed closely by the optimized sample of 11.8 gram of sweet potato flour and 3.49 g of black cumin (4.41). In contrast, excessive SPF or excessive BCB reduced acceptability, likely due to off-flavors, color, or texture. These findings are in agreement with the study reported by Khalil et al., (2021) who noted that black cumin at low-to-moderate levels improves aroma and texture, but at high levels, its strong flavor can reduce consumer preference.

Consumer acceptability varied significantly across the different blend ratios ($p < 0.05$), with higher levels of sweet potato negatively affected overall preference. This trend aligns with the results reported by Mitiku et al., (2018), Ligarnasari et al., (2018) &Melapa et al.,(2015), in which they demonstrated that the incorporation of black cumin flour into bread formulations enhances sensory qualities and helps maintain a soft texture. This improved softness is attributed to factors such as moisture, fat, and protein content.

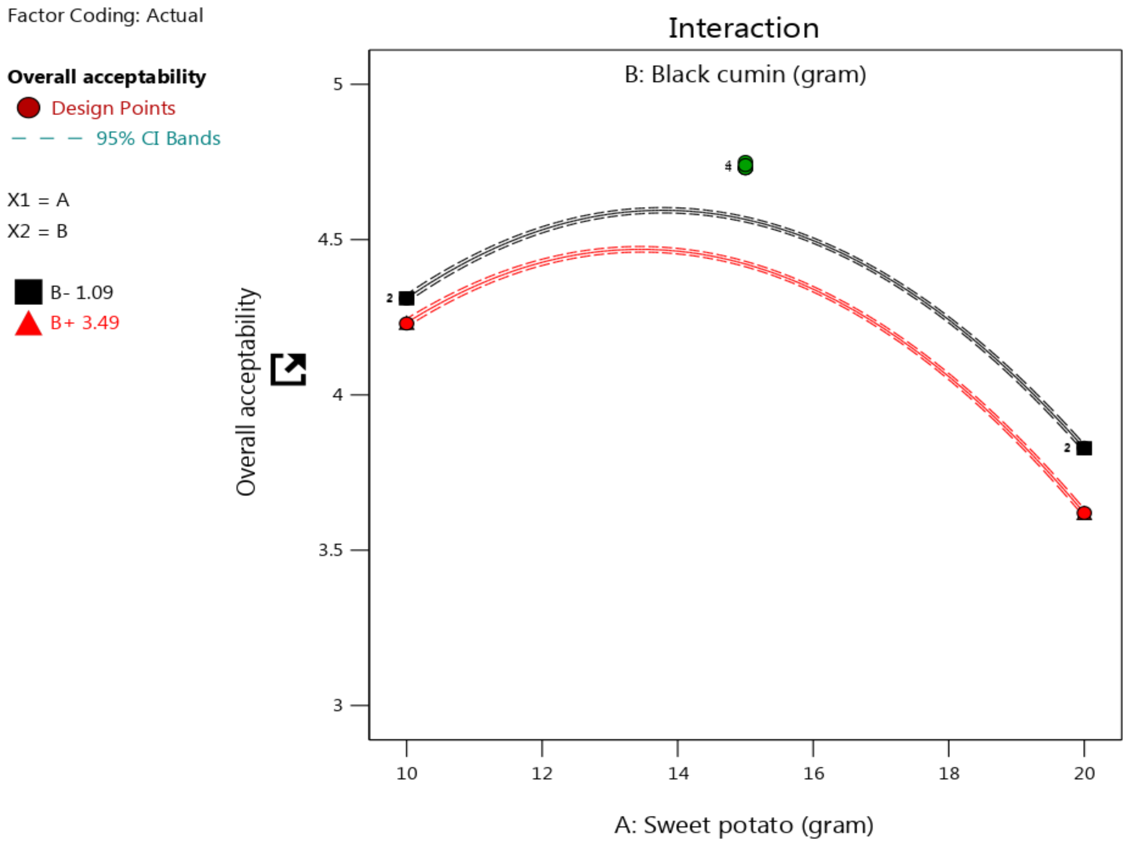

Fig 13: interaction effect of sweet potato flour and black cumin on overall acceptability

4.11. Contour plot effect of sweet potato and black cumin on overall acceptability

The overall acceptability showed significant ($p < 0.05$) moderately increase as proportion of black cumin increase and decrease as proportion of sweet potato increase ranging from 2.29-15% respectively. The optimization results showed that overall acceptability had high R^2 (0.9999) and adjusted R^2 (0.9998) values. The quadratic and linear model terms (A, B, AB A^2, B^2 terms were significant ($p \leq 0.05$) with a non-significant lack of fit.

The contour plot representing the effect of the black cumin and sweet potato flour on the overall acceptability is shown in Figure 15. These results showed that the composite flours making the bread significantly ($p \leq 0.05$) affect the overall acceptability. The areas shaded red in the contour plot is the areas with highest overall acceptability. It could be seen that the areas with high overall acceptability were as a result of the black cumin addition.

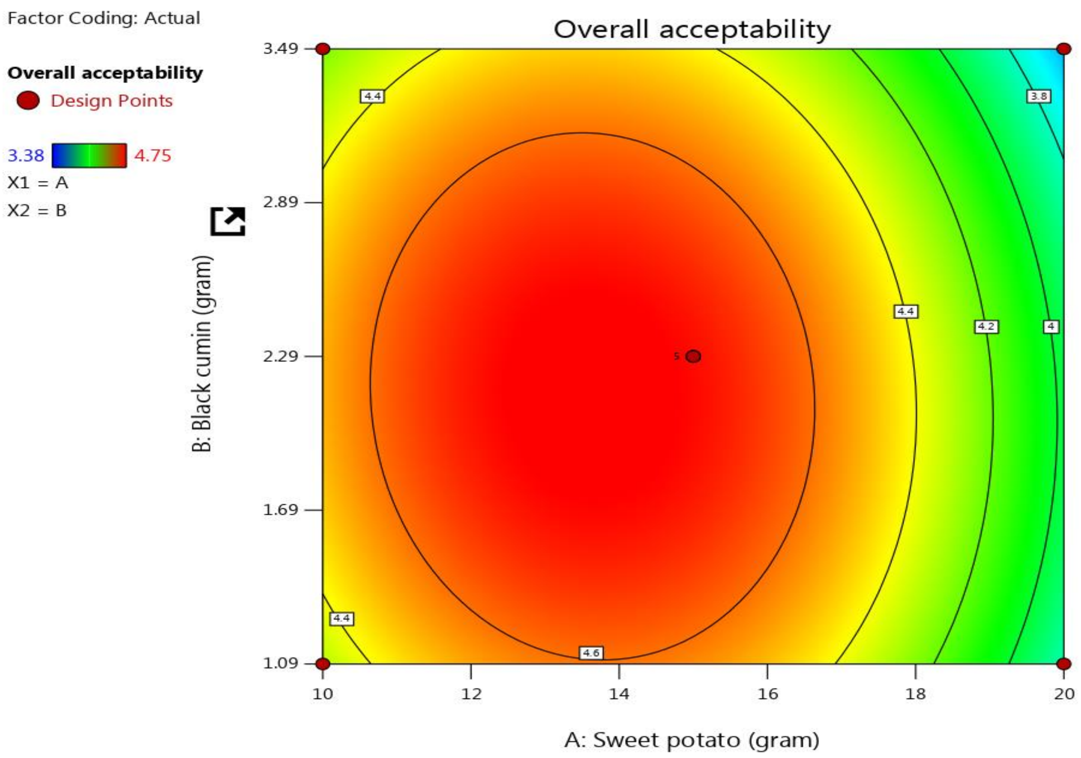

Fig 14: Contour plot effect of sweet potato and black cumin on overall acceptability

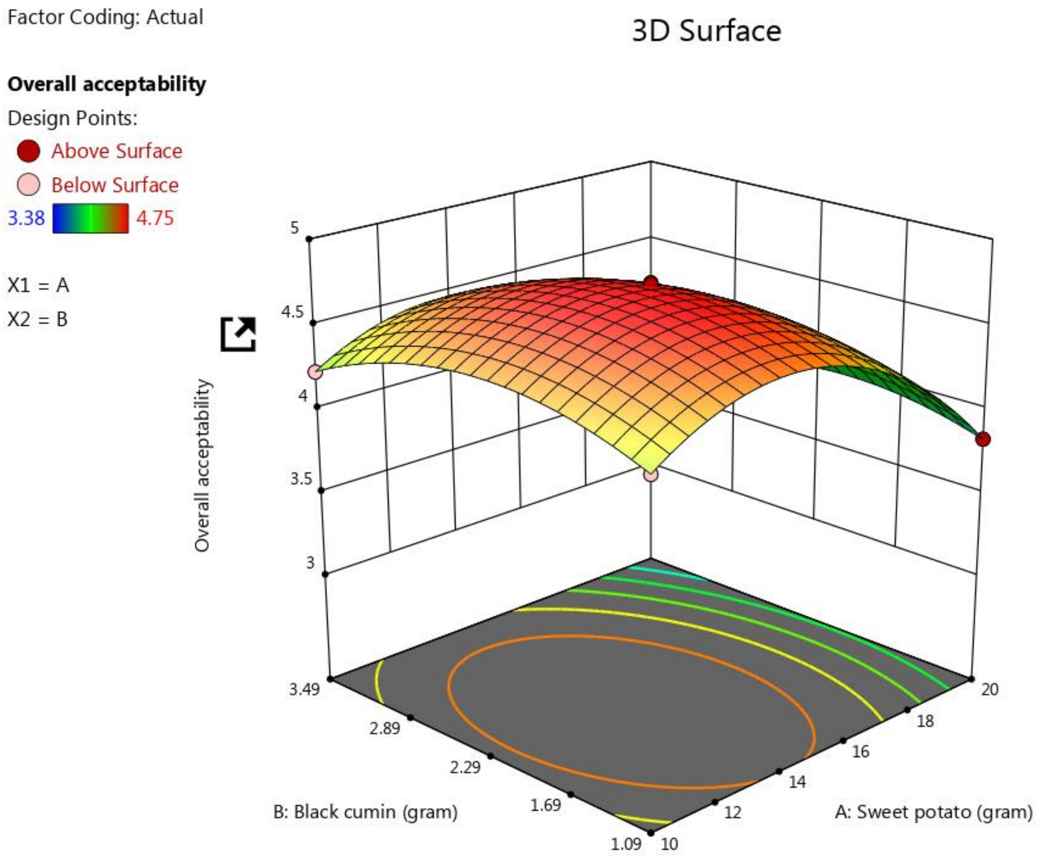

Fig15:3D plot effect of sweet potato flour and black cumin on overall acceptability

4.12. Confirmation report to validate the combination of factors on the carbohydrate, Protein and overall acceptability

The mean values for protein content (7.9%) total carbohydrate content (82.2%) and overall acceptability (4.41) were analyzed through Design Expert Software. The selected formulations (with desirability >0.744) of sweet potato flour were prepared and further evaluated for validating predicted values. Overall acceptability was evaluated by same panel of judges. Based upon the validation experiments, the formulation with optimized levels for sweet potato flour and black cumin as 11.8 g and 3.49 g respectively was found most suitable for preparation of composite bread. At the optimum values of SPB (11.8 g) and BCB (3.49 g) five experimental tests were conducted and the observed mean values are shown in Table 8.

Table 8: Confirmation report at the optimized values of SPB and BCB and the predicted values

Factor	Name	Level	Low Level	High Level	Std. Dev.	Coding		
A	SPB	11.8	10	20	0	Actual		
B	BCB	3.49	1.09	3.49	0	Actual		
Analysis	**Predicted Mean**	**Predicted Median**	**Observed data**	**StdDev**	**N**	**SE Pred**	**95% PI low**	**Data Mean**
CBH (%)	80.62	80.62	**82.2**	0.02457	5	0.0268497	80.5576	**82.2**
Protein (%)	7.18	7.18	**7.9**	0.0133	5	0.0145309	7.14524	**7.9**
Overall acceptability	4.774	4.774	**4.41**	0.00693	5	0.0075758	4.75634	**4.41**

4.13. Overall Optimization of the blending Process

The parameters like sweet potato flour and black cumin ratio were optimized within a range, while the responses protein, carbohydrate, and overall acceptability were set to maximize. If the value ranges from 0 to 1, in which as it approaches to 1 best solution. However, if it approaches to 0 it does not meet the best goal. In this study it meets the best goal at desirability of 0.744.Generally, during the optimization of the process parameters factors sweet potato flour and black cumin ratio were optimized in range but the responses protein, carbohydrate, and overall acceptability were set to be maximized in the study

Table 9: Constraints for optimization process parameters form DOE software

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
A:Sweet potato	in range	10	20	1	1	3
B:Black cumin	in range	1.09	3.49	1	1	3
Protein	maximize	5.92	8	1	1	5
Carbohydrate	maximize	78.5	85.03	1	1	5
Overall acceptability	maximize	3.38	4.75	1	1	5

4.14. Numerical optimization

The result for the optimal value, extracted by the Design-Expert software, suggested that 11.8 g of sweet potato flour and 3.49 g black cumin with desirability of 0.744 could be a better combination to achieve the best nutritional and overall acceptability of bread.

The term "desirability" refers to a method or methodology for optimizing numerous responses or criteria at once. It is especially beneficial when working with complicated systems in which enhancing one parameter may have an unfavorable effect on another. The desirability function allows you to integrate numerous objectives into one overall evaluation of desirability. Desirability functions assign a desirability value (usually between 0 and 1) to each objective depending on its proximity to the target or ideal value (Montgomery, 2017). The desirability of the data obtained was 0.744, indicating that the plan was effective.

Numerical optimization uses the models to search the factor space for the best tradeoffs to achieve multiple goals. Desirability is an objective function that ranges from zero outside of the limits to one at the goal. The numerical optimization finds a point that maximizes the desirability function. The characteristics of a goal may be altered by adjusting the weight or importance. For several responses and factors, all goals get combined into one desirability function(Montgomery, 2017).

The optimization analysis conducted using Design-Expert software identified an optimal formulation for bread enrichment using sweet potato and black cumin. According to the results, the best combination involves using 11.8 g of sweet potato flour and 3.49 g of black cumin. At these specific ingredient levels, the predicted nutritional and sensory outcomes are highly promising. The formulation is expected to yield a protein content of approximately7.9%**,** and a carbohydrate content of 82.2%**.** Additionally, the overall acceptability score**,** which reflects consumer preference and product quality, is predicted to be 4.41 on the sensory evaluation scale.

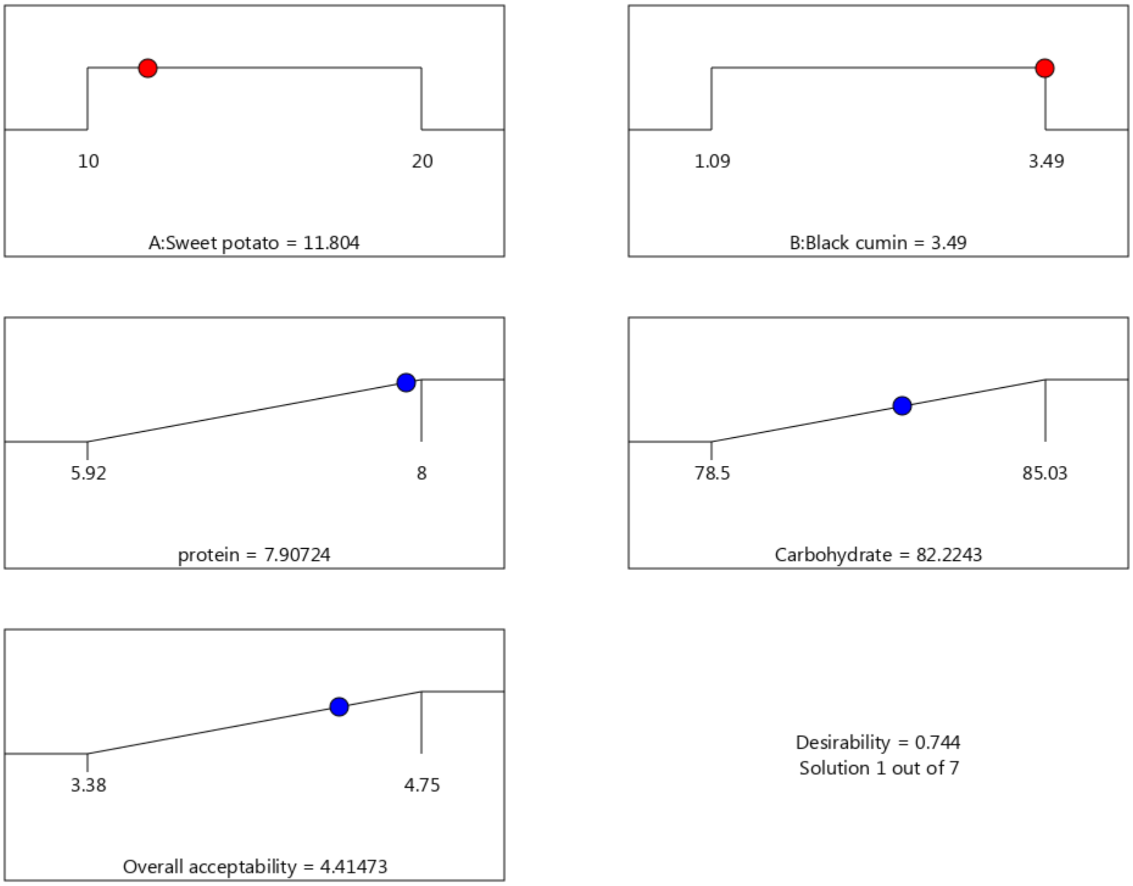

Figure 16: Ramps plot for numerical optimization at desirability 0.744

4.15. Graphical optimization

Myers and Montgomery (Response Surface Methodology, p. 244) describe a multiple response method called desirability. The method makes use of an objective function, called the desirability function. It reflects the desirable ranges for each response. The desirable ranges are from zero to one (least to most desirable, respectively). The simultaneous objective function is a geometric mean of all transformed responses. Graphical optimization uses the models to show the volume where acceptable response outcomes can be found. Graphical optimization is a method used to visually analyze and optimize processes or systems by plotting relevant variables and constraints on graphs or charts. If maximizing, specify the lowest acceptable lower limit. If trying to achieve a target, specify both a lower and upper limit. Interval estimates can be added to the optimization plot to account for uncertainty in the point predictions. On the plot, the bright yellow now shows where the entire ranges of all intervals meet the specified criteria [rule of DOE software).

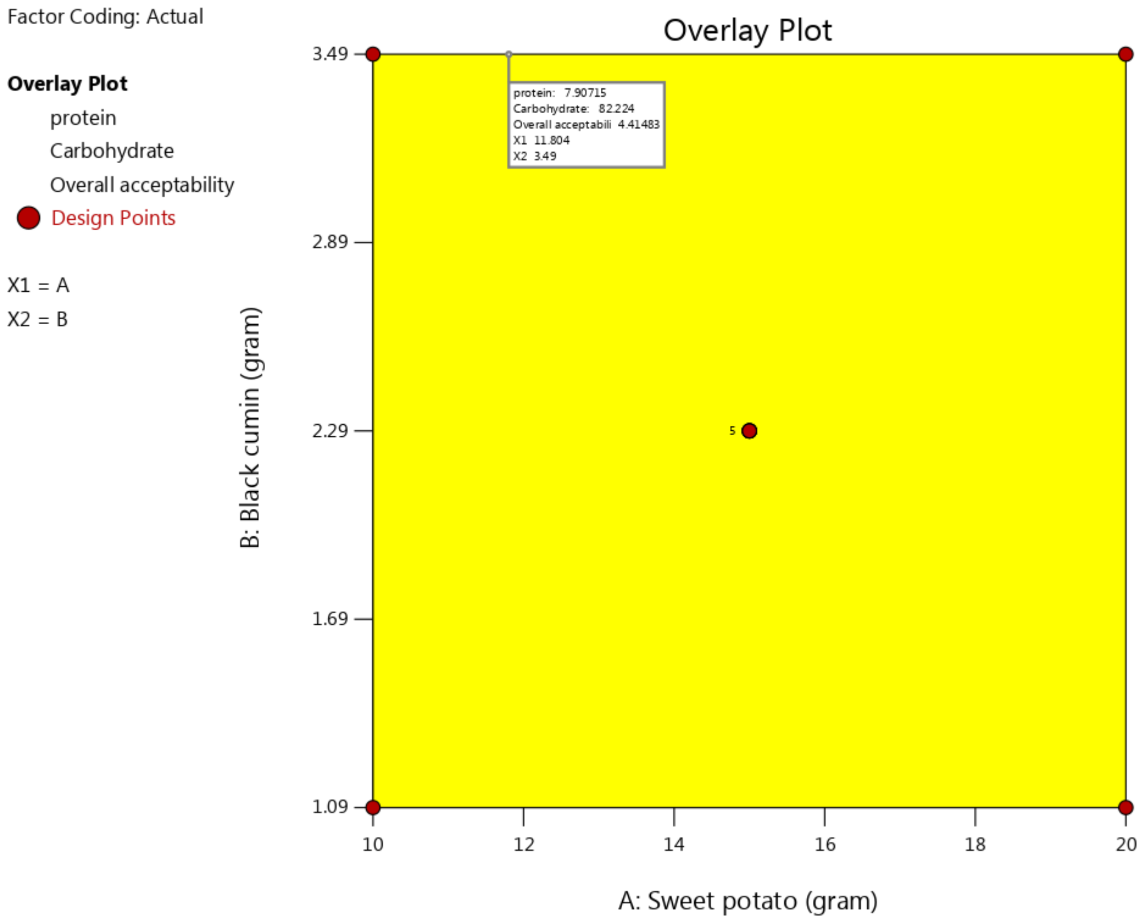

Figure 17: Interaction and Contour effect graphical optimization

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4.16. Physicochemical properties of the bread produced at the overall optimum values.

The optimized SPB and BCB were also used to evaluate proximate composition, mineral content and functional properties of the developed bread. Moisture, protein, fat, crude fiber, total carbohydrate, iron, zinc and calcium content in most acceptable range for the bread made at the optimized SPB and BCB. The present study concluded that the optimized sample of composite bread containing 11.8g sweet potato flour and 3.49 g black cumin was found the best combination with respect to overall acceptability and nutritional value.

Table 10: Proximate composition of optimized sample of sweet potato flour and black cumin

Proximate composition	Optimized sample (11.8g sweet potato flour and 3.49 g black cumin on bread
Protein%	7.9
Carbohydrate%	82.2
Overall acceptability	4.41
Fiber%	1.49
Ash%	2.59
Fat%	2.43
Moisture%	5.72
Mineral content (mg/100g)	
Ca	16.12
Fe	12.45
Zn	3
Functional properties ((g/g)	
WAC	3.09
OAC	3.85
Density (g/ml)	0.65

Control

Protein%	CHO%	Over all Acceptability	Fiber%	Ash%	Fat%	Moisture%
6.2	86.71	3.9	0.75	1.98	2.30	5.21

Ca(mg/100g)	Fe(mg/100g)	Zn(mg/100g)
15.37	3.99	1.61
WAC(g/g)	**OAC(g/g**	**Density(g/ml)**
2.99	2.86	0.49

The protein contents of the wheat bread control significantly decreased when we compared with the optimized protein content of the bread samples influenced by the amount of black cumin incorporated. Increasing the black cumin content from 1.09 g to 3.49 g led to resulted in protein levels from 7.17% to 8.00%. This pattern aligns trend the well-documented nutritional qualities of properties cumin, which is recognized for known high protein content. The optimized formulation, containing 11.8 g of Sweet potato flour sweet and 3.49 g of BCB produced a protein black cumin bread (BCB), of 7.9%, which is comparable to medium-level BCB samples such as (7.13%). These that even moderate additions of black cumin can significantly enhance the protein content without affecting sensory qualities. Similarly (Ghadarloo et al., (2023) observed an increase in protein content from 6.81% to 9.65% as BCB levels rose.

Compared to 100% wheat bread, the black cumin blend breads are lower in carbohydrates. Bread may have been made with black cumin bend and sweet potato flour, which have less starch than wheat. Supplementation of sweet potato flour and black cumin to wheat flour significantly decreased the carbohydrate content of the bread samples compared to the control (Qianqian et al., 2020)

The optimized sample yielded a carbohydrate content of 82.2%, which aligns with combinations featuring moderate levels of SPF and BCB. This trend supports earlier findings, indicating that higher BCB inclusion reduces carbohydrate content due to black cumin's low starch and high dietary fiber composition, which substitutes the starch-rich components of wheat. Similar conclusions were reported by (Mohammad et al., 2016), who noted that black cumin, lowers starch concentration, thereby decreasing overall carbohydrate levels.

The Sensory acceptability of the wheat bread or the control is decreased when comparing with the optimized Sensory acceptability and was highest in bread formulations that maintained a balanced ratio of sweet potato flour and black cumin bread. Which contained 15 g of SPF and 2.29 g of BCB, achieved the highest sensory rating (4.75), with the optimized formulation (11.8 g SPF and 3.49 g BCB) following closely behind at 4.41. In contrast, samples with excessive amounts of either SPF or BCB showed reduced acceptability, likely due to undesirable changes in flavor, color, or texture. These outcomes are consistent with the observations of (Khalil et al., (2021), who reported that low-to-moderate levels of black cumin enhance aroma and texture, while higher concentrations can introduce strong flavors that negatively impact consumer preference. The overall acceptability score of 4.41 for the optimized formulation is also in line with the findings of (Mitiku et al., (2018), who reported similar consumer responses in related bread enrichment studies.

The moisture content of the composite bread formulated with the optimized proportions of 11.8 g of sweet potato and 3.49 of black cumin was recorded at 5.72%. These findings are consistent with earlier studies by (Melaku et al., 2023) &Negasi et al., 2024), which emphasize the importance of maintaining moisture levels in cereal flours below 15.0% to ensure product stability and shelf life. This study found that the ash content in the optimized blend of sweet potato and black cumin was 2.59%. This result aligns with other reports (Parenti, 2020; Kim, 2019).The black cumin flour and various pulse flours have significantly higher ash content compared to wheat flour.

The composite bread formulated with sweet potato flour and black cumin at the optimized blend ratio had a fat content of 2.43%, which is consistent with the findings reported by (Krawecka et al., 2022). This report was talking that fat content is increased as black cumin flour content increase than the wheat flour increase. And also, they reported that the fat content is important in enhancement of the texture and flavor of baked products, contributing to greater consumer acceptance.

Likewise, in the current study, the optimized substitution of sweet potato and black cumin yielded a fiber content of 1.49%. According to Igbabulet al., (2019), substituting refined wheat flour with fava bean and black cumin flour resulted in an increase in crude fiber content in composite bread, ranging from 1.32% to 11.68%. This increase is likely attributed to the high crude fiber content found in black cumin, fava bean, and wheat flours.

The flour produced under optimal conditions exhibited a water absorption capacity (WAC) of 3.09 g/g. This value falls within the range of previously reported (WAC) measurements, such as the 5.42 g/g found in pre-gelatinized sweet potato starch, as noted in the study by (Marta &Tensiska, 2017). The optimized flour demonstrated an oil absorption capacity of 3.85 g/g. This finding is consistent with previous research reported by (Omoniyi et al., (2016), which indicated that the oil absorption capacity of composite flours tends to increase with higher protein content, as proteins play a crucial role in enhancing fat absorption in food products.

Bulk density is a vital parameter for evaluating flour weight, determining handling requirements, and selecting suitable packaging materials for storage and transportation (Oppong et al., 2015). It also reflects the load-bearing capacity of the flour when samples are stacked directly on top of one another (Onabanjo&Ighere, 2014). Previous studies have reported bulk density values ranging from 0.83 to 0.84 g/ml (Ighere, 2014), which is comparable to the result obtained in this study of 0.65 g/ml, suggesting a similar trend in functional properties despite slight variations.

The mineral analysis revealed the elevated levels of calcium (16.12 mg/100g), iron (12.45 mg/100g), and zinc (3.00 mg/100g), highlighting black cumin's established contribution to improving micronutrient content. These findings suggest that the bread may offer significant benefits for populations suffering from nutritional deficiencies. This outcome aligns with the earlier findings reported by (Ghadarloo et al., (2023).

Calcium content of the breads ranged from 18.08 to 31.42 mg/100g, with a significant increase observed as the level of sweet potato flour substitution increased (Elzainy et al., 2010). This increase is likely attributed to the higher calcium concentration in sweet potato flour compared to wheat flour. In the present study, the bread formulated with optimized levels of sweet potato and black cumin had a calcium content of 16.12 mg/100g, which is reliable with the findings reported above.

In this study, the iron content was recorded at 12.45 mg/100g in the blend containing 11.8 grams of sweet potato and 3.49 grams of black cumin. This value is different from wheat bread which was reported by (Elzainy et al., (2010) earlier findings, which is ranged from 2.92 to 5.09 mg/100g, with increased iron levels observed as the proportion of sweet potato flour increased.

The higher iron content in sweet potato-enriched bread is likely attributed to the naturally greater iron concentration in sweet potato flour compared to wheat flour. In this study, the value of zinc content was determined to be 3.00 mg per 100 grams in the formulation of bread which containing 11.8g of sweet potato and 3.49 g of black cumin. This trend may be attributed to the relatively higher zinc content in sweet potato flour compared to wheat flour. These results are different with those reported, which was recorded as 1.3ml/100g (Elzainy et al., (2010).

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSIONS

Blending sweet potato and black cumin flours into wheat-based bread significantly influenced the nutritional composition and sensory attributes. Carbohydrate content was primarily driven by sweet potato flour, while black cumin addition improved protein content. The sensory acceptability peaked at moderate levels of both ingredients, particularly in formulations with SPB and BCB, which consistently yielded high sensory scores and balanced nutrient content.

The highest protein content was found with value of 10 g sweet potato flour and 3.49g of black cumin seed and lowest was recorded having 22g of sweet potato flour and 2.29 g of black cumin seed. Bread made with different ratios of sweet potato, and black cumin showed variations in carbohydrate levels. The bread containing 22g of sweet potato, and 2.29g of black cumin had the highest carbohydrate content. The findings of this study demonstrate that partially replacing wheat flour with sweet potato flour and black cumin significantly improves both the nutritional and sensory qualities of bread compared to the wheat bread or with the control.

The optimized formulation of 11.8g of SPF and 3.49g of BCB resulted in higher sensory acceptance (score of 4.41), protein content of 7.9%, carbohydrate content of 82.2%,and elevated levels of essential micronutrients (calcium, iron, and zinc), more over improved functional properties, contributing to better dough quality comparing to the wheat bread . The experimental design also confirmed that using either too much or too little of SPF or BCB shown significant impacts on nutritional content or sensory appeal. For example, BCB levels above 3.49 g increased protein but lowered sensory scores, while SPF levels exceeding 20g led to reduced protein content and acceptability. The strong correlation between predicted and actual values validates the reliability of the model. These findings support the use of black cumin and sweet potato as functional ingredients to improve both the nutritional and sensory profiles of composite bread, offering a promising direction for health-oriented bakery products

5.2. RECOMMENDATIONS

Based on the current study, it is recommended that the optimal level of black cumin incorporation for composited bread production is 3.49g in combination with 11.8g of sweet potato flour ratios. More over for best results in terms of both nutrition and sensory appeal, a formulation comprising approximately 15 g sweet potato flour and 2.29 g black cumin is recommended.

Breads production from sweet potato flour and black cumin should be given emphasis and processors should be encouraged to utilize the potential nutrient source of sweet potato flour and black cumin. Further studies like shelf life, microbial load, vitamins, anti-nutritional constituent’s, antioxidant activity and the remained minerals such as sodium, potassium, manganese and copper are required.

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APPENDIX

I. Questioner on traditional bread preparation for survey assessment on western zone Tigray, Ethiopia

A) Socio-Demography of bread preparation

Questionnaire No	
Date of question gathering	
Name of respondent	
Educational status of respondent	1. Illiterate 2. Literate
Wereda /tabya	

B) Information gathered from the experience and knowledge of mothers in the western zone of Tigray, Ethiopia.

1. Do you use spices for bread preparation?
    A. Yes B. No
2. What type of spices does use to prepare bread?
    A. Black cumin B. Clove C. Ginger D. Cinnamon
3. From where did you purchase this spice?
    A. Market B. Home garden C. Local communal area D. Other (specify)
4. Does the spice have known ratio?
    A. Yes B. No
5. If, yes how much is the ratio of spice and for how much gram of wheat flour for bread preparation?
6. For how long do you extend the prepared bread?
    A. One week. B. Two week. C. Three week. D. Four week
7. How long can stay the prepared bread retaining its original characteristics (over all sensory characteristics)?If yes, A. One week. B. two-week. C. three week. D. month
8. Which parts of spice is used for bread preparation?
    A. Leaves B. Stem C. Seed D. Roots

9. What are the common spices of bread that you use?

   ----

10. What is the perception of the community towards consumption of bread?

    A. Not liked B. Slightly liked C. Moderately liked D. Highly liked

11. What are the selection criteria for spices verify?

    A. Price B. Consumer acceptance C. Processing method D. Other

II.Format Sheet of Sensory Evaluation for Composite bread

First I would like to thank you for your coming here. I am KidanemariamTesfay MSc. Student of Mekelle University, department of food science and post-harvest technology. I am conducting research on**Optimization of Sweet Potato and Black Cumin Blending Ratios with Wheat Composite Flour to Produce Bread: Physicochemical Qualities and Sensorial acceptance**

The preference/score you put here will help to use the exact or the ideal ratio of black cuminin scientific way. Your name will be included in the report, if it is all right with you, you can start the evaluation of the sample.

Name &code of panelist _________ Age___Sex___Occupation__

Sensory Type of test: **Five-point hedonic scale**

Instruction: Please observe the prepared bread sample on the pan in front of you. Each prepared bread sample is identified by a code. Please put the representative number according to how acceptable you find for each sample of taste, aroma, appearance, color and overall acceptability.

Bread Code	**Sensory attributes**					
	Texture	**Color**	**Appearance**	**Aroma**	**Taste**	**Overall Acceptability**
SM1						
SM2						
SM3						
SM4						
SM5						
SM6						
SM7						
SM8						
SM9						
SM10						
SM11						
SM12						
SM13						

Degree of acceptability Representative Number

5. Like very much……………………………….5
4. Like moderately…………………….................4
3. Neither like nor dislike ……………...............3
2. Dislike moderately…………………................2
1. Dislike very much…………………..................1

If you have any comments about the bread write here, please.

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Thank you very much for you’re helping me

III. Some images of the laboratory work